THE USE OF MOBILE TECHNOLOGY IN ADDRESSING MEDICATION ADHERENCE: A MIXED-METHODS STUDY

A THESIS SUBMITTED TO AUCKLAND UNIVERSITY OF TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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Abstract

"The most rewarding projects involve a new approach to solve an old problem" - Nawal Chanane

It has been estimated that every year in New Zealand, hundreds of thousands of medicines are dispensed to patients but never used. Ensuring patients' adherence to prescribed medication is a significant challenge, and lack of Medication Adherence (MA) creates a burden on the overloaded healthcare system. Studies have reported that MA is estimated to cause at least 10% of unplanned hospitalisations and approximately 125,000 deaths annually in the US alone. Recent studies have highlighted the role of technology in providing interventions that contribute to MA. The most common technological interventions to assist MA fall under the umbrella of digital technology like text messaging, voice calls, mobile applications and digital pill boxes. However, the efficacy of these solutions varied from one study to another for several reasons, including variations in users' acceptance, performance expectancy, and facilitating conditions that lead to low usage or abandonment and, therefore, a lack of sustainability. What remains unclear is the role of end-users and the factors that contribute to the usage of these types of technologies. Our research aims to investigate the use of digital technology in addressing medication adherence. This thesis has four primary objectives: (1) to investigate the perceptions of multidisciplinary experts (e.g. health providers, health system designers and health informatics researchers) in New Zealand on mHealth interventions in addressing MA; (2) to co-design and develop a mobile

app Minimum Viable Product (MVP) based on the theoretical investigation; (3) to evaluate the MVP with end-users through focus-groups; and (4) to assess the feasibility, acceptability and efficacy of the MVP by end-users through a pilot study. To achieve our aims, we followed a Design Science Research (DSR) methodology, and a complex mixed-methods design was implemented to include the integration of multiple forms of data collection at different stages of the study (i.e. questionnaires, interviews, focus groups and a pilot study) as well as multiple forms of data analysis (grounded theory, descriptive statistics, statistical analysis) to answer the research questions. The results from the quantitative study (questionnaire) informed the qualitative study (interviews and focus-groups), which in turn validated the qualitative results. Purposeful sampling was utilised throughout the phases of the study. Descriptive and exploratory data analyses were performed for the quantitative data and inductive thematic analysis for the qualitative data. The findings of the quantitative and qualitative parts of the study were mixed and integrated at different points of the DSR methodology. The results show that four main features contributed to improving MA: (1) *medication reminders using multi-channel notifications*; (2) *medication intake acknowledgement and history reporting*; (3) *auto-loading of medication*; and (4) *caregiver involvement*. These novel features remained significant when built into the MVP and benefited the end-users in improving their medication intake during the pilot. This study confirmed that mHealth could have a significant impact on improving MA. Our findings from the rigorous iterative design process with end-users produced novel results validated through the trial by end-users. This work indicated that medication management applications could gain and sustain high usage, when integrated with an extensive digital health system, and can successfully keep the patient at the centre of care, connected and informed.

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the qualification of any other degree or diploma of a university or other institution of higher learning.

Nawal Chanane

Signature of candidate

Publications

Chanane, N., Mirza, F., & Naeem, M. A. (2020). Co-designing a medication notification application with multi-channel reminders. *ACIS 2020 Proceedings*. 29.

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Chanane, N., Mirza, F., & Naeem, M. A. (2018). Technology-driven medication management: A vision through the lens of New Zealand experts. *HiNZ 2018 Conference Proceedings*. 32.

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Dedication

I dedicate this thesis to my mother Mrs. Houria Chanane and father Professor Bilal Chanane

Chapter 1

Introduction

"Technology made large populations possible; large populations now make technology indispensable." - Joseph Wood Krutch

The research presented in this thesis studies the use of mobile technology to address Medication Adherence (MA). A technology-driven MA model is proposed and an MA Minimum Viable Product (MVP) is developed and piloted with end-users in New Zealand (NZ). The Design Science Research (DSR) methodology is followed to conduct the activities of each phase of the study. The findings of the pilot study are analysed and discussed, then the research challenges and limitations are highlighted, and future work directions are provided. In this chapter we introduce briefly the background on the use of technology in approaching MA. Next, we explain the research problem and demonstrate its significance and impact on the real world, which gave us the motivation to contribute to the current body of knowledge of the wider domain of Digital Health in NZ. This chapter presents the following main outcomes:

- Significance of addressing MA and its impact on the real world
- Our contributions to the current body of knowledge
- Thesis structure and the chapters' orientation.

The following sections consist of the introduction in **section 1.1**. Then, **section 1.2** presents the motivation and significance of addressing this topic in our study, and **section 1.3** gives an overview of the acceptance of mHealth applications. Next, in **section 1.4**, we give a brief idea about medication management and mHealth. Then, **section 1.5** explains the research problem, followed by the research questions, aim and objectives in **section 1.6**. After that, we introduce the study approach in **section 1.7**. Then, we present our research scope and contributions in **section 1.8**, followed by the thesis' contributions in **section 1.9** outlining the expected study contributions. Finally, **section 1.10** briefly explains the structure of each chapter along with the output expected.

1.1 Introduction

Over the years, technology has created remarkable tools and resources which have simplified our lives in several ways: providing on-the-go services, easy access to information, and advanced communication innovations that have enhanced productivity and efficiency (Cotten, 2017). The ubiquity of these technologies has shaped every aspect of how people live their lives (Pejovic, Mehrotra & Musolesi, 2017). The number of smartphone users worldwide has exceeded three billion and is expected to grow further in the next few years by several hundred million (Statista, 2020). In NZ alone, in 2019, at least 80% of the population owned a smartphone and 393,000 owned a wearable device (Joyce, 2019). Many of them rapidly adopted the technologies to improve their access to the healthcare system. According to Herndon et al. (2007), healthcare technology could be defined as "the drugs, devices, medical and surgical procedures used in medical care, and the organisational and supportive systems within which such care is provided". These include diagnostic, preventive, organisational, educational information, and supportive technologies such as electronic Health (eHealth)

and mobile Health (mHealth) (S. Wali, Keshavjee & Demers, 2018).

mHealth is placed under the umbrella of eHealth and defined as "mobile computing, medical sensor and communication technologies for healthcare" (Istepanian, Jovanov & Zhang, 2004). Then, further defined by Iriibarren et al. (2017) as the "medical and public health practices supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, sensors, wireless networks and other wireless devices". Furthermore, we have the definition given by Larson et al. (2018) as "the implementation of digital health services, which has the possibility of enhancing self-management using mobile and wearable devices".

The World Health Organisation (WHO) (2016) has praised eHealth for providing cost-effective and secure care, in which mHealth is expected to play a remarkable part. They are driving the future of healthcare and closely empowering individuals to take care of their health through technologies, with the beauty of making patients the point-of-care (Wang & Kricka, 2018).

For example, mobile applications (apps) allow us to keep track of our doctor appointments, medication reminders, heart rate, food intake and exercise. Moreover, there are advanced apps that offer us customised solutions by tracking what we eat as well as our level of activity like fitness apps (West et al., 2012). Some new apps allow users to upload their prescriptions (Rxs) and have their medication delivered to their door, saving time and money spent visiting the pharmacy (Ahmed et al., 2018). Other apps allow healthcare providers to communicate directly with patients and keep track of their vital health signs like pulse rate, body temperature, respiration rate and blood pressure. However, learning rate, memorability rate, efficiency and satisfaction are issues faced when implementing these mHealth apps (Pires et al., 2020).

Despite the critical issues of their reliability, mHealth apps can still help transform unsustainable healthcare systems into sustainable ones, providing cheaper, faster and more effective solutions that can be used between healthcare providers and patients

(Iribarren et al., 2017; Oniani et al., 2018; Alam, Hoque, Hu & Barua, 2019). We will briefly present them in the next sections and further investigate and discuss these aspects in **Chapter 2**.

1.2 Motivation and Significance of the Study

Medication non-adherence is widely spread and varies according to the disease and patient's characteristics (Iuga & McGuire, 2014). The non-adherence rates range from 35% to 50% in the US alone, with up to half of the prescribed medications not taken as prescribed and 20% to 30% of all persistent medication are never filled (Harrison, 2018). According to WHO (2019), 30% of patients worldwide do not adhere to new medication requirements. A survey in the US showed that 89% of patients acknowledged that adhering to prescribed medication was necessary to maintain their health (Lehmann et al., 2014). A study conducted by NZ Care Chemist (2010) revealed that 21% acknowledged poor adherence due to carelessness, 28% of patients forget to refill their Rx as scheduled, and 43% admitted missing taking their medication. Another study conducted recently in NZ by Tordoff et al. (2019) shows 30% of their survey participants considered MA to be a significant burden.

In the majority of studies reported medication non-adherence ranged from 4% to 100% depending on patient populations, diseases and medicines, with consideration to study designs and measurements of adherence (Elliott, 2013). Poor MA increases the risk of serious consequences, including death. It was estimated in the US that premature deaths could reach 89,000 annually due to non-adherence to antihypertensive treatment, and it was predicted that 75% of deaths in the world could be attributed to chronic diseases by 2020 (Cutler, Fernandez-Llimos, Frommer, Benrimoj & Garcia-Cardenas, 2018). Furthermore, medication non-adherence causes medication wastage of billions of dollars per annum worldwide, from patients stocking medication from

repeat prescriptions even if they no longer take the medicine (New Zealand Health Innovation Hub, 2016).

In a survey of 452 individuals across NZ, 56% reported that they collect all their prescribed medications from the pharmacy, even if they do not intend to take them (Bpacnz, 2015). An estimate of NZ$700 million is caused by unplanned and avoidable hospitalisation mainly due to non-adherence (Williams, 2016). Non-adherence to prescribed medication is considered to be a significant healthcare challenge, and a burden on an overloaded healthcare system (McDaniel & Einstein, 2016). It has been linked directly to poor clinical outcomes, and an increase in hospital admissions and healthcare costs (Mongkhon, Ashcroft, Scholfield & Kongkaew, 2018). Therefore, non-adherence not only causes health risks for patients but also creates an enormous and growing cost burden for the whole healthcare system (PhRMA, 2011). As mentioned in the introduction section, mHealth, as an intervention, helped to improve MA, using different tools of interventions such as phone calls, text messaging and mobile apps (Choi, Lovett, Kang, Lee & Choi, 2015; Lingala et al., 2016). According to research reviews conducted by Alam et al. (2019), mHealth apps are growing in popularity, considering the affordability of technology nowadays, yet, evidence for their acceptance and efficacy is still limited.

1.3 Acceptance of mHealth Applications

mHealth has become an essential solution for providing accessible, equitable and quality healthcare services at reasonable cost (Alam et al., 2019). According to Car et al.'s (2017) research findings, mHealth could transform the worldwide delivery of healthcare services. This includes simple apps with text messaging service and/or complex technologies including multimedia message service (Silva, Rodrigues, de la Torre Díez, López-Coronado & Saleem, 2015). Despite the growing interest in the use

of mHealth apps, discussing their potential value for adoption to patients is a challenge for clinicians (Car et al., 2017). We can learn from the literature that technology will possibly widen health inequality when used only by patients who already adhere to their treatment (Petersen, Jacobs & Pather, 2020). The research on this examined the factors affecting the adoption of mHealth services utilising the Unified Theory of Acceptance and Use of Technology (UTAUT2) model in the health context (Sudburya et al., 2013). UTAUT2 gives particular attention to the actual use of technology, giving it a greater relevance to the healthcare context (Venkatesh, 2012).

We can see these newly developed technologies are rapidly accepted and have spread in some industries like Online Social Networking (OSN), online shopping, and fitness apps, due to their importance in daily lives, and have become an indispensable element (Vahdat, Alizadeh, Quach & Hamelin, 2020; Wei, Vinnikova, Lu & Xu, 2020). However, other apps such as health and medication management apps have encountered resistance and have not progressed to the same extent (Andrade & Roughead, 2019). This may be either because of the crowded market, so end-users end-up not knowing which app to choose, or lack of evidence of their effectiveness and/or their perceived value. Therefore, a deeper understanding is needed, through investigating and exploring the users' perspectives and needs, of their willingness to accept and use the technology; which is regarded as one of the fields of Information Systems (IS) research (Venkatesh, 2012).

Research shows that we can explain the low usage of mHealth by individuals from their purpose for using it and the challenges they faced (Petersen et al., 2020). That means the individuals' reactions to technology drive their intention to use it, which in turn could be applied to mHealth technology use. For example, if the technology is difficult to use and slow, it is less expected to be less used if not abandoned. Drawing from the literature, to clarify the challenges users are facing to accept these apps, the UTAUT model provided four key constructs: (1) *performance expectancy*, (2) *effort*

expectancy, (3) *social influence*, and (4) *facilitating conditions*, where the UTAUT2 model appended the gender, age, experience, and voluntariness of use (Sudburya et al., 2013).

1.4 Medication Management and mHealth

Medication management usually starts when the patient visits the healthcare provider, and they both decide and agree during the consultation on the treatment and prescription (Rx). When a patient is handed the Rx, the question of how the medication will affect such a patient becomes an open observation for both the patient and healthcare provider (Deegan & Drake, 2014). After collecting the medication from the pharmacy, the patient starts to take the medication. Here, non-adherence can occur, either when the patient skips the first dose, does not take the prescribed treatment at the correct dose and frequency, or discontinues taking the medication after a while (van Dulmen et al., 2007). Medication-related issues are significant and undetected most of the time, which can delay or prevent improvements and treatment outcomes resulting in unpreventable issues (Andrade & Roughead, 2019).

Using medications is a dynamic journey, especially for people with long-term conditions or multiple conditions, causing the healthcare systems major challenges with patients' adherence and medication management. Medication management determines medication effectiveness, which leads to improving health outcomes (Car et al., 2017). For this, there are non-digital solutions like blister packs, dose administration aids, and home medicine reviews (Rathbone, Mansoor, Krass, Hamrosi & Aslani, 2016). However, with the involvement of technology in the health industry, as mentioned in **section 1.1**, medication management systems extend their scope to offering assistance in reducing medication-related problems through mHealth. Yet, patients' poor adherence to medication is an ongoing issue (S. Wali et al., 2018).

mHealth apps for medication management are still gaining visibility in the market with a significant increase over the last few years (Priyadarshini & Quinlan, 2016). It is anticipated that eHealth interventions will grow worldwide and mHealth will play a big role in the patient's medication management journey (Car et al., 2017). With the rise in mobile phone use, mHealth apps are considered one of the rapidly growing innovations in the healthcare sector (S. Wali et al., 2018). They provide individuals with a simple and accessible way to manage their own health (Aitkin, Clancy & Nass, 2017). These mHealth apps may help in the clinical data collection and health services. Moreover, they could support healthcare providers to monitor the health status of their patients, share information, and perform diagnoses for some health problems (The National Institue for Health Innovation, 2020). According to Kaye et al. (2020), use of a digital platform tracker enabled monitoring adherence to daily medications by patients with respiratory illness during the present pandemic, to avoid confusion with COVID-19. Tackling adherence requires a collaborative, patient-centric approach and can be guided by technologies that offer efficient ways of managing healthcare (Priyadarshini & Quinlan, 2016).

1.5 Research Problem

MA is a challenge for many patients, even if taking medication as prescribed is critical for their health condition (Cramer et al., 2008). The clinical outcomes of treatment are affected by "how long patients take their medications" as much as "how well they take the medications" (Vrijens et al., 2012). WHO (2016) declared medication non-adherence an epidemic and recommended feasible patient-centred solutions. We can see that mobile apps' usage in the healthcare industry is showing promise as a solutions to help users manage their health (Mourouzis, Chouvarda & Maglaveras, 2015). However, with the unprecedented saturation of mobile technologies demonstrated in the past few

years, there was a need for reviews to identify and describe these apps (Pérez-Jover, Sala-González, Guilabert & Mira, 2019). Studies showed that mHealth apps evolved much faster than other technological artefacts, but their validation and updates need to be continued over time; and more features and improvements are required for the initial versions (Anglada-Martinez et al., 2015).

These mHealth apps provide various functions where the users can select from a range of features like setting goals, planning, providing performance feedback, and communicating with other users (Smahel, Elavsky & Machackova, 2017). It is not difficult to find an app for managing medication or reminding about medication intake (Singh et al., 2016). However, the question is, which ones are going to be different and useful?, knowing that usability is the key factor in the adoption of these apps. In many cases, the degree to which these apps are usable may impact their effectiveness. Therefore, it is essential to keep in mind the users of these apps, who are not only the young generation and the technology savvy, but may also be individuals with problems in using mobile devices due to limited experience with technology (Mourouzis et al., 2015). A detailed analysis on this is carried out in **Chapter 2**.

From past research and reflecting on our own experiences, we can see people from different age groups and conditions could face challenges with medication intake, such as integrating medication into their daily routine or keeping the history of complex medication regimens (Tabi et al., 2019). According to the latest overview study conducted by Tabi et al. (2019) on medication management apps, 73% of the apps were developed by the software industry, 15% were co-developed by healthcare professionals, and 2.1% by academia. However, they lacked feedback at the early stages of the design from end-users and healthcare providers, who were considered the primary users. Their study found that the frequent occurring features were reminders, symptom trackers, and the sharing of the patient health record with a family member or doctor. Those findings align with the UK National Institute for Health and Care Excellence (NICE) guidelines

and the National Health Service (NHS) recommendations (National Health Service, 2020; National Institue for Health and Care Excellence, 2020).

According to Singh et al.'s (2016) findings, only a few mHealth apps addressed the patients needs, although a wide variety of those apps targeted a range of health issues by including 'alerts to patients' whether to remind them of medication intake or to remind about filling their Rx or any sort of habit-related reminders. Moreover, there was the challenge of digital health literacy, which demands skills as much as health literacy itself (Baldwin, Singh, Sittig & Giardina, 2017). Therefore, when looking at a solution for persisting issues we try to make use of what the majority of people already have. In saying this, we can refer to the design science research approach when using existing solutions in one field to solve problems in another field (Gregor & Hevner, 2013).

As observed, there is still ongoing research on medication management apps and how they can address patients' needs: Do they work for different age groups? Are their features useful to patients with different needs? What features help patients most? What is their effectiveness in increasing adherence?

1.6 Aim of the Study, Research Questions and Objectives

The aim of this study is to investigate the use of digital technology in addressing MA. Our main RQ and sub-questions are postulated from the significance of MA, the concerns about the use of technology in addressing the issue of MA and its impact on patients and on the health system. Our main RQ is:

- **RQ**: How can digital technology improve users' medication intake?

Answering this question requires a deep understanding of the current state of addressing the issue of MA in NZ, the role of end-users in exploring solutions to solve

the problem and whether or not the proposed solutions actually work. Therefore, our sub-questions are:

- **RQ 1**: What are the key design considerations for constructing an MA programme?
- **RQ 2**: How can users articulate the approach to MA?
- **RQ 3**: What impact could the intervention have on users' medication intake?

To achieve our aim and answer the RQs, we set our research objectives as follows:

1. To investigate the perceptions of multidisciplinary experts (e.g., healthcare providers, health system designers and health informatics researchers) in NZ on mHealth interventions in addressing MA
2. To develop a technology-driven MA theoretical model
3. To co-design an MA mobile MVP with end-users guided by our theoretical model
4. To build an MA mobile MVP
5. To evaluate the MA MVP with end-users in an iterative process through focus-groups
6. To assess the acceptance, feasibility and efficacy of the MA MVP by end-users through a pilot study.

1.7 Study Approach

This study mostly follows an explanatory sequential approach, as described by Creswell (2003), which involves first collecting and analysing the quantitative data first, then the qualitative data in two sequential phases within the same study. Thus, the two methods (quantitative and qualitative) will complement each other by taking the advantages of both to allow a robust analysis. We first investigate the study phenomena from the literature and explore individuals' perspectives through a questionnaire. The findings allow us to investigate further and seek explanations from experts in the field, which

will provide us with the necessary data to form our theoretical model grounded on experts perspectives. Then, a proposed solution is presented to end-users to collect their feedback according to their current requirements and expected future needs. After mixing and integrating the collected data, a solution is developed and assessed with end-users to evaluate its feasibility and efficacy. Designing and implementing the study is a main focus of this research. The detailed descriptions of the research methodology and the investigation process including data gathering and analysis represents the most significant part of this thesis. This study is conducted through multiple activities adopted from the Peffer's (2007) DSR model, which will be explained in detail in **Chapter 3**.

1.8 Research Scope and Contributions

According to our literature review analysis, the lack of adherence to medication falls into four main areas: *patient-related*, *healthcare professional-related*, *healthcare system related*, and *economical-related*. Based on our investigation and exploration, most barriers to adherence could be controlled by patients themselves, therefore, the scope of our thesis will cover the *patient-related* aspect. These barriers require attention, as overcoming them is an important step to improving adherence. Forgetfulness, and difficulties of managing a complex regimen appears as the primary reason leading to lack of MA. Other reasons are the burden of follow-up for medication change, lack of communication between healthcare professionals and patients, and medication side effects (Treskes, Van der Velde, Schoones & Schalij, 2018). **Figure 1.1** presents the four factors contributing to MA and the scope of this thesis.

As shown in **Figure 1.2** our contributions to this study are theoretical (MA and acceptance of technology being an area of concern in our research) and practical (the use of technology to solve MA), and they were achieved by answering the main RQ including the research process and findings. Our knowledge outcomes consist of further

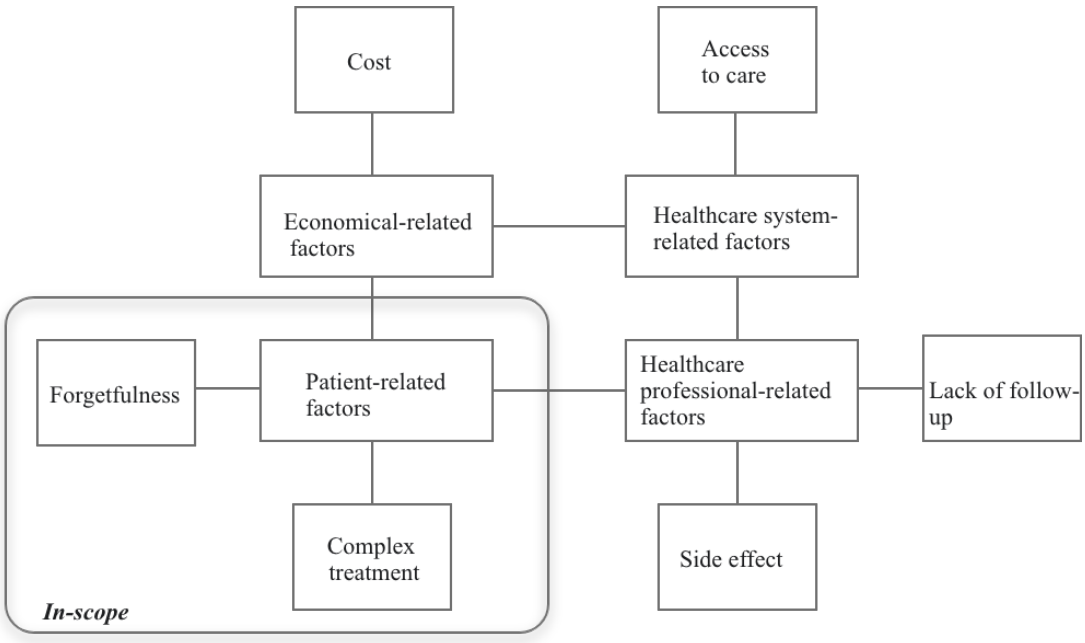

Figure 1.1: Thesis scope

exploration of mHealth to improve MA, which contributes to the body of knowledge by:

1. Exploring MA programmes to build a theoretical model that can inform the design of future studies. The model postulates from the perceptions of multidisciplinary experts (including healthcare experts, health technology designers, researchers). This will be presented in **Chapter 4**.

2. Building a solution that is generic, easy to use, and with novel features to benefit the end-users by meeting their present and anticipated future needs and expectations. The outcomes may benefit the participants from multidisciplinary fields by providing them with a full picture of end-users' requirements and helping them understand the significance of their presence in designing future solutions. This will be presented in **Chapter 5**.

3. Explaining how the sequential explanatory mixed-methods approach helps us understand the existing issue from multiple angles. In addition, how the methods

we used increased the validity of our findings and assisted with the knowledge creation. This will be presented in **Chapter 4**, **5** and **7**.

4. Validating the contributions of mHealth technology in improving adherence and providing enhanced services. This will be presented in **Chapter 7**.

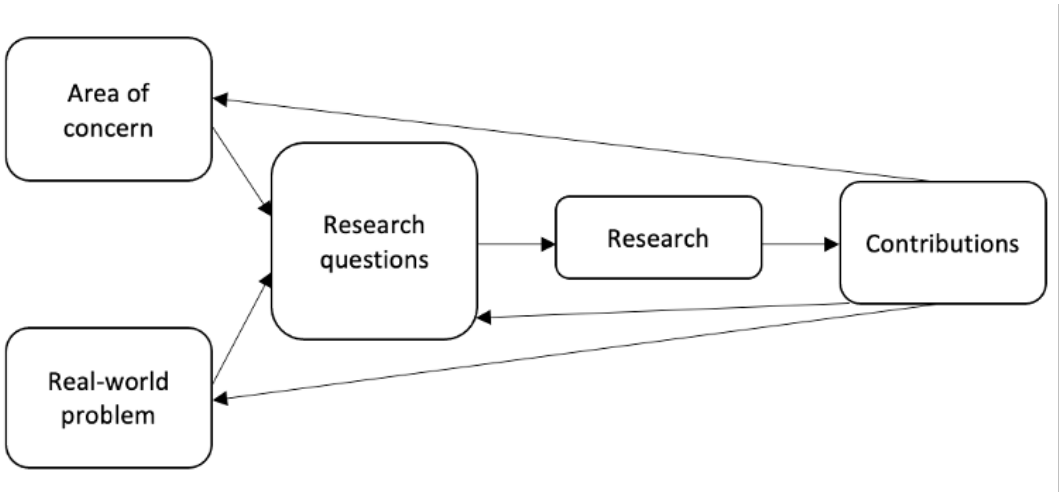

Figure 1.2: Research contributions structure, adapted from Mathiassen et al. (2012)

1.9 Thesis Publications

To validate this thesis' contributions, phases of this study have been peer-reviewed through publications or presentations as a conference abstract, conference papers and/or seminar presentation.

HiNZ Digital Magazine: This article presents the pilot of MAMA, a simple-to-use medication management mobile app. The goals of MAMA are to help end-users keep records of their medication list, medication intake logs and remind them to take their medication on time through a multi-channel notification workflow. MAMA builds on the UTAUT 2 model for mobile IT in the healthcare context. The primary goal of the pilot was to (1) evaluate its feasibility and acceptability through acquiring early

adopters' feedback and recommendations for future development and enhancements; (2) evaluate the efficacy of MAMA in improving on-time medication intake.

- Chanane, N. & Mirza, F. (2021). Smart reminders to improve medication intake. *Digital Health CONNECT Magazine*, Student Showcase.

Conference Paper: This paper focuses on the design of an MVP for a medication reminder app, following a qualitative approach with end-users as the first beneficiaries of the app. This research is foreseen to inform future mHealth attempts and assist providers to better guide app designers and developers on user-centred design that serves the users' needs. The contributions of this study are as follows: (1) It collects end-user's feedback and identifies what are considered main elements in a medication reminder app from the user's perspective. (2) It captures the key elements to overcome the challenge of medication reminder apps' usage continuity. (3) It builds an MVP through an iterative design process.

- Chanane,N., Mirza, F. & Naeem, M. A. (2020). Co-designing a medication notification application with multi-channel reminders. *ACIS 2020 Proceedings*. 29.

Conference Paper: This paper aims to explore MA from the perspectives of healthcare professionals and health technology designers. The contributions of this study are as follows: (1) It captures healthcare professionals' understanding of the multifaceted dilemma of MA. (2) It provides insights into how mHealth could be used to improve collaboration among the members of healthcare delivery teams and the patient.

- Chanane, N., Mirza, F. & Naeem, M. A. (2019). Insights of medication adherence management: A qualitative study with healthcare professionals and technology designers. *ACIS 2019 Proceedings*. 145.

Abstract: This abstract aimed to explore the perceptions of healthcare experts and health system designers, on the features an MA app could include, which will benefit patients and healthcare team alike.

- Chanane, N., Mirza, F. & Naeem, M. A. (2018). Technology-driven medication management: A vision through the lens of New Zealand experts. *HiNZ 2018 Conference Proceedings*. 32.

1.10 Thesis Structure

This thesis is structured in eight chapters, as summarised below. **Figure 1.3** draws the relationship between the research process, research objectives, RQs and chapter outcomes.

Chapter 1: Introduction. This chapter gives an overview and presents the structure of the whole thesis. It demonstrates the area of concern of the research topic and its significance as a real-world problem. The chapter sets the RQ to be investigated throughout the study. It also outlines the expected contributions of this research.

Chapter 2: Literature review. This chapter presents an overview of MA, its issues and challenges, and the role of technology in addressing them. Then, a comprehensive analysis of the literature is conducted. It includes a critical comparison of the current medication management apps with an in-depth discussion around limitations, challenges and research gaps.

Chapter 3: Study design. This chapter outlines the design and methodology followed in this thesis. This chapter starts with the underlying research philosophy and research design theory. Then, it details the methods used for the data collection of each phase, followed by the reason for using each method and the importance of their contributions to the current body of knowledge.

Chapter 4: Requirements elicitation. This chapter discusses the exploration of requirements guided by a sequential mixed methods approach. It explores the opinions of NZ experts on health mobile apps, which can help patients and the health team alike. Following this, the highly recommended features are proposed as components of a mobile app wireframe, given the name Medication Adherence Mobile Application (MAMA).

Chapter 5: Co-designing MAMA with end-users. This chapter presents co-designing MAMA through three iterative focus group (FG) sessions to obtain feedback and suggestions from the actual end-users of MAMA. Following this, the summarised features from the three FGs are compared with the list of features from **Chapter 4**, then those most similar or highly recommended by participants or with novel features will be selected for development in the next chapter.

Chapter 6: System development. This chapter describes the MAMA system workflow, presents the architecture, lists the development tools and presents the MAMA screens. Then it details some of the screen functions and how to steps for end-users as presented in the MAMA user manual and MAMA webform manual.

Chapter 7: Piloting with end-users: MAMA feasibility and acceptability. This chapter presents the evaluation process and results from piloting the MAMA MVP with end-users. The pilot validates the usefulness and acceptability of MAMA in improving end-users' medication intake. Moreover, it presents the participants recommendations for future updates which could better improve MAMA to address their future needs.

Chapter 8: Conclusion and future work. This chapter lists the challenges and limitations of the study. Then, it highlights its original and significant contributions. Finally, it suggests key future research directions.

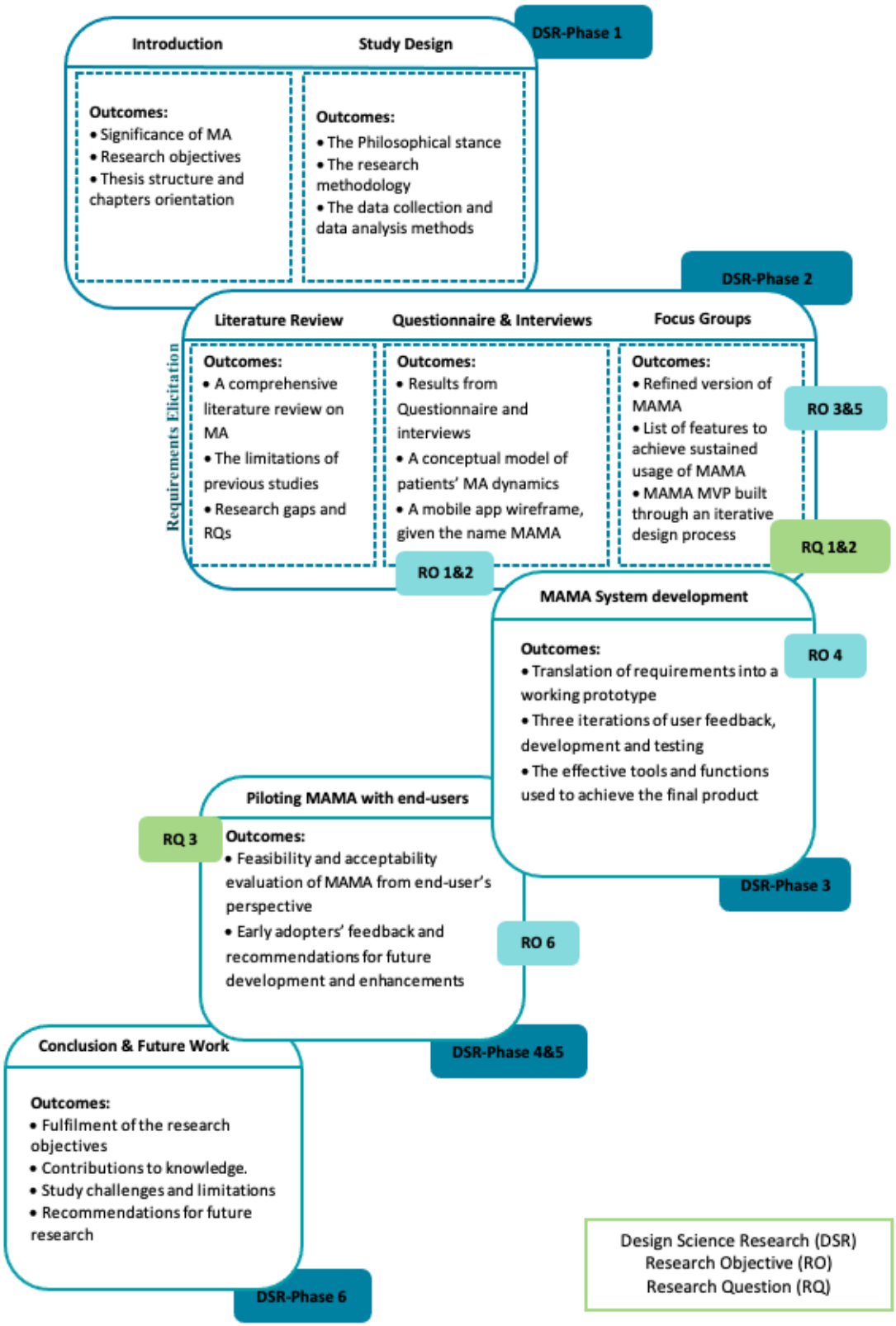

Figure 1.3: The relationship between the research process, objectives, RQs and chapter outcomes

Chapter 2

Literature Review

"Our review of the literature says this appears to be bigger than in the past" - Robert Deitz

This research aimed to investigate the use of digital technology in addressing MA by involving multi-disciplinary experts and end-users to understand their perspectives. The main research question of this study is: *How can digital technology improve users' medication intake?*. We collected requirements for managing MA and an MA MVP was developed and piloted with end-users in NZ.

This chapter presents an overview of MA issues and challenges, and the role of technology in addressing those issues and overcoming the challenges, then it conducts a comprehensive analysis of the literature on the existing work so far. It includes a critical comparison of the current medication management apps with an in-depth discussion of their limitations, challenges and research gaps. By the end of this chapter, we will gain a clear interpretation and a comprehensive view of what is missing and what needs to be studied further. This will allow us to expound further our contributions to the current body of knowledge. This chapter presents the following main outcomes:

- A comprehensive literature review on MA
- The limitations of the previous studies

- Cultivated research gaps and refined RQs.

The following sections consist of the introduction in **section 2.1**. Then, **section 2.2** presents the literature search strategy as an overview of the researched topic. Next, **section 2.3** defines MA, followed by the issues and challenges in **section 2.4**. Then, **section 2.5** presents ways of managing MA, followed by the use of technology for managing adherence in **section 2.6**. After that, we discuss the users' acceptance of technology in the health context in **section 2.7**, then, clarify the importance of adherence management via m-Health in **section 2.8**, followed by presenting the existing mHealth work to improve MA in **section 2.9**. Next, we evaluate the top existing MA apps identified in the literature in **section 2.10**, followed by an investigation of eHealth services in NZ in **section 2.11**. Then, we present the identified research gaps in **section 2.12**, followed by the articulated research questions in **section 2.13**. Finally, **section 2.14** summarises the chapter with its key points.

2.1 Introduction

WHO considers MA a priority global problem because failing to take medication as prescribed is an out-of-control epidemic (Dekoekkoek et al., 2015). MA not only affects the individual patient but disrupts the whole health system (Ali, Chan, Leow, Chew & Yap, 2018). It is proven that MA causes poor clinical outcomes, low quality of life, and increased healthcare costs (Choi et al., 2015). Statistics show that 30%-50% of failures in treatment and 10%-40% of hospitalisation risks are attributable to non-adherence to medication (Prakash, Jayaprakash, Linus, Roby & Sambathkumar, 2015). Moreover, as cited in the Skeptical Scalpel report (2018), failing to take medication as prescribed causes an approximate total of 125,000 annual deaths.

Pharmacy Today in NZ news stated that between 15% and 30% of patients do not dispense their prescribed medication compared with the Rxs issued by the health

providers, which, as a consequence, leads to unplanned hospitalisation. Non-adherence not only causes health risks for patients but also creates a cost burden for the whole health system (PhRMA, 2011). It incurs an annual cost of a hundred billion dollars in the US alone (Conn, Ruppar, Enriquez & Cooper, 2016). In NZ, it was reported that treating one person for diabetes over their lifetime is estimated to cost up to NZ$ 1,000,000, when this cost could be spent on preventative solutions instead (Udanga, 2011).

2.2 Literature Search Strategy

To achieve a comprehensive background and literature review on this topic, we conducted an extensive search, utilising multiple electronic databases. The search applied to records of all available fields of the IS, health informatics, pharmacology and medicine, at the time of the literature review search between 2011 and 2020. Specifically, we searched five electronic databases considered the most widely used sources in the fields of IS and health sciences. These included PMC (PubMed Central®) including MEDLINE journals, Science Direct, Google Scholar, IEEE Xplore, and Scopus as presented in **Figure 2.1**. Most selected papers were from open access, peer-reviewed, and/or systematic reviews from well-known scientific journals, as these are reliable sources of information.

We used, but were not limited to, the following keyword search terms: *medication adherence, medication self-management, mobile app reminders, mobile health, medication adherence intervention or compliance intervention, and medication reminders*. The rationale for using these keywords is that they provided us with articles primarily focused on MA interventions and systematic reviews analysing the past research on MA. Our initial screening found 3831 articles from the specified five databases. Excluding all articles not on mobile medication management apps or systematic reviews

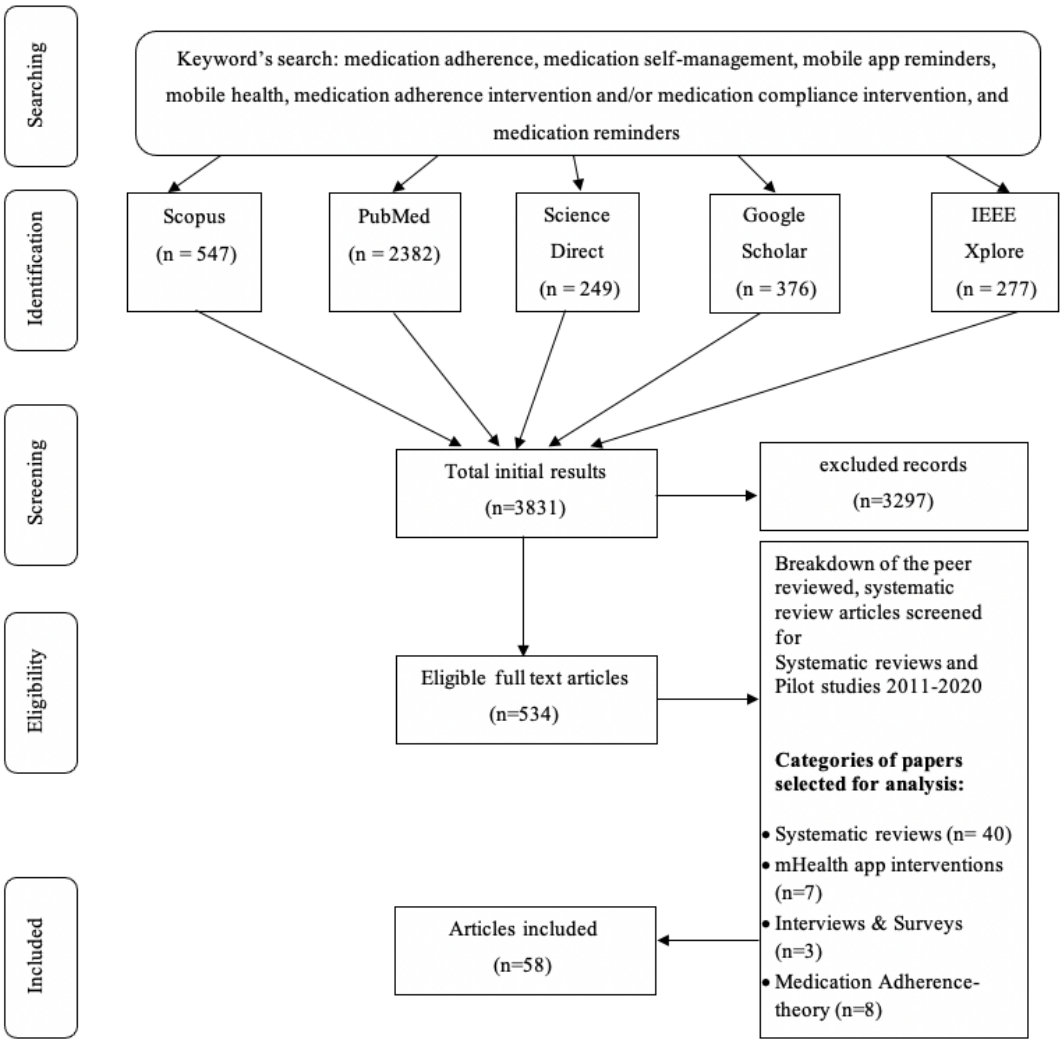

Figure 2.1: The identification and flow of potential eligible studies

of medication management or mobile app pilot studies and their duplicates across the databases, we arrived at our list of 534 eligible full-text articles. We included the highly cited systematic reviews, mHealth app interventions, interviews and surveys evaluating medication adherence apps and medication adherence theory peer-reviewed journal articles from those studies and that filtered the articles to the top 58 peer-reviewed journal articles.

Figure 2.2 presents the process we followed to obtain a comprehensive summary that yielded the identification of the research problems, which we named "Need for

research". We started by looking at academic journals, conference papers, workshops' discussions and results from the industry. The broader view across all available work to date allowed us to conduct an in-depth and rigorous investigation. We then listed the gaps within academic research and industry products (detailed in **Section 2.12**). **Figure 2.3** presents the eligible full text articles for screening per year. The following section presents a background overview of the journey to investigate and learn what has been researched and achieved to date.

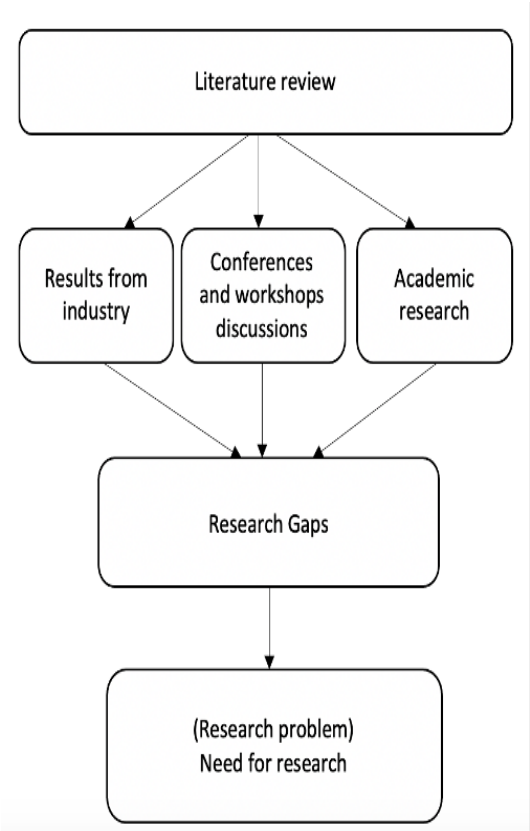

Figure 2.2: Literature review source process

2.3 Defining Medication Adherence

MA is referred to as 'compliance' by the healthcare providers, which considers the patient as passively following the doctor's instructions, and the treatment plan being

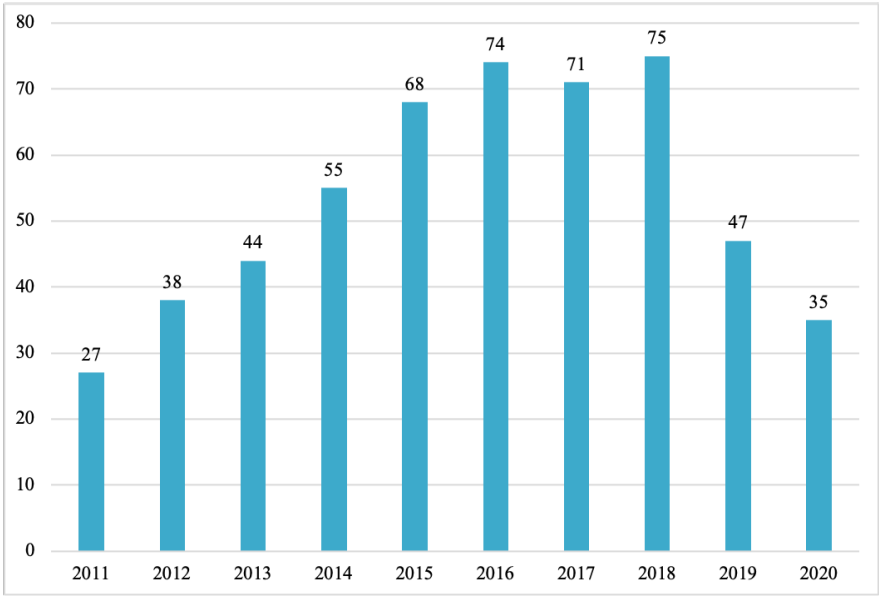

Figure 2.3: Number of eligible articles for screening per year

based on an agreement between the patient and the healthcare provider (Osterberg & Blaschke, 2005). Ho et al. (2009) defined it as "a situation in which patients take their medications as per the healthcare provider's prescription, at the right dose, at the right time and for the prescribed length of time". Other researchers in the field developed the definition of MA further to include the dose (taking the prescribed amount of medication each day) and dose timing (taking medication on time) (Lüscher & Vetter, 2005).

Our definition of MA is: *to actively take the needed medication, with the exact dose, at the right time, for the specified period of time and acknowledge its intake for the healthcare record.*

Despite the number of definitions of MA, it is clear to us that the complete benefit of most medications is achieved only if patients follow the prescribed treatment carefully and reasonably. Following the prescribed medication persistently is a challenge which we will be discussing in the next section.

2.4 Issues and Challenges of Medication Adherence

MA is a well-discussed matter among pharma, healthcare professionals, and health technologists, yet it continues to be considered an unsolved issue (Treskes et al., 2018). The concern is that failing to adhere to medication will most likely reduce the quality of life in general, negatively impact the treatment results and lead to poor outcomes in the long term. These include increased illness with the risk of health deterioration, which will lead to a greater need for treatment, resulting in a higher overall cost of care (Kane, 2005). Poor MA contributes to increased healthcare utilisation and costs, poor health outcomes, decreased quality of life, and worsening of disease, or death (Jimmy & Jose, 2011). Moreover, numerous previous studies have summarised the known reasons for not following MA, such as forgetfulness, ineffectiveness of medication, and taking too many medications (Vik, Maxwell & Hogan, 2004). In another study conducted by Muller (2018), he found determining the adherence of patients with multiple medications (known as polypharmacy) is critical to achieving safe use of medication, otherwise they will show a red flag.

In another study related to MA interventions conducted by Elliott (2013), it was mentioned that to be able to solve the issue of MA correctly, the reasons for non-adherence should always be included. Furthermore, previous studies on MA interventions categorised the reasons for non-adherence into five main factors:

- Healthcare system/team factors, which include the source of medications, provider communication, and access to care
- Patient-related factors, which include age and gender
- Therapy-related factors including polypharmacy, side effects, duration of therapy, frequency of changes, and ineffective therapy
- Condition-related factors, representing the current health status
- Social and economic factors, which cover the cultural side, the cost of medication,

and health literacy.

In Gajria et al.'s (2014) research, they reported on the discontinuation of medication based on age range. According to their findings, the reasons differed slightly between each age group; for example, parents/caregivers' decisions, poor adherence, school factors, and misdiagnosis were more likely to be factors for children rather than for adults. Moreover, the study conducted by Wali and Grindrod (2016) shows that health literacy plays a significant role in treatment progress. It was reported that patients showing low health literacy are 10 to 18 times less likely to correctly identify their medication than those with adequate health literacy skills. Therefore, we find that patients with difficulties in understanding health information will either forget to take their medication, or want more details on instructions and side effects, and will make poor health decisions. In these cases, patients were in need of tailored medication counselling to meet their basic needs (Ngoh, 2009). According to Martin et al. (2005), some of the health conditions see more than 40% of patients sustaining significant risks by ignoring healthcare advice, misunderstanding instructions, or forgetting to take their medication.

Since 1975, more than 200 variables in improving MA have been studied (Donovan & Blake, 1992; Vermeire, Hearnshaw, Royen & Denekens, 2001; Haynes, McDonald, Garg & Montague, 2002). And looking at more recent summaries of interventions we found Conn et al.'s (2017) research summarising 771 intervention trials in their systematic review conducted in 2015, where they grouped the interventions as follows:

- **Intervention content:** Cognitive-focused content to change the patient's knowledge, beliefs or attitude has less influence on adherence than have behaviour-focused content (prompts, rewards or goal settings), or habit-based intervention (linking medication with habits).
- **Intervention delivery:** Face-to-face pharmacist intervention and interventions delivered to patients directly have higher adherence than interventions delivered

to clinicians with the assumption that they will effect patient adherence.

- **Intervention recipient:** Younger adults have better MA than older adults have, and the homeless have low adherence.

MA is a major issue and solving it is a major challenge (Kvarnstrom, Airaksinen & Liira, 2018). **Table 2.1** presents the studies which benefited this research. As we can see the key points from each research study prove that the reasons for MA are multidimensional and rooted in human behaviour as concluded in another research by Neiman et al. (2017). From our literature review analysis of the selected papers we summarise below the most common challenges to MA:

- **Patients' lack of understanding**: It takes time and effort to educate and instruct patients about the benefits, side effects and potential risks of taking their medicines. This challenge occurs with patients with multiple prescriptions, such as elderly patients and those with chronic conditions. Also, when patients take a daily medication that does not produce an immediate change or result, they often question why they are taking the medicine.
- **Side effects**: The secondary effects of medications can be both real and perceived. Some side effects cause symptoms that become too annoying or uncomfortable to patients, so they stop taking the medicine. For example, patients who are not able to drive for two hours after taking a pill due to the side effect of dizziness. Perceived side effects are those that patients read about on the Internet or hear about from friends. While many of them may not be true, they can be scary enough for the patient to stop taking the medicine without informing their physician.
- **Complicated regimen and/or too many medicines**: Patients must take some pills once a day, twice a day or even once a month, and it is easy to forget the schedule. Also, some pills are taken with food and some without.
- **Accessibility**: Many low-income, elderly, young and disabled patients may not have easy access to pharmacies, and it can be costly to ship pills to their homes.

This lack of access affects both rural and urban residents, as many urban patients live in non-serviced areas, or their mobility issues limit them from taking certain forms of transport.

- **Cost**: When it comes to choosing between paying the electrical bill, buying groceries and picking up a new prescription, unfortunately many patients, especially older patients, or individuals with low income, can only choose one of these because they cannot afford all three. This situation can result in not refilling their prescription or rationing their pills to make them last longer.

2.5 Managing Medication Adherence

Adherence to medication is an important public health issue; it negatively affects the safety and efficacy of the treatment and leads to a medication struggle (McGuire et al., 2014). There are over 700 factors associated with MA, and these may occur at any stage of the treatment plan, therefore, MA is not easily predictable (Vrijens, 2019). Interest in the problem of MA has only continued to grow; the number of publications has increased exponentially in the last 40 years since the first studies were published in the mid-1970s, reaching more than 1,200 articles in 2015 (Kronish, 2017). With the increase of interest in solving this issue, the terminology surrounding MA and non-adherence has also grown and evolved which has made the language ambiguous (Vrijens, 2019).We found some of the more commonly used terms have various meanings for different people, as defined in **section 2.3**.

MA research has increased substantially using observational and experimental research designs (Tougas, Hayden, McGrath, Huguet & Rozario, 2015). Despite the research efforts across disciplines, including technology, the results did not effectively tackle the MA issue (De Geest et al., 2019).

The Delphi experts, the international multidisciplinary panel, developed the European

Society for Patient Adherence, Compliance and Persistence, issuing 'EMERGE', the MA Reporting Guideline (Helmy et al., 2017). EMERGE is built on a previous taxonomy, which divides adherence into three interrelated, but still distinct, phases: (1) **initiation**, (2) **implementation**, (3) **persistence**, and **discontinuation**. *Initiation* is taking the first dose of prescribed medication, followed by *implementation*, which is the extent to which the patient's actual dose corresponds to the prescribed dose from the first dose taken until the last dose taken. Then, *persistence* is the time between initiation and the last dose, followed by *discontinuation*, which refers to patients stopping medication on their initiative, taking no doses after that. Issues with taking the proper medication can occur in any of these phases and can be classified as 'late', 'incomplete', or 'no initiation'. Each of the three phases creates a challenge regarding how we define medication use, measurement, and analysis (De Geest et al., 2019).

2.6 Use of Technology for Managing Adherence

The causes and influencing factors of MA are difficult for healthcare providers to define (Gücin & Berk, 2015). When health providers issue Rx to patients, many changing variables affect the patient's medication intake, and the result is often related to the patient's effort to adhere to the planned treatment (Vrijens, 2019). The healthcare provider and patient can develop a plan that works with the patient's lifestyle to improve adherence (Fogel & Kvedar, 2018). It has been demonstrated that the combination of personal and automated reminders has produced effective results for improving MA and clinical outcomes (Vervloet et al., 2012). This combination has also increased patient and caregiver satisfaction (Granger & Bosworth, 2011).

Digital technologies extend the scope of care beyond healthcare clinics, and provide additional support for minimising medication issues (Nicholls, MacKenzie & Braund, 2017). From our search, we explored several non-digital methods, still usable to date, to

support people in taking their medicines accurately, such as dose administration, home visits for medicine checks, and pharmacy assistance. However, we find technologies such as phone calls by trained health professionals, medication apps, and wearable sensor devices can potentially support patients in a more manageable and cost-effective way (Usherwood, 2017; Jeminiwa et al., 2019). Still, current research provides insufficient evidence of their effectiveness, and their broad adoption can not be recommended (Andrade & Roughead, 2019).

In Weidenbacher et al.'s (2015) study, it was suggested that healthcare providers could tailor interventions to improve adherence to specific treatment, such as those for depressive symptoms. They concluded that other health conditions also affect adherence, and not only because of the patient's effort or their choice of adhering to medication. Another study confirmed that mHealth interventions for chronic conditions seem to have positive or mixed outcomes for MA (Gandapur et al., 2016). Those outcomes differ according to the user's acceptance of technology, which will be the next angle we look at in the following section. According to Hincapie et al. (2019), there has been a surge in research to examine the use of technology, specifically mHealth interventions, its development and use, to improve MA.

Table 2.1: Summary of systematic reviews conducted on interventions to improve MA

No	Study	Condition	Number of Participants	Years Covers	Age	Interventions Used	Study Trial Period	Key Points
1	Conn et al.(2017)	Focused on studies covering adherence outcomes	Median 98 participants	1971 - 2015	Median age 56	Electronic event monitoring Pill count MA measures Face-to-face by pharmacists	Not specified	Published and unpublished studies with adherence outcome were included. To change behaviour, behaviour intervention may be required; however, clinicians emphasised patient education although evidence in the study shows that knowledge is insufficient to change adherence. Habit based interventions are needed. People with poor adherence may also be less likely to enrol in studies, which may lead to selection bias and may influence the outcome.
2	Ruppar et al.(2016)	All studies focused on heart failure	10-3902	1998-2013	45+	SMS, video educational and counselling Structured interviews Home visits Educational booklets	2 weeks – 3 months	Most interventions done by pharmacist or nurses. None of the interventions involved clinicians. Percentage of females ranged from 0 % to 100%. Very few studies applied more than one intervention by groups and compared between them. There was no reporting of the most effective intervention. None of the studies integrated MA interventions into practice to improve clinical outcome.
3	Park et al.(2016)	Cardiovascular disease	6-303	2002-2016	50+	SMS 2 studies only Mobile apps	4 weeks – 6 months	A number of SMS participants much higher than mobile app participants. Most studies were experimental. Very few studies used more than one intervention and compared between groups. Most studies addressed MA and few of them measured clinical endpoint (i.e. death, hospitalisation, and emergency department visits).
4	Anglada-Martinez(2015)	Asthma HIV Coronary heart disease Hypertension Infection disease Psoriasis Vitamin C	18-580	2009-2014	18+	Self-report Pharmacy refill data Adherence survey MARS Pill count Phone calls SMS reminder Self-reported questionnaire	4 weeks - 3 months	Comparison between studies was not clear due to difference in study design, intervention, treatment regimen, and duration and measurement method. All interventions were SMS reminders or motivational content. Most studies did not include detailed description of their implementation and message delivery when using SMS, which could be important as the missing information could be useful for the design of future studies. In three studies, participants were paid and two studies provided mobile devices. Therefore, findings do not provide useful insights into the potential scope of the intervention since it is not feasible to provide a mobile phone to all the population.
5	Grajria et al.(2014)	Attention-deficit	Not reported in most studies	1990-2013	Children Adolescents Adults	Database analysis Parent / caregiver survey Physician survey	30 days Follow up 12 months	Compared studies addressing medication discontinuation in ADHD patients. Identified reasons of non-adherence in each study with a brief comparison between them.
6	Vervloet(2012)	Hypertension Asthma Glaucoma HIV (Chronic medication)	13 - 224	1996- 2011	Adults adolescent	SMS Electronic reminder device with audio visual reminder Self-report Pill count	2 weeks - 1 year	It included studies for different health conditions, which made the comparison different as each condition may have its own intervention. Most studies found short term improvement. However, long-term improvement was not investigated. The interventions were provided to patients with no clinician's involvement. The studies included but did not identify which groups the electronic reminder was beneficial to the most.
7	Haynes (2002)	mental disorders but not addictions	37-255	1984- 2007	Children age 0 – 5 Adults all ages	Patient interview Pill counts Pharmacist telephone follow-up self-reports	4-6 weeks Follow up 1 – 6 months	Short-term treatments with simple interventions increased adherence and improved patient outcomes. Lack of reporting interventions to medication prescriptions for long-term medical disorders. Most long-term condition had a multi-interventions and the most effective interventions did not lead to large improvements in adherence and treatment outcomes.

2.7 Users' Acceptance of Technology in the Health Context

With the rise in mobile ownership and the expansion of healthcare apps, it is important to explore the factors impacting the user's acceptance of mobile technology (Sudburya et al., 2013). If the technology is used only by users who are already motivated and keen to use it, this will contribute to expanding the gap between the users and the interventions (Petersen et al., 2020). Therefore, it is important to continuously involve end-users in the process of development and implementation, so health apps are better tailored to meet the needs of the end users (Ali et al., 2018). This will allow the developers to pinpoint the factors affecting acceptability and usability because the success of the apps depends on them (Gücin & Berk, 2015). According to past research, many theories and models have explained technology acceptance and usage (Venkatesh, 2012; Sudburya et al., 2013).

A significant example includes using the Technology Acceptance Model (TAM) and its alternatives, with the primary factor of users' acceptance being the ease of use of technology and its perceived usefulness. However, most of these studies incorporate other variables into the original TAM model. Thus, it is not easy to find a single model of acceptability of the mHealth app that is entirely accepted (Ali et al., 2018). Venkatesh et al. (2012) created the UTAUT model, which covered various theories. This model proposed four primary factors affecting the individual's acceptance and usage of technology: (1) *effort expectancy*, which is related to the ease of using the technology accepted; (2) *performance expectancy*, which is related to the increase in performance; (3) *social influence*, and (4) *facilitating conditions* (Gücin & Berk, 2015).

In Everett Roger's (1962) book, *Diffusion of Innovations Theory*, it is stated that relative advantage, complexity, compatibility, trialability, and observability, are the features determining the acceptance of technology. Therefore, for the success of

mHealth apps interventions the adoption of the mHealth apps is significant (Ali et al., 2018). This brings us to the importance of adherence management through mHealth, which we will be discussing in the next section.

2.8 The Importance of Adherence Management via m-Health

The widespread adoption of mobile phones offers an innovative opportunity for healthcare providers to incorporate mHealth as means of providing a personalised and cost-efficient method of healthcare (Gandapur et al., 2016). Enabling patients to manage their health using mobile apps improves medication management, which in turn could help the healthcare system save billions of dollars each year (Kalantarian, Alshurafa, Nemati, Le & Sarrafzadeh, 2015). As suggested by Tani et al. (2019) success comes from integrating these tools into the daily routine; reminding patients about their well-being could be a key.

mHealth apps can deliver reminders to patients to refill prescriptions, take medication on time, as well as report their adherence, pain levels, and symptoms using surveys (Santo et al., 2019). According to Smahel et al. (2017), a high-quality MA app include features such as medication tracking, a medication database and data security. However, to achieve success, it must be used consistently by patients, provide the sharing of data, and assist patients who have to manage multiple health conditions (Digital Health, 2018).

Current medication management apps apply different techniques to improve medication intake and can be divided into three types: *education*, *reminder and management*, and *behavioural*. Education techniques could include interactive texts and videos. Reminder and management techniques could include push notifications and short message

services. Behavioural techniques include personal tracking, where users monitor their use and data is shared to create common responsibility and promote the desired behaviour (Andrade & Roughead, 2019). In the next section, we present examples of MA apps from our exploration of past research and industry sources (New Zealand Health IT, 2018; Ministry of Health, 2020).

2.9 Existing mHealth Work to Improve Medication Adherence

For more than four decades, researchers have presented intervention techniques to improve MA (Atreja, Bellam & Levy, 2005; Horne et al., 2005; Chen, Kehtarnavaz & Jafari, 2014; Kalantarian et al., 2015). These studies approached managing medication for patients with long-term illnesses, such as hypertension, diabetes, heart failure, epilepsy, cancer, and Parkinson's (Tang, Zhu, Jiao, Ma & Wang, 2013; Krass, Schieback & Dhippayom, 2015; Lakshminarayana et al., 2017). Most of these applied, tested and evaluated several intervention techniques to assess patients' MA, identified as individual self-reports of medication taking (Morisky, Green & Levine, 1986). For example: wearable sensors, real-time electronic monitoring, pharmacy refills, text messaging, pillboxes and mobile apps (Vervloet et al., 2012; Chen et al., 2014; Kalantarian et al., 2015; DiDonato, Liu, Lindsey, Hartwig & Stoner, 2015; Pringle & Coley, 2015; Haase, Farris & Dorsch, 2017).

Results of each study varied based on the methodology used and the selected population. While there are several methods used for measuring MA, none was considered a gold standard due to the varied patient populations, diseases, and medicines considered, determined by different study designs and measurement of adherence (Fairman & Matheral, 2000; Buelow & Smith, 2004; Elliott, 2013). Although technology has made an

immense contribution to the healthcare system, solving MA is considered one of the biggest challenges (McDaniel & Einstein, 2016).

As per the systematic review conducted by Anglada-Martinez et al. (2015) on using mHealth to increase MA, most of the studies demonstrated improved clinical outcomes. Moreover, in the integrative review conducted by Park et al. (2016), 22 out of 28 studies validated the effectiveness of mobile phone intervention in improving clinical outcomes due to improved MA. From our review of the literature, we came to the conclusion that we could categorise the studies on MA interventions using mobile phone technology into three main categories: Voice calls, mobile phone text messaging, and mobile phone apps (Vervloet et al., 2012; Choi et al., 2015).

2.9.1 Voice call interventions to improve MA

In a review study conducted by Haynes et al. (2008), patients received telephone calls after the first, second, and fourth weeks of the intervention. Voice calls were used in many MA interventional researches, to follow-up and collect feedback during or after the study ended (Griffiths et al., 2017). Moreover, in the systematic review conducted by Rootes-Murday et al. (2017), two studies used phone calls as the only intervention for patients taking anti-depression medicines, and the results showed an increase in MA. However, it was difficult to conclude that this is the best solution due to its use over a short period, as well as the impracticality of the intervention, as it needs qualified staff to make the phone calls, compared with text messaging and mobile apps.

2.9.2 Text message interventions to improve MA

In a study conducted by Dekoekkoek et al. (2015), nine out of 13 studies evaluated showed that adherence rates improved by 15% to 18% when using text messages to promote MA. Text messages that were tailored according to the medication regimen,

showed an improvement in MA. The authors set guidelines for the future development of text messages and recommended translating evidence into practice. Another study conducted by Kannisto et al. (2015), investigated patients' opinions on receiving SMS reminders on antipsychotic medication for twelve months. The participants completed a survey based on existing service experience and the technology acceptance model. Their study concluded that the participants endorsed the use of simple, already existing technology, such as mobile phones and SMS. Their findings were in line with the other studies we present in **Table 2.1**, which showed a wide use of SMS reminders in different interventions.

2.9.3 Mobile app interventions to improve MA

Currently, there are approximately 3.6 billion smartphone users worldwide, including healthcare providers, consumers and patients, who can potentially use healthcare apps (Statista, 2020). The requirement for apps has improved; the need to utilise apps with more compelling features and with easier to follow instructions has developed (Choi et al., 2015). Gu et al. argue that mobile health technology could save the healthcare system approximately US$290 billion in medication management costs (Gu et al., 2016). However, the increase in the number of mHealth apps to more than 318,000 worries healthcare providers, due to risks that there may be a violation of the users' online privacy, or the offering of dubious medical information and advice (Aitkin et al., 2017). Several studies have presented the beneficial results of MA apps in various health conditions (Park, 2016; Wytiaz, Lee & Odukoya, 2015). We present in **Table 2.2** examples of systematic reviews on MA interventions using mobile app technology.

mHealth apps are continuously increasing in the app stores, but insufficient evidence exists to extend their use. Their rapid growth has resulted in confusion among healthcare providers and the apps' users about which products are evidence-based (Larson, 2018).

In Jake-Schoffman et al.'s (2017) paper, they summarised methods for assessing the *content*, *usability*, and *efficacy* of commercially available health apps using content analysis to compare app features with behaviour change techniques, clinical guidelines, and evidence-based protocols.

In the study of "Mobile Phone Interventions for the Secondary Prevention of Cardiovascular Disease" by Park et al. (2016), they found the majority of the explored studies had a 79% effectiveness in improved outcomes with the use of text messaging and mobile apps as reminders. However, the reasons for the 21% failure rate were not justified or reported.

In another study by Ismail et al. (2017) a randomised control trial showed the impact of a daily SMS reminder for tuberculosis treatment outcomes as having a success rate of 83% (30% treatment completed and 53% cured), and a failure rate of 2%, which was attributed to the non-acceptance of change, and 15% shared between having transferred out or died. In a three-month study of asthma treatment, the patients were randomised to receive or not receive a daily SMS reminder (Strandbygaard, Thomsen & Backer, 2010). The study concluded that the mean adherence rate increased from 77.9% to 81.5% for the ones who received SMS reminders. However, they did not mention any reason for the 18.5% who showed no improvement, and it was unclear if they were not adherent, or they did not receive the SMS. This leads us to highlight the importance of smartphone apps that develop more significantly than other interventions because they can be validated and updated over time, and enhanced features can be added to the original version (Anglada-Martinez et al., 2015).

Some recent studies have adopted available methods such as smartphone apps (Rootes-Murdy et al., 2017). MedLink and Mobilyze! examined the feasibility and acceptance but not the effectiveness of the apps (Burns et al., 2011; Corden et al., 2016). Other studies presented the pros and cons of mobile apps and evaluated the top five patient-centred apps capable of performing a wide range of functions (Kamel Boulos,

Brewer, Karimkhani, Buller & Dellavalle, 2014; Nguyen et al., 2016; Santo et al., 2017; Mna, 2018).

In another study by Park et al. (2016), the following themes emerged: (1) the ability to customise medication plans, medication reminders, monitor health data, and support healthcare visits; (2) optimisation of information input and upgrading; and (3) negative user experiences captured technical difficulties, dosage schedule and reminder setup inflexibility. Through our investigation we were able to classify the apps identified in the past research into commercial self-managing apps and clinically-led apps, which we present in the following subsections.

Self-managing apps

These apps refer to mobile apps that can be downloaded from an app store (Google Play or Apple App) and used without any intervention by the health team or integration with the health system. In Dayer et al.'s (2013) research, they provided an overview of the available MA apps from the leading app platforms (Apple, Android, and Blackberry) and discussed their potential to improve MA. They found the advanced functionality apps were widespread on the Apple store. For example, MyMedSchedule, MyMeds, and RxmindMe rated highly among all apps because of their basic medication reminder features and their enhanced levels of functionality. Moreover, a study by Choi et al. (2015), categorised the findings based on the pros and cons of the health apps and concluded that the majority offered manual reminders and access to medication information; these features help to facilitate patient adherence and quality of life. Moreover, the study conducted by Santo et al. (2016) identified high-quality apps which were rated as appealing, easy to use, and providing good quality information.

Table 2.2: Studies discussed smartphone apps as an intervention to improve MA

No	Title (Year)	Aim of Research	Conclusion	Gaps and Challenges
1	Medication Adherence Apps: Review and Content Analysis (2018)	To review MA apps available in app stores in terms of their evidence base, medical professional involvement in development, and strategies used to facilitate behaviour change and improve adherence. Provide a system of classification for these apps	From the selected 805 apps, 420 free apps analysed to identify strategies (reminder, behavioural and educational) used to improve MA. A total of 250 used a single method, 149 used two methods and 22 used all three methods.	There is a concerning lack of health care professional involvement in app development and evidence base of effectiveness. Lack of collaboration between relevant stakeholders to ensure development of high quality and relevant adherence apps with well-powered and robust clinical trials to investigate the effectiveness of these interventions.
2	IntelliCare: An Eclectic, Skills-Based App Suite for the Treatment of Depression and Anxiety (2015)	To pilot a coach-assisted version of IntelliCare and evaluate its use and efficacy at reducing symptoms of depression and anxiety	Assessments outcome was Patient Health Questionnaire-9 for depression and the Generalised Anxiety Disorder-7 (GAD-7) for anxiety. 99 participants who initiated treatment, 90.1% (90/99) completed 8 weeks. Participants showed substantial reductions in the PHQ-9 and GAD-7	The app lacks using the collected data to monitor efficacy and provide evidence-based recommendations.
3	Text Messaging and Mobile Phone Apps as Interventions to Improve Adherence in Adolescents With Chronic Health Conditions: A Systematic Review (2015)	To review and to systematically evaluate the most recent evidence for the efficacy of text messaging and mobile phone apps as interventions to promote medication adherence among adolescents with chronic health conditions.	The text messaging and mobile app show promising feasibility and acceptability, and there is modest evidence to support the efficacy of these interventions.	Evaluation of short and long term efficacy and cost-effectiveness of these interventions.
4	Mobile Phone Apps to Improve Medication Adherence: A Systematic Step-wise Process to Identify High-Quality Apps (2016)	To review the medication reminder apps available in the Australian iTunes store to assess their features and their quality in order to identify high-quality apps.	Google play apps had more customer reviews, higher star feasibility and acceptability and the efficacy of the apps are modest.	Identification of high-quality apps and testing them to provide evidence on the use of medication reminder apps to improve MA.
5	MedLink: A mobile intervention to improve medication adherence and processes of care for treatment of depression in general medicine (2016)	To evaluate the feasibility of MedLink designed to improve treatment of depression in primary care among patients during the first eight weeks of initiating a new course of antidepressant therapy.	Participants showed a significant decrease in depressive symptoms on health questionnaire and the Quick Inventory of Depressive Symptomatology.	Further evaluation of MedLink through a randomised controlled trial to evaluate the efficacy of the improvement of processes of care, symptoms of depression and patient adherence.
6	Mobile Applications to Improve Medication Adherence: Existing Apps, Quality of Life and Future Directions (2015)	To review the existing mobile apps used to improve non-adherence, quality of life. To discuss the pros and cons of currently marketed mobile apps.	Various apps are helpful to facilitate patients' adherence, but the majority have similar functionalities, such as manual reminder alerts, access to sources for drug information. The target population for the apps are caregivers, elderly, low literacy patients, low income individuals.	Reinforcing patient's health information security with unique code and passcode as well as automatic linking of prescriptions.
7	Expert Involvement and Adherence to Medical Evidence in Medical Mobile Phone Apps: A Systematic Review (2015)	To systematically review studies evaluating expert involvement or adherence of app content to medical evidence in medical mobile phone apps.	From 6520 apps only 52 apps were included in the review. In the 28 apps assessed, experts' involvement ranged between 9-76%. 30 studies assessed content to current medical evidence; 17 found that none of the assessed apps adhered to the compared evidence; and 13 adhered to the compared evidence with a range between 10-87%.	Lack of experts' involvement in most of the assessed apps and adhering to relevant medical evidence.
8	Don't Forget Your Pill! Designing Effective Medication Reminder Apps That Support Users' Daily Routines (2014)	To report the findings of a functionality review of 229 medication reminder apps. To highlight the gap between the theory and practice.To present design requirements for building medication reminders that support the routine aspect of medication-taking.	Regardless of the type, functionality or complexity of the app they focus on timer-based reminders. The snooze option is rarely available. Although taking medication is a habitual task, the functions that explicitly support routine-based reminders are not available.	The functionality of existing apps' lack of support for personalised daily routines, to add notifications, and to allow post-completion checks.

Clinically-led featured apps

Referred to as 'medically-featured apps' are apps used by patients with specific health conditions and used in specific settings; the patient's health is monitored by the health team through the app. A research study conducted by Boulos et al. (2014) examined the state-of-the-art in these types of apps by presenting a brief survey evaluation. They also discussed the concept of apps as medical devices and the measures for successful apps, covering content quality and usability, device connectivity standards, as well as security and user privacy. It was concluded that it is not possible to rate every app available. However, the most important aspect was to educate users regarding the possible risky content of some apps.

Furthermore, Ventola (2014) presented the use and advantages of medical devices and apps by healthcare providers. They conducted a thorough evaluation, validation, and development of the best practice standards for medical apps to assure they met the necessary quality and safety level before using them. Ultimately, they were required to provide accurate, timely and meaningful information and guidance. In addition, other studies presented the pros and cons of mobile apps. And further studies evaluated the top five patient-centred apps that performed a wide range of functions, which we re-evaluate in our next section (Dayer et al., 2013; Kamel Boulos et al., 2014; Santo et al., 2016).

2.10 Evaluation of Existing MA Apps

We evaluated the five top-ranked MA apps identified by Santo et al. (2016): My Pillbox, Dosecast, Medisafe, MyMeds and CareZone (My PillBox, 2015; Montuno Software, 2015; Medisafe, 2017; MyMeds, 2017; CareZone, 2018). **Table 2.3** lists the functionalities of each app. These apps were selected based on a number of

functionalities, along with an assessment based on the Medication Application Rating Scale (MARS) (Stoyanov et al., 2015).

The apps have similar functionalities of flexible scheduling, medication tracking history, customisable alert sounds, multiple users support, multilingual options, and adherence rewards. However, the top-ranked app, Medisafe, lacks the functionality of reminders with no connectivity and medication database. The second-best app, MyMeds, does not include the snooze option, data sharing, refill reminders, data security, adherence statistics and charts, and the time zone support. Moreover, the last three apps, Dosecast, CareZone and MyPillbox had more than seven criteria missing. In summary, most of the apps lacked data security, a medication database and adherence statistics.

Table 2.3: Functionality criteria for the top MA Apps based on MARS

Functionality Criteria	Medisafe	MyMeds	Dosecast	CareZone	My Pillbox
Flexible scheduling	Yes	Yes	Yes	Yes	Yes
Medication tracking history	Yes	Yes	Yes	Yes	Yes
Snooze option	Yes	No	Yes	Yes	Yes
Visual aids	Yes	Yes	No	Yes	Yes
Customisable alert sounds	Yes	Yes	Yes	Yes	Yes
Multiple users support	Yes	Yes	Yes	Yes	Yes
Data exporting / sharing	Yes	Yes	Yes	Yes	Yes
Multilingual	Yes	Yes	Yes	Yes	Yes
Refill reminders	Yes	No	No	Yes	No
Reminders with no connectivity	Yes	Yes	Yes	Yes	No
Data privacy: password protection	No	Yes	No	No	Yes
Data security	No	No	No	No	No
Adherence statistics and charts	Yes	No	No	Yes	No
Medication database	Yes	Yes	Yes	No	No
Notification for other people	Yes	Yes	Yes	Yes	No
Time zone support	Yes	No	Yes	No	Yes
Adherence rewards	No	Yes	Yes	Yes	Yes

Table 2.4: Re-evaluating MA apps based on SHARP

SHARP assessment criteria	MA Apps				
	Medisafe	Dosecast	MyMeds	CareZone	My Pillbox
Sustainable	Yes	No	Yes	No	No
Holistic	Yes	Yes	Yes	Yes	Yes
Adaptive	Yes	Yes	No	Yes	Yes
Real-time	Yes	No	Yes	No	No
Precise	Yes	Yes	Yes	No	No

2.10.1 Re-evaluating the top MA apps using the SHARP approach

In our further assessment, as shown in **Table 2.4**, for re-evaluating the existing MA apps using the SHARP approach, we verified the availability of the five concepts: Sustainable, Holistic, Adaptive, Real-time, and Precise, for each MA app (Mirza, Mirza, Chung & Sundaram, 2016). We can see that MediSafe fulfils the five concepts. However, the Dosecast application excluded sustainability and real-time but included holistic, adaptability and precision concepts.

The MyMeds application also included all concepts except real-time communication, whereas the CareZone app had only holistic and adaptability features and it lacked the other concepts. The last app was My Pillbox, which was a commercial app and that also had only holistic and adaptability features; like the CareZone app it missed the valuable features of precision, real-time feedback and sustainability.

2.10.2 Selecting the top MA apps using the SHARP approach

We designed a flowchart to go through during the selection process, as shown in **Figure 2.4**. We started by selecting the apps designated for medication management and excluded the general health and well-being reminders. Thereafter, we excluded the commercial self-managed apps, and selected clinically-led featured apps because clinicians and patients are in need of reputable and unbiased resources to improve MA

and the patient-clinician relationship (Iprescribeapps, 2016). Therefore, there is a need for apps that can be prescribed to patients while prescribing medication.

In addition, the patients want to share their health questions and conditions with the people they trust and feel comfortable communicating with (Brien, Petrie & Raeburn, 1992). Consequently, our last step was to indicate the apps with an Online Social Networks (OSN) feature which highlights the health communication part. Due to the high influence of online connection and collaboration in our daily decision making, we added specific criteria covered by features of OSN in health communication to re-evaluate the MA apps (Sadovykh, Sundaram & Piramuthu, 2015).

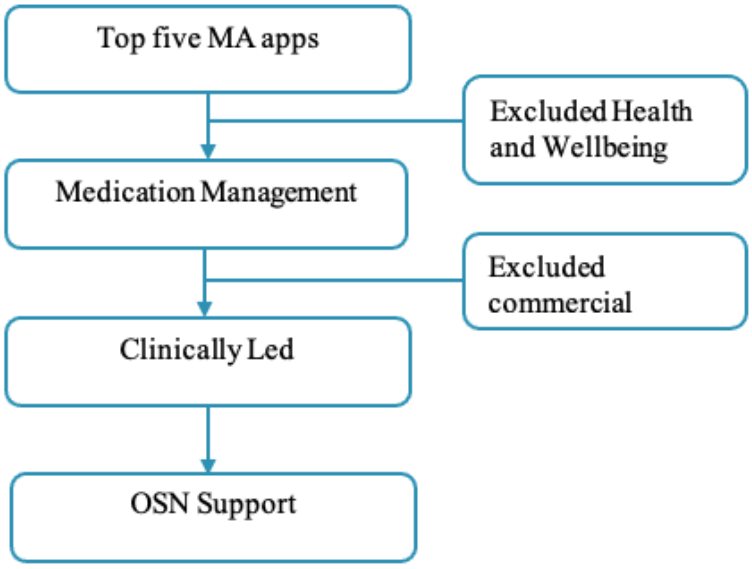

Figure 2.4: Flowchart of app selection criteria

By applying the app selection criteria to the five apps, we can see that MediSafe, Dosecast and MyMeds applications fulfilled most concepts of the SHARP approach. Therefore, we were able to assess them on the advanced features of being clinically led and having OSN. We found that Medisafe and MyMeds had the features of being clinically-led and having online health communication, satisfying our criteria as concluded in **Figure 2.5**. As these two apps provide these innovative features, it suggests they may satisfy the clinician's needs. In this work, we described our process to identify

clinically-led MA apps with OSN features, which may be valuable to help health providers and researchers consider them as reliable apps with advanced specifications.

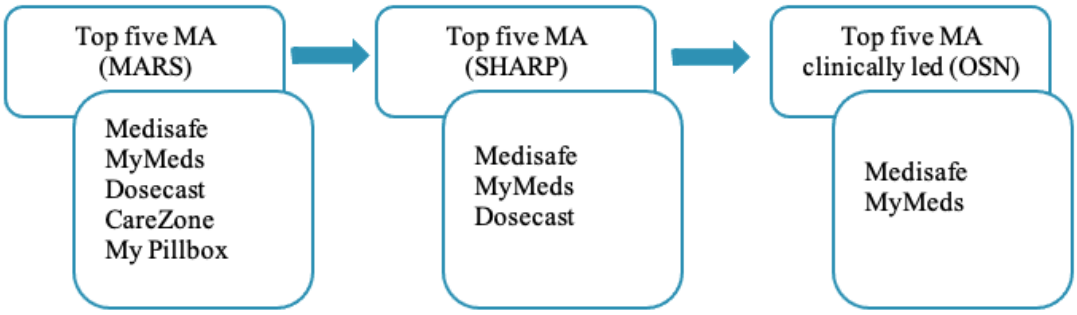

Figure 2.5: Re-evaluating the top five MA apps

2.10.3 Conclusion of the app evaluation

We re-evaluated the top-ranked mobile applications via the SHARP perception, an approach for managing the long-term well-being of individuals. We concluded that most existing reviews and studies focused on the availability of medication management and health status more than patient communication and its impact on decision making towards adherence to medication. We identified specific criteria and the assessment process. By applying the new criteria of OSN features, clinically-led specifications, and the SHARP approach to the MA apps, we found that only two MA apps considered the feature of patient communication. The two apps, Medisafe and MyMeds, were theoretically successful. However, in practice we do not have a deep understanding of the extent to which they improved MA.

This evaluation tested both apps and proposed different features to be added to an app which may allow us to approach MA from another angle. The proposed app gives the patient the opportunity to be at the centre of care and the main source of information of medication intake and health status. Moreover, piloting the app with the clinicians'

involvement will give us a better evaluation of the efficacy of the app in improving MA.

2.11 eHealth Services in New Zealand

The Ministry of Health (2020) in NZ defined digital health as "the use of digital technologies and accessible data, and the associated cultural change it induces" to help us as New Zealanders to manage our health and wellbeing and transform the nature of our healthcare delivery. In an interview with the NZ Director of the National Health IT Board, he stated that for New Zealanders to have successful digital eHealth solutions, we must design them from a person-centred or customers point of view. Then, these solutions must be acceptable and widely adopted by healthcare providers from a workflow point of view, and clinical quality (Ministry of Health, 2020). This is discussed further in **Chapter 5**.

The user-centred approach to improve accessing and sharing health information supports better quality and more timely care for New Zealanders. Over the past 11 years, the NZ Ministry of Health has focused on enabling high-quality information to be shared between healthcare providers and consumers; for example, 93,000 New Zealanders now use the patient portals to access their health information online to manage aspects of their healthcare securely (Ministry of Health, 2020).

In 2020, telehealth was primarily accepted and used in NZ. Several places began to offer virtual care, including a virtual GP service called CareHQ (2020), which offered video consults to patients after working hours or when their GP was not available. This was accessible by patients through the CareHQ app or "My Southern Cross" (2020). GPs used the video capabilities in the Indici (2020) practice management system. After the COVID-19 pandemic, the NZ Ministry of Health resumed working on the National Health Information Platform (NHIP) programme. The NHIP follows an approach that provides consumers and providers with access to healthcare data and services

(McDonald, 2020a).

In 2018, a *Medical Futurist* article on digital health (2018) mentioned NZ as having the digital health strategy underway in 2016, and subsequently announcing a digital health strategy in 2017. The Ministry of Health developed the NZ Digital Health Strategic Framework to guide digital technologies and data. A person-centred approach underpinned the framework; the design is driven primarily by the needs of the health service consumers, healthcare professionals, managers, researchers and others, and the development and implementation of digital resources (Ministry of Health, 2020). Studying the NZ Digital Health Ecosystem outcome, we can see that the strategic objectives encapsulate the digital objectives, which encompass five main goals: (1) the people are in control of their health information; (2) the digital services and health information improve health outcomes, and equity; (3) the digital services empower health providers to perform more valuable services; (4) the digital services increase the performance of the public health system; and (5) the data insights provide evidence to make and support informed decisions.

Despite the advancements so far with digital health, patients still struggled and faced a real challenge with telehealth, according to recent research conducted by the University of Auckland to understand and monitor NZ GPs who use phone consultations. According to the NZ Health IT (NZHIT) (2018) news, both the market-leading general practice and pharmacy software providers launched an integrated electronic Rx messaging service called Secure Script that will allow GPs to send signature-exempt eScripts directly to pharmacies. However, this service works only to notify patients that their prescription is ready to be collected from the pharmacy but does not serve the MA goal of the treatment prescribed.

The NZ ePharmacy (NZePS) provides complete inventory management, dispensing, compounding, and repacking functionality for hospital pharmacy services, which

integrates with patient management systems and the MedChart prescription and administration software (McDonald, 2020b). With NZePS, if patients do not have their medication dispensed, the prescriber can be notified, but it cannot help determine whether or not a patient's treatment plan is followed nor provide medication history information, but only ensures the patient's clinical record can be updated when a patient's medicines are dispensed. Although they assume this helps to address patient MA, it only looks at dispensing the medicine from the pharmacy and not the medication intake by patients, which we will be further discussing in **Chapter 7**.

2.12 Research Gaps

We have learnt from the literature review that the applicability of the interventions to patients who do not take medications, or who take medications but whose health condition does not improve, needs to be considered as does patients' acceptance of using mobile apps in their treatment process as a communication tool. In addition, how reporting medication intake can improve adherence also needs to be investigated. Our preliminary findings from past and current research show that there are limitations in approaching MA. Some of these limitations are shown in **Table 2.5**.

2.13 The Study Research Questions

Within the scope of this study we will:

- Investigate the acceptance of or barriers to using a mobile app in healthcare communication in comparison to those shown in previous studies
- Co-design and develop a simple-to-use, mobile MVP informed by multidisciplinary experts and underpinned by theory
- Evaluate the MVP with end-users through focus-groups

Table 2.5: Studies limitations on addressing MA

Limitation	Description
Limited applied usage	Findings from the existing trial studies were conducted in idealised settings, which can not reflect real-life situations, thus leading to biased results.
Specific use-case evaluation	Many apps provided support for specific health conditions, like heart failure or asthma. Comparisons between studies were not clear due to the differences in health condition and type of intervention.
Requirements elicitation	Most studies did not include detailed descriptions of the implementation, which could be important information for the design of future studies.
Patient involvement	None of the app interventions explicitly included the medication intake acknowledgement from users. Most of the reported studies used phone calls or surveys for follow-up or to collect users' feedback on adherence to the use of apps.
Clinical involvement	The lack of clinician involvement is clearly evident from most of the studies None of the previous research states explicitly that the apps are prescribed by clinicians at the point of care or by the pharmacists during a medication dispensing or hospital discharge.
Demographics consideration	Very few studies considered participants' gender as a variable. However, women tend to adhere to medication more than men, which warrants further investigation If the intervention was provided to both genders, it may give more satisfactory results.
Theory consideration	There is limited incorporation of theory into the intervention design and development process. The existing MA interventions do not explain the theory behind the approach followed e.g. incentives and reminders are derived from the behavioural theories.

- Assess the acceptance and efficacy of the MVP by end-users through a pilot study.

Our main **RQ** is ***How can digital technology improve patients' medication intake?***

Sub-questions:

- **RQ 1** – what are the key design considerations for constructing an MA programme?

The answer to this RQ is extracted from the data collected through the questionnaire and interviews with the multidisciplinary experts in **Chapter 4**.

- **RQ 2** – how can users articulate the approach to MA?

The answer to this RQ is extracted from the data collected from the FG participants in **Chapter 5**.

- **RQ 3** – what impact could the intervention have on users' medication intake?

The answer to this RQ is extracted from the 2-week MVP pilot study with end users in **Chapter 7**.

2.14 Summary of Chapter 2

This chapter presented the literature on MA and how the use of technology addressed its issues and challenges, specifically the use of mHealth. We conducted our search of academic journals, commercial and online news, articles and/or magazines issued in the past ten years, then we filtered these according to the scope of this study. We presented our literature review in a logical structure, starting with the definition of MA and compliance, and how they are used interchangeably by patients, even though they differ. Then, we illustrated the issues and challenges of medication non-adherence. After that, we presented the academic studies conducted on MA management, the technologies used in managing MA were explored and we explained the importance of managing MA via mHealth and the existing work achieved in this field. Then, we summarised the current state of digital health services in NZ and our preliminary findings and limitations from the literature. Finally, we drew the aim of this study based on the significance of addressing MA and the gaps in the literature. Our next chapter will introduce the study design and the methods utilised.

Chapter 3

Study Design

"To make the information clear to the reader, the structure of a mixed method study should mirror the design used" - J. W. Creswell

This research aimed to investigate the use of digital technology in addressing MA by involving multi-disciplinary experts and end-users to understand their perspectives. The main research question of this study is: *How can digital technology improve users' medication intake?*. We collected requirements for managing MA and an MA MVP was developed and piloted with end-users in NZ.

In this chapter we introduce the worldview underpinning this research, our methodology and methods utilised throughout the study. We will also identify and explain the methods of analysis performed for each type of data collected. Moreover, the phases and activities are explained and aligned with the study methodology. This chapter presents the following main outcomes:

- A research methodology framework (blueprint) that guides our research throughout the whole study, underpinned by the worldview
- The data collection and data analysis methods.

The chapter sections are constructed as follows: Introduction in **section 3.1**. Then

section 3.2 explains the research framework, detailing the research methodology, strategy and methods. **Section 3.3** introduces the research process and methods mapping. **Section 3.4** presents the ethics considerations and **section 3.5** explains the validity and reliability of the study. Finally, **section 3.6** summarises the overall research process.

3.1 Introduction

Research has a special significance in solving various real-world problems (Holden & Lynch, 2006). To achieve our research objectives and answer the RQs, we searched for a methodology that considers approaching the real-world problem scientifically (Goddard & Melville, 2001). The methodology provides us with steps which we can adopt or adapt in studying the research problem, along with the logic behind them. It also considers the logic behind choosing the data collection methods in the context of our research study. Moreover, it will guide us when explaining the use of a particular method, to ensure that our research results are at a level to be evaluated either by us or other researchers (Kothari, 2004). To achieve the desired results to the RQs in **section 2.13**, we first looked at the research framework that presents the interconnection of the worldviews, research strategy and research methods as shown in **Figure 3.1**. The latter will guide the processes to achieve our objectives.

3.2 Research Framework

The understanding of the interconnection between the worldview, design and research methods is significant for making the decision about which approach helps us in solving our research problem (Creswell, 2009). We used the research onion to help us create organised research design elements, highlighting the different six main layers of the study research model as presented in **Figure 3.2**, adapting Saunder's (2019) model.

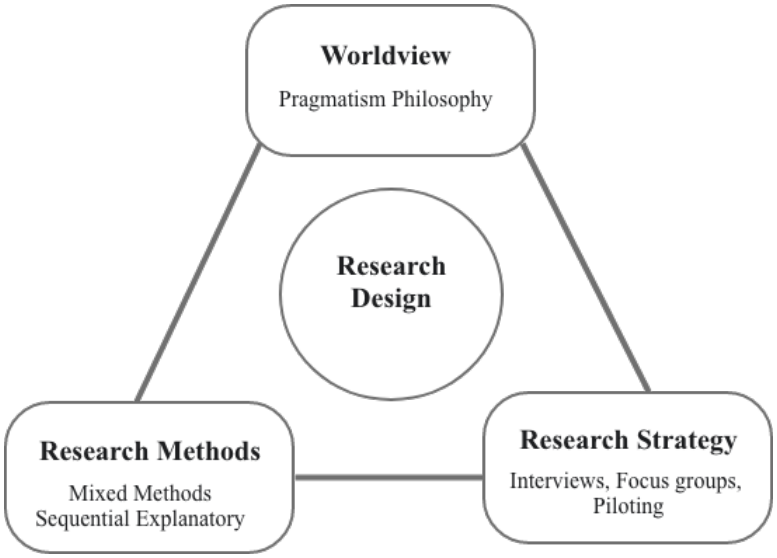

Figure 3.1: Research framework, adapted from Creswell's book: *Research design: Qualitative, quantitative, and mixed methods approaches* (2009)

3.2.1 Worldview

According to Holden and Lynch (2006), a review of the research philosophy is a key phase of the research process, as it unwraps our minds to other options, enriches our research skills and increases our confidence about choosing the appropriate methodology (Holden & Lynch, 2006). With this in mind, we undertook an in-depth investigation into a philosophical approach that could guide us in solving our research problem. Moreover, from Goddard and Melville's (2001) research, we knew that "the philosophy refers to the set of beliefs concerning the nature of the topic being investigated", which can vary according to the purposes of the research and the best way used to fulfil its purposes. They also mentioned that choosing the research philosophy to answer the RQs of the study depends on the type of topic being investigated. In saying that, our topic is problem centred, addressing the use of technology in improving MA, as detailed in **section 2.6**, therefore it requires investigating previous solutions and exploring multiple stakeholders for insights into existing approaches, then, proposing a solution that can serve current and future needs for end users. After that we need to develop the artefact

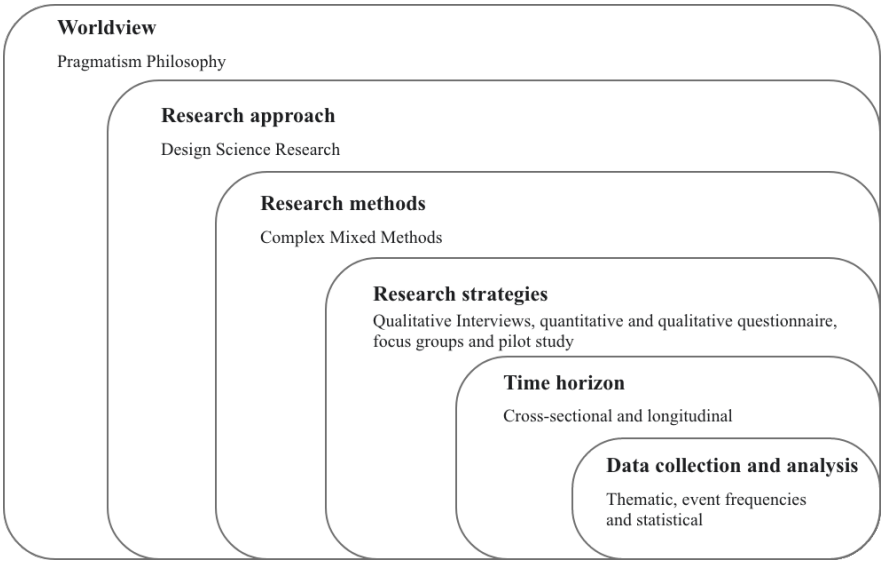

Figure 3.2: Study research model, adapting Saunders's research onion model (Saunders, 2019)

and gather end-users' feedback on our proposal, before piloting its feasibility and acceptability by end-users. With this in mind, and from exploring the four philosophical approaches from Holden and Lynch (2006) research, it became clear to us that the Pragmatism Philosophy approach fits best to underpin our research.

This approach is based on the belief that individuals can use the 'constructivist' view to create a practical approach to research and come up with a solution to the MA problem (Johnson & Onwuegbuzie, 2004). The constructivist philosophy suggests that the required meaning of a social phenomenon is generated by each observer or group (Holden & Lynch, 2006). In this philosophy, we can never assume that what is observed will be interpreted in the same way by all the participants, and the key approach is to examine differences in the respondents' understanding (Creswell, 2009). Moreover, from the limitations identified in **Table 2.5**, our knowledge will be constructed through our interaction with the participants (Guba & Guba, 1994). For example, the interview process requires us to interpret the data inductively, deductively and abductively (relying on the best explanations for understanding the results) in answering the RQs, rather

than restricting or constraining our choices (Creswell, 2009).

3.2.2 Research methodology

Due to the nature of our study, which involves a sequence of multiple activities, for us to be able to design, develop and evaluate the performance and acceptability of our solution in improving MA we have followed the Design Science Research (DSR) methodology of Peffers et al. (2007), as presented in **Figure 3.3**. The DSR Model focuses on the development and performance of a designed system, with the explicit intention of improving the functional performance. According to their research, the DSR process should include six conceptual steps or phases in a nominal sequence in the field of IS. It is also referred to as 'improvement research', and this designation emphasises the problem-solving/performance-improving nature of the activities. This design process will allow us to perform a sequence of activities in each phase of our study. It also enables us to develop a better grasp of the issues through the iterative evaluation of our solution, which improves the quality of the design before our final design is generated. Below we explain the role of each phase and the required resources to conduct the activities within the phase as presented in **Table 3.1**.

- **Phase 1: Problem Identification and Motivation**
  - **Role:** This phase consists of two activities (**Activity** 1.1 and **Activity** 1.2), which include defining the research problem and justifying the significance of our solution. By achieving this, we would have accomplished the motivation to pursue our proposed solution and accept its results. This will also help us understand the reasoning associated with our understanding of the MA problem and acceptance of the technology to improve it.
  - **Resources required:** Knowledge of the state of the problem and the importance of its solution.

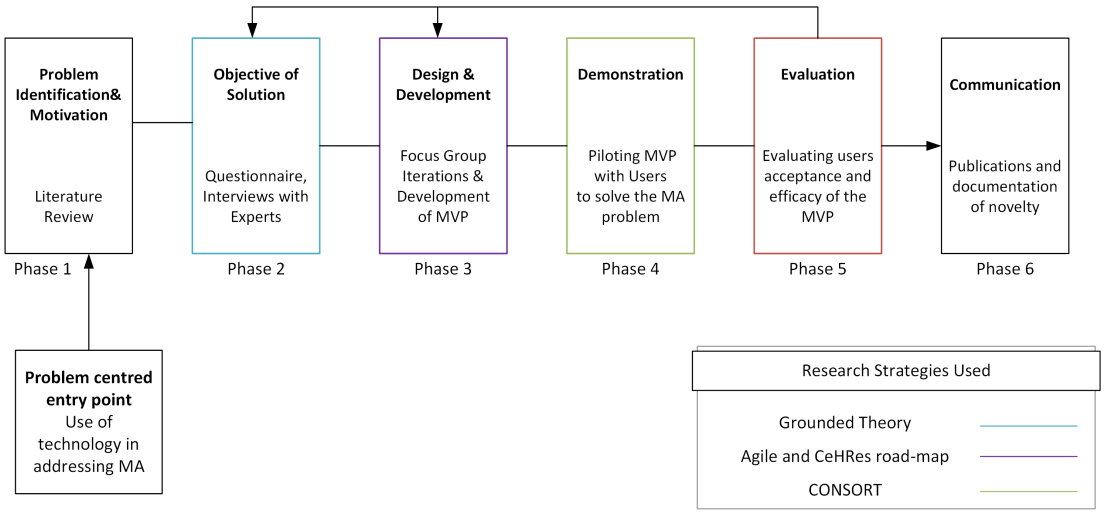

Figure 3.3: Research methodology model, adapting the DSR model by Peffers et al (2007)

- **Phase 2: Objectives of a Solution**
  - **Role:** This phase suggests the objectives of the solution from the problem definition, where the objectives are determined according to the rationale of the problem specification and through an explanatory investigation conducted through three activities (**Activity** 2.1, **Activity** 2.2 and **Activity** 2.3).
  - **Resources required:** Knowledge of the current state of the problem, the current solutions and their efficacy.
- **Phase 3: Design and Development**
  - **Role:** In this phase we create a prototype of the solution. Through an iterative process of the two activities (**Activity** 3.1 and **Activity** 3.2). We will determine the prototype's anticipated functionality, and the design and creation of the actual MVP.
  - **Resources required:** Translating the objectives to design and development includes knowledge of theory that can be conveyed into a solution.
- **Phase 4: Demonstration**

  - **Role:** In this phase we demonstrate the MVP to test its feasibility, user acceptance and efficacy to improve the MA problem. This will involve its use in the pilot study (see **Activity** 4.1).
  - **Resources required:** Knowledge of how to analyse the quantitative and qualitative data collected through the MVP and questionnaire.

- **Phase 5: Evaluation**

  - **Role:** Here we compare the objectives of the study to the actual observed results from piloting the MVP in the demonstration phase (see **Activity** 5.1). At the end of this phase, we continue to the communication phase and leave the further improvement to future work.
  - **Resources required:** Knowledge of how to use the MVP to solve the MA problem. This is done by asking suitable main end-users to test the MVP for a period of two weeks.

- **Phase 6: Communication**

  - **Role:** Here we document the problem and its importance, the theoretical contributions and practical contributions, the MVP design and development, its utility and novelty, and the rigour of the design. Also, its effectiveness for all beneficiaries such as the users of the MVP and professional participants throughout the phases. This process will also be used to structure the study according to the research process (see **Activity** 6.1).

According to Peffers et al. (2007), this process is structured in sequential order. However, there is no expectation that we will always proceed in sequential order from **Phase 1** to **6**. Instead, we can start at any activity and move outward. The problem-centred approach is the basis; starting from **Phase 1**, which we followed because our

research idea resulted from the observation of the problem of MA and its significant impact on the individual's health and on the health system in general.

There are other entries like the objective-centred process, starting with **Phase 2**, which could be the by-product of consulting experiences. Next, there is the design and development-centred approach, starting with **Phase 3**, which can be used in the case of the availability of a solution that has not yet been formally thought through to be used for the identified problem, or it might have already been used to solve a different problem. Finally, there is the option of starting with **Phase 4**, observing a practical solution that worked. From the mentioned entry points to the research, we selected the most suitable entry that served the needs of our study.

3.2.3 Research methods

This research deals with multiple activities, including system development, observations and experimentation. Due to the difficulty and complexity of knowing which method will offer accurate results for our RQs, this study follows a mixed methods approach. This approach utilises both quantitative and qualitative techniques to gain answers to RQs that focus on real life implications. Although the mixed methods approach is less known than the quantitative and qualitative approaches, employing this method allows us to examine multiple ways of data collection (Creswell, 2009). We can either merge both quantitative and qualitative methods, by using them side by side to reinforce each other this will give us a better shaping of the investigated topic. Moreover, combining data from both methods enables us to increase the breadth and depth of our understanding. This method is most suitable due to the nature of the research problems, which are examined from multiple perspectives. These perspectives tend to offer flexibility and provide better opportunities for us to answer questions and draw strengths from multiple methods (Creswell, 2009).

According to Creswell (2009), the mixed-method approach for collecting data has three general strategies: *sequential*, *concurrent* and *transformative*. When timeliness is important for the data collection, requiring collecting some data before moving to the next phase, the sequential strategy is the most suitable method to implement. Furthermore, following his book on design research as a guide for conducting and implementing mixed methods research, there are three types of sequential designs: *Sequential Explanatory* design is used to explain and interpret quantitative results by collecting and analysing follow-up qualitative data. *Sequential Exploratory* design uses quantitative data and results to assist in the interpretation of qualitative findings. *Sequential Transformative* design is the best for serving the theoretical perspective. Unfortunately, there is little guidance on how to use the transformative vision to guide the methods.

From investigating the three strategies further and exploring what best suits the phases of our research process and what we require within each phase, we have looked further into Sequential Explanatory design. Its initial phase is collecting and analysing the quantitative data, followed by collecting and analysing the qualitative data in the second phase. The mixing of the data happens when the quantitative results inform the following qualitative data collection, where the two forms of data are separate but connected, as pictured in **Figure 3.4**.

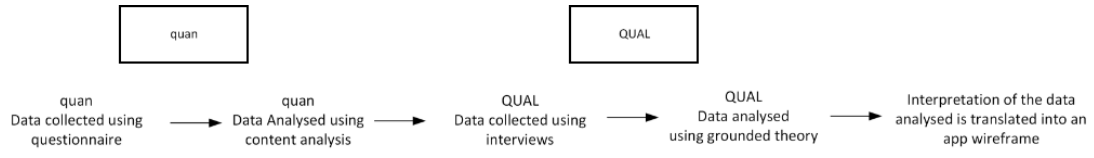

Figure 3.4: Mixed method sequential explanatory design, adopted from Creswell's book: *Research design: Qualitative, quantitative, and mixed methods approaches* (Creswell, 2009)

A Sequential Explanatory design can be useful, especially when unexpected results

arise from the quantitative study (Creswell, 2009). The steps of this design fall into a clear and separate phase making it easy to describe and report, which is one of its main strengths. However, the data collection takes longer, especially when the two phases are given equal priority. We also had to go back and forth between qualitative, quantitative and mixed methods, but they build on each other to address our study objectives (Creswell, 2009). However, due to the nature of our study and its need for multi-phased data collection, which consequently needed several mixed methods depending on the phase of the study, we chose to base our work on the multi-phase mixed methods which is referred to as complex. This allowed us to conduct several mixed-methods, as small-projects, within our big project (Creswell, 2009). The sub-activities explained in the later section (see **section 3.2**) will present a better picture of the small projects mentioned.

3.2.4 Use of mixed method design

According to Creswell (2018), there are several advantages and limitations when conducting mixed methods study. Below we list some of the main advantages and limitations:

Advantages

- **Considers participants' insights.** It gives participants a voice, then ensures that participants' experiences support the study findings.
- **Adopts researchers' interaction.** It encourages the interaction of quantitative, qualitative, and mixed methods researches, which adds breadth to the multidisciplinary research.
- **Offers methodological flexibility.** It is adaptable and flexible, which allows us to assemble more information than we can achieve with one method.

- **Gathers comprehensive data.** It corresponds to the way we collect information in real life by integrating quantitative and qualitative data. For example, we may also add descriptions and images to provide a complete story when collecting scores and numbers rather than relying on a single source of information.

Limitations

- **Increased evaluation complexity.** Its planning and conducting are complex. It requires a more careful eye to thoroughly plan all aspects of research, including the study samples, the timing and the integration of data. Integrating qualitative and quantitative data during analysis is considered another challenge.
- **Relies on a multidisciplinary team of researchers.** They require a multidisciplinary team of researchers who need to be open to methods that may not be their area of expertise.
- **Requires increased resources.** It requires extra resources and concentrated efforts; thus, more time is needed compared to single method studies.

3.3 Research Process and Methods Mapping

After explaining the methodology in **section 3.2.2** and establishing the method used in **section 3.2.3**, we demonstrate the multiple activities carried throughout this research, guided by the DSR model as follows:

3.3.1 Phase 1: Problem identification and motivation

Activity 1.1: Literature review

In this activity an extensive search was conducted utilising six electronic databases: PMC (PubMed Central®), Science Direct, MEDLINE, Google Scholar, IEEE Xplore, and Scopus. The following keyword search terms were used: *medication adherence, medication self-management, mobile app reminders, mobile health, medication adherence intervention and/or medication compliance intervention, and medication reminders.*

Activity 1.2: Evaluation of existing MA apps

This activity evaluates the top-ranked MAs in the past research, from which they will be selected based on their functionalities and using the Medication Application Rating Scale (MARS) (Stoyanov et al., 2015).

3.3.2 Phase 2: Objectives of a solution

Activity 2.1: Requirements elicitation: Online questionnaire

This activity aims to gather information from healthcare experts and health system designers to articulate features that a mobile app could include to benefit patients in a range of aspects of managing medication intake. The research followed an explanatory sequential design (Creswell, 2009). The questionnaire was created to collect preliminary data through a questionnaire, from healthcare planners and IT health system designers on the use of technology in addressing MA issues.

- **Sampling**: A non-probability sampling method was selected based on the objective of the study and the characteristics of the population. Through its use, it was possible to find people who were willing to provide the information from their

experience. An email was sent to experts whose email addresses were obtained from public websites or through LinkedIn. One success factor in obtaining such a wide involvement was the circulation of the questionnaire via Health Informatics New Zealand's (HiNZ) newsletter, which was emailed to a mailing list of six thousand email addresses. HiNZ (2020) is a not-for-profit organisation with a focus on health informatics and digital health in NZ, including events, education and networking.

- **Data gathering**: An online questionnaire consisting of seven questions was designed using Qualtrics Software (2017). This was used due to its ease of accessibility: participants could answer questionnaires online at suitable times, as an alternative to a paper-based approach. This also allowed the automatic processing of collected data for analysis easily and efficiently. We used a questionnaire to collect feedback from experts about their insights regarding the functionalities of mobile apps. The study was based in Auckland, NZ, for a period of three months, from December 2017 to March 2018.

- **Methods of analysis**: A descriptive statistics method was used to summarise the first six questions, while thematic analysis was applied to analyse the themes generated in the open-ended question. Quantitative data were handled and computed using Qualtrics. The qualitative data from the seventh question in the questionnaire were downloaded as text from Qualtrics and uploaded to QSR NVIVO software (2018). Data were analysed for themes following a descriptive analysis process (Colorafi & Evans, 2016). These themes were then developed into qualitative response categories which then were quantified based on the responses, and exported to be associated with the quantitative data from the first six questions.

Activity 2.2: Requirements elicitation: semi-structured interviews

In this activity we gain a deeper understanding from healthcare experts and health system designers about their perceptions of MA and the approaches they might have used in the past. This will allow us to articulate features that a mobile app could include, to benefit patients in a range of aspects of managing medication intake. The interviews were audio-recorded. All recordings were transcribed and deconstructed for analysis. In this study, we used semi-structured questions to allow the participants to approach the subject from their experience. The face-to-face semi-structured interviews were conducted to collect feedback and consultation from field experts in the health and mobile app design domains.

- **Sampling**: Purposeful sampling was used to select participants (M. Martin, 1996). The participants were selected through LinkedIn based on the following criteria: they work in NZ in the role of either a healthcare professional, technology designer, pharmacist, nurse, or as a researcher in the field of health informatics. In the recruitment process, experience and workplace were considered. Most participants showed interest in the topic when first approached. At the time of the study the participants were working in hospitals, pharmacies, GP clinics, the technology industry, and universities in NZ researching in the health IT domain.

- **Data gathering**: Data collection was performed using online or face-to-face semi-structured interviews with healthcare professionals and health technology designers. We aimed to continue recruitment and data collection until it became clear that no new information was being provided or there was a repetition of information from several participants, which meant the saturation of data had been reached for this targeted topic (Wray & Manderson, 2011). The interviews were recorded using Zoom when the interviews were conducted online, and iPhone recorder when they were face-to-face interviews, then saved to a local Auckland

University of Technology (AUT) laptop provided for the study.

- **Methods of analysis**: The recordings were transcribed and deconstructed for thematic analysis. Using a Word document, they were then uploaded to NVIVO for analysis. Several initial codes were identified for each interview question during the analysis phase. As they emerged, the data were clustered into focused codes, which then led to more generalised categories. With the theory-building in mind, the categories were placed under the umbrella of the themes. We considered the themes to be any point discussed by the FG participants on more than one occasion during the session (Vaismoradi, Turunen & Bondas, 2013). Then, from the main themes, the theoretical relationships were postulated. We paid particular attention to the data contradicting theoretical relationships, to avoid research bias from the literature review.

  We utilised Grounded Theory (GT) to analyse the data. GT is a qualitative methodology, defined as "the discovery of theory from data, which is systematically obtained and analysed" (Urquhart, 2013). It can utilise in-depth interviews as one of its data collection methods. GT uses both the process of category identification and integration as a method and produces a theory. GT as a method provides us with guidelines on how to link and establish relationships between the categories (Strauss, 1987). Hence, it provides us with a deeper understanding of our study and its process, leading to building a theoretical model. Coding is an essential step in GT, as Strauss (1987) stated: "The excellence of the research rests in large part on the excellence of the coding". And according to Glaser and Strauss (1967), the GT method implies data coding, "a bottom-up technique concerning the data, and begins at the word or sentence level".

Activity 2.3: Requirements elicitation: Wireframe design and evaluation

In this activity, a rapid wireframe is proposed including the highly recommended elements as features in the mobile app wireframe, which were concluded from **Activity** 2.1 and **Activity** 2.2. This process includes users who bring a deep understanding of their context and the opportunities that can be explored. It also fosters creativity and further develops ideas on the design and features of the wireframe.

- **Sampling**: Purposeful sampling was used to select the participants (M. Martin, 1996). Our sample was a subset of the questionnaire participants, who agreed to give feedback on the proposed wireframe.

- **Data gathering**: In general, our participants were not User Interface (UI) designers. However, their insights as testers can helped improve the design of an artefact. The qualitative data was gathered using Adobe Xd Software (2017). Participants gave their feedback on the UI in terms of colours, layout and the number of functions added to each screen of the wireframe. This gave us an idea of whether the data collected from the questionnaire was correctly and reasonably translated to the actual artefact. The feedback was provided through a web link to the Xd webpage access, where the participants could enter their review in the comment area.

- **Methods of analysis**: The qualitative data from the experts' feedback were analysed using descriptive analysis. Actionable points of tweaks and enhancements were identified and listed, to be amended before the next activity started.

3.3.3 Phase 3: Design and development

Activity 3.1: Focus groups: Co-design MAMA with users and evaluation

In this activity we followed the principles of co-design, being: inclusive, respectful, participative, iterative, and outcome focused. Designing an mHealth intervention that can be sustained beyond the scientific evaluation is immensely important; it needs planning for adoption and maintenance (Bartholomew, 2011). To increase the impact of technology and avoid the ad-hoc style developments that neglect the needs of the target population and the usage context, this activity adopted the Centre of Health Research (CeHRes) road map for eHealth design and development, which contains not only technological but also human and contextual factors. According to van Germert-Pijnen et al. (2011), the CeHRes road map considers that eHealth development requires continuous iterations and evaluation from participants which crosses the entire development process as presented in **Figure 3.5**.

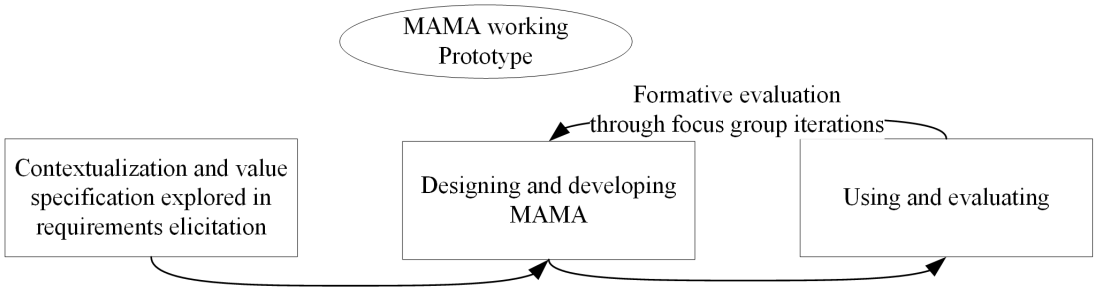

Figure 3.5: eHealth technologies development road-map adopted from the CeHRes road map (van Gemert-Pijnen et al., 2011)

- **Sampling**: This activity follows a purposive sampling methods (M. Martin, 1996). Participants in the FG were either previous participants from the requirements elicitation phase (questionnaire or interviews) who agreed to be contacted to participate, or were personal contacts who showed an interest in participating as users of medication reminder apps and/or consumers of medication. To get a well-shaped picture of why people used or did not use medication reminder apps,

both individuals with and without prior knowledge or usage of those apps were emailed an invitation.

- **Data gathering**: The data were collected in four ways during the FG. The data collection began after all participants signed the consent forms and downloaded MAMA. There was an open discussion which was audio recorded when the participants started the discussion. The recording remained switched on until the discussion ended. As supplementary material, the sketches by the participants were captured. All the questions asked, and their answers, were recorded for better understanding of their concerns and feedback. At the end of the session, the data collected were from: (1) the evaluation form; (2) notes of questions asked during the navigation of the app; (3) sketches; and (4) the group discussion recording. The processes followed to gather data during the FG sessions are listed below:

  - **Evaluation form:** The participants were given the time to discover the prototype screens. A form was given to them to collect their feedback on the prototype sections. They were also given the option of including further views and comments after each main section of the evaluation form.
  - **Note taking:** The researcher took notes on all the questions and feedback given while the participants were navigating the prototype and answering the evaluation form sections. Furthermore, the ambiguous sections were noted for detailed explanation and clarification.
  - **Sketching/drawing on A3 white paper:** After completing the form, the participants were asked to include all that they considered missing from the prototype and to further express it as a visual representation of the prototype screens according to what they saw needed improving in terms of visuals, content and functions.

  - **Group discussion audio recording:** The participants' drawings were discussed among the team. The discussion was audio recorded to make sure the details of the discussion were not missed and were included in the discussion section in detail.

- **Methods of analysis**: Data were analysed using thematic analysis, a flexible method for qualitative analysis that allows us to identify patterns within the data (Braun & Clarke, 2006). This analysis is considered suitable in providing a detailed explanation of the data set and generates insights into participants' perspectives on the topic (Vaismoradi et al., 2013). The extracted features suggested by the users are implemented into the prototype. The drawings on the A3 papers were compared and evaluated according to the goal of the project: visual, navigation, purpose, content and layout. Data were separately analysed after each FG iteration. The output of each iteration was implemented in the prototype design to be presented in the second FG. The intersected features identified within the data were amended into the prototype after the third/last iteration.

Activity 3.2: App development

After completing the wireframe and showing all of the app screens including the visual designs and how they connect with each other, we built an interactive prototype to give a sense of how using the app would feel. In this activity, we adopted the Agile methodology (Duc & Abrahamsson, 2013). This follows an incremental approach as represented in the workflow presented in **Figure 3.6**. We started with a simplistic design concluded from **Activity** 2.3 and then began to work on small parts. The work on these parts was done in sprints, and at the end of each sprint a test was run. These sprints allowed errors to be discovered and users' feedback to be incorporated into the design before the next sprint. The Agile development emphasises four core values: (1)

individual and group interactions over processes and tools; (2) working solutions over comprehensive documentation; (3) team collaboration over contract negotiation; and (4) responding to change over following a plan (Duc & Abrahamsson, 2013).

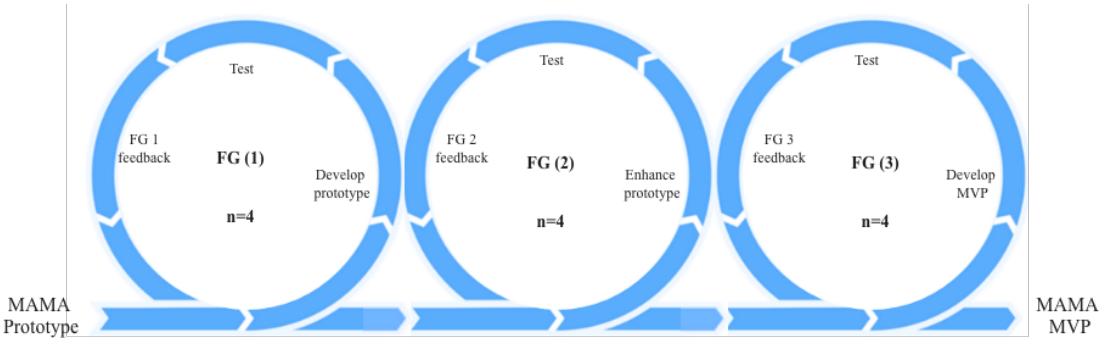

Figure 3.6: App development process adapted from the Agile methodology process

3.3.4 Phase 4: Demonstration

Activity 4.1: Pilot study

The primary objective of this activity is to pilot MAMA with end users for a period of two weeks, then gather feedback from the participants to improve the app to better serve their needs.

- **Sampling**: A purposive criterion sampling method was used, which appeared to be used most commonly in implementation research according to Palinkas et al. (2015), to invite individuals from previous phases of this research who showed interest in participating in the piloting. There are several rules of thumb for a pilot study sample size, ranging from 12 to 35 individuals per arm (Bell, Whitehead & Julious, 2018). According to Mark Mason (2010), sample size among those studies was 20 to 30 and, in adherence to BERTAUX's (1982) guidelines, 15 was the smallest number of participants for a qualitative study, irrespective of the methodology.

- **Data gathering**: Data collection was conducted using two tools: (1) MAMA for collecting user details when creating an account/signup, adding medication or scanning a prescription, adjusting medication time, and using medication status logs; and (2) feedback questionnaires as an external anonymous Qualtrics link. The responses were not linked to participants' accounts to avoid the possibility of reporting biases that may arise with the in-app assessment. The app was intended to collect users' medication intakes and the questionnaire to collect feedback from unidentifiable users' experiences.

3.3.5 Phase 5: Evaluation

The primary objective of this study is to evaluate the feasibility and acceptability of MAMA and gather feedback from users to improve the app to better serve their needs. MA is assessed and the results from the questionnaire are compared against the UTAUT2 model for the use of IT in the health context. Based on these results, the feasibility of MAMA in improving medication intake among individuals will be assessed.

Activity 5.1: Pilot study evaluation

The app is evaluated for its feasibility, effectiveness in improving MA and users' acceptance, based on the results from the consolidated findings in **Activity** 4.1.

- **Data Analysis**: Descriptive analyses of the demographics and characteristics were reported as event frequencies and percentages for categorical variables, and as a standard deviation (SD) for continuous variables. The usability of MAMA was described using event frequencies. All statistical analyses were performed using Qualtrics (2017) and SPSS (2020). Content Analysis was performed for the survey of qualitative data, to capture participants' perceptions and identify the quotes that highlighted the features suggested by participants. The Relative

Importance Index (RII) analysis ranked the features according to their relative importance, based on the participants' replies. It is an appropriate tool to prioritise the features rated on Likert Scales (Rooshdi, Majid, Sahamir & Ismail, 2018). Formula (3.1) was used to determine the Relative Importance Index (RII)

$$RII = \frac{\sum w}{(AN)} \tag{3.1}$$

Where:

w is the given weighting by each respondent on a scale of one to five with one implying the least and five the highest.

A is the highest weight.

N is the total number of the sample.

Based on the Ranking (R) of Relative Indices (RI), the weighted average for the two groups is determined. According to Moruza et al. (2016), five important levels are transformed from RI values: High (H) ($0.8 \leq RI \leq 1$), High-Medium (H–M) ($0.6 \leq RI \leq 0.8$), Medium (M) ($0.4 \leq RI \leq 0.6$), Medium-Low (M-L) ($0.2 \leq RI \leq 0.4$) and Low (L) ($0 \leq RI \leq 0.2$).

The adherence rate is calculated using the Proportion of Days Covered (PDC) in **Formula 3.2**, a newer method of calculating adherence rates according to the Pharmacy Quality Alliance (PQA) recommendations (Nau, 2006). The resulting PDC ranges from 0 to 1. A value of 1 corresponds to 100% adherence. This metric defines adherence as > 0.8 or 80% of days covered. It is important to note that medications such as those for HIV and birth control may require closer to 100% adherence for effectiveness.

$$PDC = \frac{Number\ of\ Days\ in\ Period\ "Covered"}{Number\ of\ Days\ in\ Period} \tag{3.2}$$

Furthermore, the UTAUT2 model for mobile IT in a healthcare context was used to examine MAMA usage patterns and acceptability, in addition to comparing them to previous pilot results using the same method (Sudburya et al., 2013; Gatwood et al., 2016; Santo et al., 2019).

3.3.6 Phase 6: Communication

Activity 6.1: Documentation

This activity presents the documentation of the activities and novelty of the study contributing to the body of knowledge. Scientific publications, seminars and workshops are summarised in publications **section 1.9**. To better encapsulate the activities within each phase, we present them in **Table 3.1**, along with a description and specifications of each phase.

Table 3.1: Activities mapping within the study framework

No	Phases	Activities	DSR Mapping	Output	RQ	Sample Size	Data Collection Method	Data Analysis Method	Tool	Chapter	Cross-ref
1	Problem identification and motivation	1.1	Literature review	Significance of addressing MA and RQs	1 & 2	534	Qual	Systematic Review	Mendeley	1 & 2	3.3.1
		1.2	Evaluation of existing MA Apps	App limitations	1	5 top ranked apps	Qual	MARS and SHARP	Mobile Phone	4	3.3.1
2	Objective of solution	2.1	Online questionnaire	App features	1	246	Quan	Event Frequency	Qualtrics	4	3.3.2
		2.2	Semi-structured interviews	MA model	2	23	Qual	Grounded Theory	face-to-face/Zoom recording & NVIVO	4	3.3.2
		2.3	MAMA wireframe design & wireframe evaluation	MAMA Prototype features	2	7	Qual	Descriptive analysis & Event Frequency	Adobe Xd	4	3.3.2
3	Design and development	3.1	Co-design with end-users	MVP Feedback	1	12	Qual	Descriptive analysis & Event Frequency	Paper Questionnaire & Mobile phone	5	3.3.3
		3.2	MAMA prototype development	MVP	1, 2 & 3	N/A	N/A	Agile	React Native	6	3.3.3
4	Demonstration	4.1	MVP Piloting	Pilot Feedback	3	26	Qual and Quan	Descriptive analysis & Event Frequency	MVP	7	3.3.4
5	Evaluation	5.1	MVP Evaluation	MVP Validation	3	22	Qual and Quan	Descriptive analysis & Event Frequency	Qualtrics & SPSS	7	3.3.5
6	Communication	6.1	Documenting novelty & research activities	Publication & Thesis	3	N/A	N/A	Publications	Overleaf	Thesis	3.3.6

3.4 Ethics Considerations

To conduct the activities listed in **Table 3.1**, required us to apply for three Ethics applications for three phases of the study: Requirements Elicitation, Focus Groups and Piloting. Our applications were approved by the Auckland University of Technology Ethics Committee. The ***first application*** with *AUTEC Reference # 17/372, title: "A technology driven approach for improving patients' medication adherence: A pilot study"* had a date of approval: 13/11/2017, which was for the RE phase. Then, the ***second application*** with *AUTEC Reference # 19/343, title: "A focus-group co-design and evaluation of an mHealth medication adherence application"* had a date of approval: 13/09/2019, which was for conducting FG sessions with end-users. Then, the ***third application*** with *AUTEC Reference # 19/343, title: "Smart reminders to improve medication intake"* had a date of approval: 02/04/2020, which was for the MAMA trial with end-users (see **Appendix** C).

3.5 Validity and Reliability of the Study

Besides the reasons mentioned earlier in this chapter for choosing the mixed-method approach, it was also chosen to improve the validity of the theoretical part and to obtain a complete picture of the study. According to Brewer and Hunter (2006) using multiple or mixed methods "affects not only measurement but all stages of research". It also allows us to find a balance between the strengths and weaknesses of each of the two approaches. It is believed that using different types of procedures for collecting data, and obtaining information through different sources can increase the validity and reliability of the data and their interpretation (Zohrabi, 2013). Although the benefits of mixed-method design include increased reliability and validity of the data, there are added costs to conducting the study. These costs include the time spent, the money for

third-party support and energy used, as well as the additional cost of applying different methods for data collection at different phases and entry points (Abowitz & Toole, 2010).

Whether a mixed-method design results in data convergence or not, it is likely to provide more valid and reliable data and thereby allows us to have greater confidence in our conclusions. The validity and reliability are explained below along with their types. Then, in each chapter we discuss the validity of each tool used for the data collection and the reliability of the results from each activity.

3.5.1 Validity

According to Creswell (2003), validity is a matter of the trustworthiness that the evaluator and the participants place on the qualitative research. Zohrabi et al. (2013), defined four types of validity as follows:

- **Content validity:** This is achieved when different elements of the research are effectively measured, and where the research instruments and data are reviewed by experts in the field of research. Then, based on the reviewers' feedback, the unclear or complex questions can be revised or reworded. Also, ineffective and non-functioning questions can be omitted. These questions can also be face-validated by the experts in the field.

- **Internal validity:** This is concerned with the resemblance of the research findings to reality. Also, to what extent the researcher observes and measures what is supposed to be measured. In general, to boost the internal validity of the research data and instruments, any of the following six criteria methods can be used: triangulation, member checks, long-term observation at a research site, peer examination, collaborative modes of research, and researcher's bias.

- **Utility criterion:** In addition to the six methods of criteria checking, there is the utility criterion, which asks if the research works or not. That means it checks if the generated results are sufficient to make decisions about the effectiveness and appropriateness of the solution. Validity is achieved when the evaluation process provides participants and researchers with sufficient information.

- **External validity:** This checks if the research findings are applicable to other contexts or to other subjects. It also may depend on the similarities between our context and other contexts in terms of research design and states. This asks whether the research design can be generalised to the wider population, beyond the investigated topic.

3.5.2 Reliability

The reliability of the data and findings is one of the main requirements of any research process. It refers to the consistency, dependability and replicability of the research results and it has two types according to Zohrabi et al. (2013):

- **External reliability** is concerned with the replication of the study. This asks whether an independent researcher can reproduce the study and obtain results similar to the original study.

- **Internal reliability** deals with the consistency of collecting, analysing and interpreting the data. It can be achieved when re-analysing the information results with similar findings to the original research results. This asks whether we can achieve the same results as another researcher when using the same analysis.

3.6 Summary of Chapter 3

This chapter presented the methodological approach followed in conducting this research. The research design approach was first outlined, explaining the philosophy underpinning our research. We explained the framework which guided our study along with phases and activities, and how each phase contributed toward achieving the outcomes and answering our main RQ. We also detailed our methods of data collection and analysis. We can consider this chapter as the backbone and the blueprint for the whole study, underpinned by our pragmatist worldview, to guide us in solving a real-world problem.

Our next chapter will investigate the proposed solutions rationally concluded from the problem specification in the introduction and literature review chapters. This will cover the exploration of what a better artefact accomplishes, and that is the Second Phase in the DSR - Objective of the solution as shown in **Figure 3.7**.

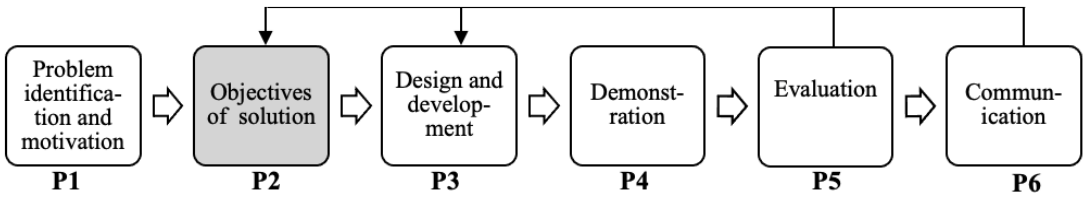

Figure 3.7: The second phase in the DSR - Objective of the solution

Chapter 4

Requirements Elicitation

"... the purpose is to collect, capture, discover, and develop the requirements from a variety of sources" - Sommerville and Sawyer

This research aims to investigate the use of digital technology in addressing MA by involving multi-disciplinary experts and end-users to understand their perspectives. The main research question of this study is: *How can digital technology improve users' medication intake?* We collected requirements for managing MA and an MA MVP was developed and piloted with end-users in NZ.

In this chapter we explore how MA is approached in NZ and investigate the role of mHealth apps in approaching MA, from a multidisciplinary expert perspective. This phase of the research process allows us to take an in-depth look at an age-old problem from a different perspective to achieve a better solution, which we believe will help patients and health teams. This could be from the perspective of the people who experienced the problem of MA, or from those looking for solutions to improve it. This chapter presents the following main outcomes:

- Results from the questionnaire and interviews with participants
- A conceptual model of patients' MA dynamics

- Generation of a mobile app wireframe, given the name MAMA, based on the RE
- Further work is conducted and presented in **Chapters 5 and 6**.

The remainder of this chapter is structured as follows: **Section 4.1** presents the introduction. **Section 4.2** describes the research methods followed in this chapter and the instruments used for each phase. **Section 4.3** presents the ethics consideration for RE. **Section 4.4** confirms the validity and reliability of the study instruments. **Section 4.5** describes the quantitative method, the first phase in collecting the data, then analysing and discussing them. This is followed by **section 4.6**, which describes the qualitative method, the second phase in collecting data, analysing and discussing them. **Section 4.7** presents the results integration and visual interpretation of RE via a Wireframe. **Section 4.8** presents the wireframe design and evaluation. Finally, in **section 4.9**, we conclude the chapter by summarising the work conducted, its strengths and limitations.

4.1 Introduction

The RE process is deconstructed into three activities (Rzepka, 1992): *first*, eliciting requirements from a diverse individual; *secondly*, ensuring that the needs of all users are consistent and feasible; and *thirdly*, validating that the requirements obtained reflect the users' needs.

> *The construction of the requirements specification is inevitably an iterative process which is not, in general, self-terminating. Thus, at each iteration, it is necessary to consider whether the current version of the requirements specification adequately defines the purchaser's requirement, and, if not, how it must be changed or expanded further* (Southwell 87, as cited in (Christel & Kang, 1992)).

According to Christel and Kang's (1992) research, the requirements elicitation process itself can be broken down into activities: investigating, information gathering, and integrating. These in turn were further broken down in Rzepka's (2016) research as follows:

- Identifying the relevant participants who are sources of the requirements.
- Gathering the wish list for each relevant participant. Most likely this will include ambiguous, inconsistent, unreasonable requirements and it may be incomplete.
- Documenting and refining the wish list for each relevant participant. The wish list includes all important data, which will need to be repeatedly analysed until it is consistent.
- Integrating the wish lists across the participants' viewpoints. Consistency checking is an important part of this process as much as feasibility.
- Determining the non-functional requirements, such as performance and reliability issues, and stating these in the requirements document.

In our context this includes investigating MA, gathering information from healthcare experts and health system designers, and then integrating the elicited data. In the next section, we demonstrate our exploration for **Phase 2** through three sub-activities: (1) *questionnaire*; (2) *semi-structured interviews*; and (3) *wireframe design and evaluation*. As previously stated in **Chapter 3**, this study follows a complex mixed-methods approach, where we benefit from the three methods at different phases of the study.

4.2 Requirements Elicitation Methodology

This phase followed a Mixed-Methods Sequential Explanatory (MMSE) design as introduced by Creswell (2009). This method consists of two different phases: a quantitative method followed by a qualitative method. Then, the data integration refers to the stage where the mixing of the quantitative and qualitative methods occurs. The mixing can be

at the beginning of the study when formulating the purpose, or at the end, which is the findings stage.

Benefiting from Ivankova, Creswell and Stick's (2006) research in MMSE designs, the quantitative and qualitative phases are connected in the intermediate stage when the results of the data analysis in the first phase of the study inform or guide the data collection in the second phase. This method is rich and provides us with detailed insights. Creswell (2003) made it clear that data collection has the issue of dealing with priority on the implementation and integration of the quantitative and qualitative approaches. Therefore, we had to consider which approach, quantitative or qualitative, would have more attention or whether both would have the same amount of attention in this phase of the study. It was necessary to establish the sequence of the quantitative and qualitative data collection and analysis, and determine where the integration could best occur for the maximum benefit based on the purpose and needs of the study .

Further to listing the advantages and limitations of this method in **section 3.2.4**, we can add to its advantage by also including its straightforwardness and opportunities for the exploration of the quantitative results in more detail.

In this RE phase, we first collected and analysed the quantitative data through a questionnaire. Then, we collected and analysed the QUALITATIVE data through semi-structured interviews, which helped elaborate the quantitative results. We considered connecting both methods at two points: (1) when our interview questions built on the questionnaire results; then, (2) when we integrated the results of both outcomes. The rationale for this approach is that the quantitative data and their analysis provide us with a general understanding, and the QUALITATIVE data explains and refines the in-depth views to finalise our RE.

4.2.1 A visual model for mixed-methods sequential explanatory design procedures

Multistage format research is difficult to grasp without graphically representing the mixed methods procedures used in the study (Ivankova et al., 2006). In saying this, using the ten rules presented by Ivankova, Creswell and Stick (2006), we drew a graphical representation of the MMSE Design procedures followed in the activities of this chapter, as presented in **Figure 4.1**. This helps visualise the sequence of the data collection, the priority of the methods, and the connecting and mixing points of the two phases we applied. It also helps us understand where, how, and when to make adjustments to augment the information in addition to making it simple for the readers to comprehend.

The visual model describes the sequence of the research activities conducted and indicates the priority of the qualitative phase by capitalising the term QUALITATIVE. It specifies all the data collection and analysis procedures and lists the outcomes from each of the activities. It also shows the quantitative and qualitative phases' connecting points and the related outcomes, as well as specifying the place in the research process where the results of both quantitative and qualitative are mixed.

The *quantitative phase* consisted of the ***first activity*** (**A1.1**); where the quantitative questions focused on exploring experts' input on the possible features that could be included in a mobile app to improve patients' medication management and remind patients to take medication as planned and on time. The online questionnaire was designed using Qualtrics Software (2017); this was used due to its ease of accessibility: Participants could answer questionnaires online at suitable times, as an alternative to a paper-based approach. This also allowed automatic processing of collected data for analysis, easily and quickly.

Next, in the ***second activity*** (**A1.2**), we analysed the data collected conducting event frequencies for the numerical data and descriptive analysis for the text data. All

numerical calculations were performed in Qualtrics, and the text data was analysed using NVIVO.

After, in the ***third activity*** (**A1.3**), we connected the quantitative activity with the qualitative activity while designing the questions for our interviews according to the response to the questionnaire in (**A1.1**).

Then, the *QUALITATIVE* phase, which consisted of the ***first activity*** (**A2.1**), where the qualitative questions addressed (1) how MA is approached or discussed within the clinic settings with patients; and (2) how mobile apps can play a role in helping patients and healthcare providers with managing medication and keeping treatment plans on track.

Next, in the ***second activity*** (**A2.2**), where the second connecting point occurred, we mixed and integrated the highly recommended features suggested in the questionnaire with the ideas obtained from the semi-structured interviews during the interpretation of the outcomes.

Then, in the ***third activity*** (**A2.3**), the second connecting point occurred. We mixed and integrated the highly recommended features suggested in the questionnaire with the ideas obtained from the semi-structured interviews during the interpretation of the outcomes.

4.3 Ethics Considerations for Requirements Elicitation

Our research involved human participants. We needed to give them the confidence to share their experience and details. A low-risk ethics application had to be obtained for the RE phase. The application was approved by *AUTEC on 13/11/2017, AUTEC Reference # 17/372, A technology driven approach for improving patients medication adherence: A pilot study*. The consent forms were electronically stored in the researchers' AUT password-protected computer. Consent forms are stored for six years then

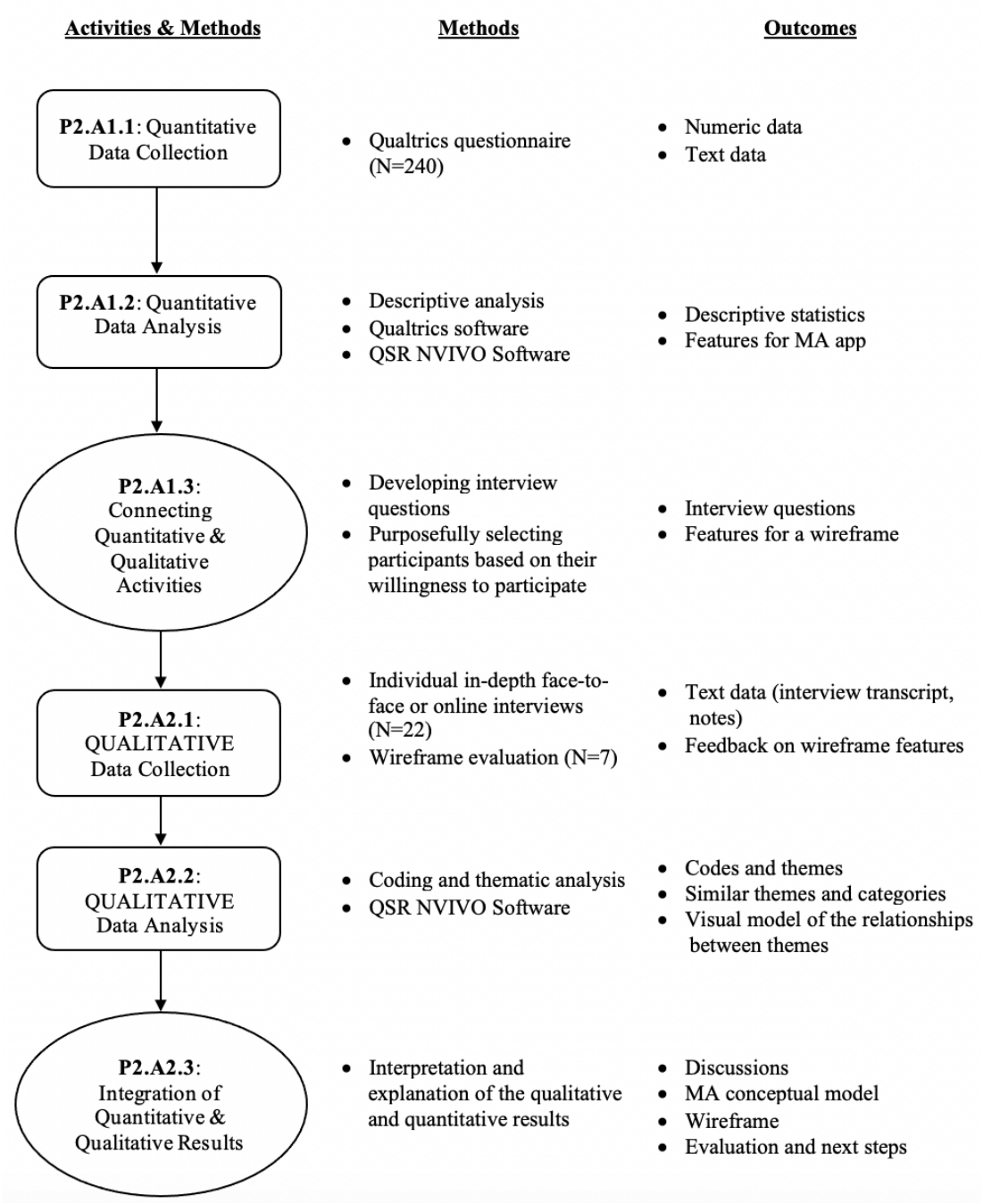

Figure 4.1: A visual model for the sequential explanatory design process; activities, procedures and outcome

destroyed through the AUT confidential documents system.

4.4 Validity of Instruments and Reliability of Results

The study instruments were tested for validity before starting the data collection for both the quantitative and QUALITATIVE phases. All questionnaire questions were selected from different sources in the literature, mainly from the factors associated with medication non-adherence (Rooksby et al., 2017). The interview questions were designed according to the results from the quantitative phase. Both instruments were tested for content validity and internal validity, which were achieved through the reviews and suggestions given by the research team and experts in the field. The instruments were examined by peers and tested among the research team members before using them for collecting the actual study data. The results were considered reliable as they achieved the purpose and fulfilled the participants' needs.

4.5 DSR-P2.A1: Health-Technology Experts' Questionnaire

This section details the first two activities of the quantitative phase, the questionnaire data collection and data analysis, as shown in **Figure 4.2**.

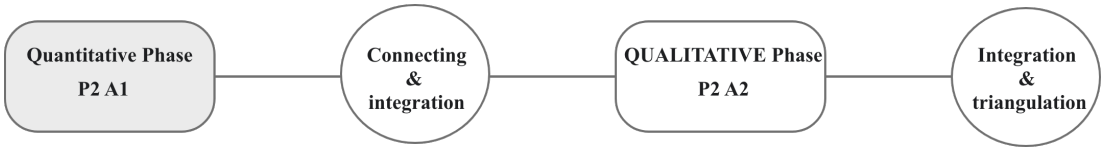

Figure 4.2: The quantitative phase in the Explanatory Sequential Mixed-Methods Design

4.5.1 Instrument

The questionnaire contained seven structured questions followed by an open-ended question, with an unlimited field, to give the respondents an opportunity for extensive

responses. The following documents were used to facilitate the interviews:

- Email invitation (D1.a)
- Information sheet, consent form and questionnaire (D1.b)

The six structured questions and one open-ended question were as follows:

Questionnaire Questions

1. Before starting the survey, please choose your role.
2. Which region do you work in?
3. Do you think patients need to be reminded for taking their medication?
4. How many times a day should the patient be reminded?
5. Do you think daily activities or diet will affect medication adherence?
6. Do you think two-way communication between the patient and health provider will improve medication adherence?
7. If a mobile app is designed to improve medication adherence, what would be the best feature to be added other than a reminder?

The *first two questions* were about the participant's role and work location to make sure we covered most regions across NZ and gained a better understanding of the relationship between the location and the suggested feature (Costa et al., 2015). The *third question* was a Likert scale (yes/maybe/no), concerning whether the patient needs to be reminded to take their medication on time (Costa et al., 2015). The *fourth question* was related to the previous question, asking how many times a day should the patient be reminded (once, twice, or based on the prescription given). The *fifth question* asked whether or not they thought their daily activities or diet would affect medication adherence (Costa et al., 2015). The *sixth question* was of a Likert scale type (yes/maybe/no), and inquired whether a two-way communication between the patient and health provider would improve MA (Luxton, Mccann, Bush, Mishkind & Reger, 2011). The *seventh* and last question captured their opinions on what they considered the best features that

should be part of a mobile app (Balkrishnan, 1998).

4.5.2 Data gathering and process overview

We used the questionnaire to collect feedback from experts about their insights regarding the functionalities of the mobile app. The study was based in Auckland, NZ, from December 2017 to March 2018. The questionnaire was sent through a purposeful sampling technique. The sample was from HINZ's (2020) mailing list members, a six-thousand-address database.

From the responses submitted, only fully answered questions were considered, and the ones with missing data were not recorded. According to Castro et al. (2010), a sample size of at least 160 participants is needed for the study to get a feasible result. Descriptive Statistics were used to summarise the first six questions, while Descriptive Analysis was applied to analyse the open-ended question. Quantitative data were handled and computed using Qualtrics. The qualitative data from the seventh question in the questionnaire were downloaded as text from Qualtrics and uploaded to QSR NVIVO (2018). It was analysed for themes following a thematic analysis process (Vaismoradi et al., 2013). These themes were then developed into qualitative response categories that were quantified based on the responses and exported to be associated with the quantitative data from the first six questions.

4.5.3 Results

A total of 253 participants completed the questionnaire; of those, 240 participants answered most of the questions. In the *first question*, we asked about the participant's role. The majority of the respondents were health providers (103), followed by pharmacists (62), health technology developers (16), and others (67). 'Others' included

researchers, health administrators, health analysts, health insurers, programme managers, health IT managers, nurses and policymakers, and five participants did not specify their role (see **Figure 4.3**).

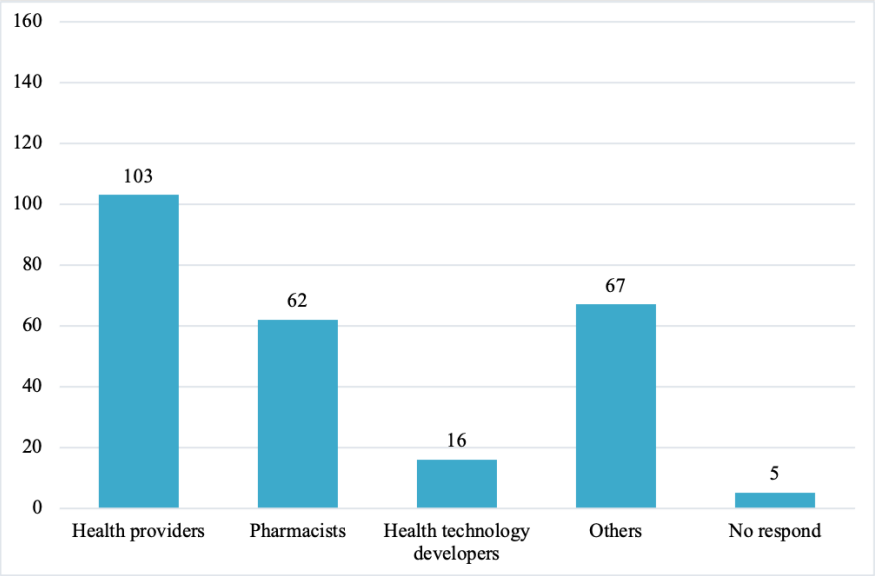

Figure 4.3: Participants' professions

In the *second question*, participants were asked about their work region. All respondents were from NZ. The majority of 128 were from Auckland, 33 from Wellington, 27 from the Waikato, and 54 from other regions including the Bay of Plenty, Canterbury, Hawkes Bay, Southland, Northland, Otago, the West Coast, and Manawatu-Wanganui. We were able to attract participation from most main regions in NZ and to gain a good insight into how the responses differed. NZ is a multicultural country, and each area has a different majority and minority background. We found that participants from Auckland (the largest metropolitan city) proposed having a multi-language feature; this could be due to the city's ethnic diversity (see **Figure 4.4**).

The *third question* asked whether the patient needed to be reminded to take medication, as all MA mobile apps are based on reminding patients to take their medication (Dayer et al., 2013). We found that 152 participants answered "Yes" for reminding patients about their medication, 86 said "Maybe" and five responded with "No" (see

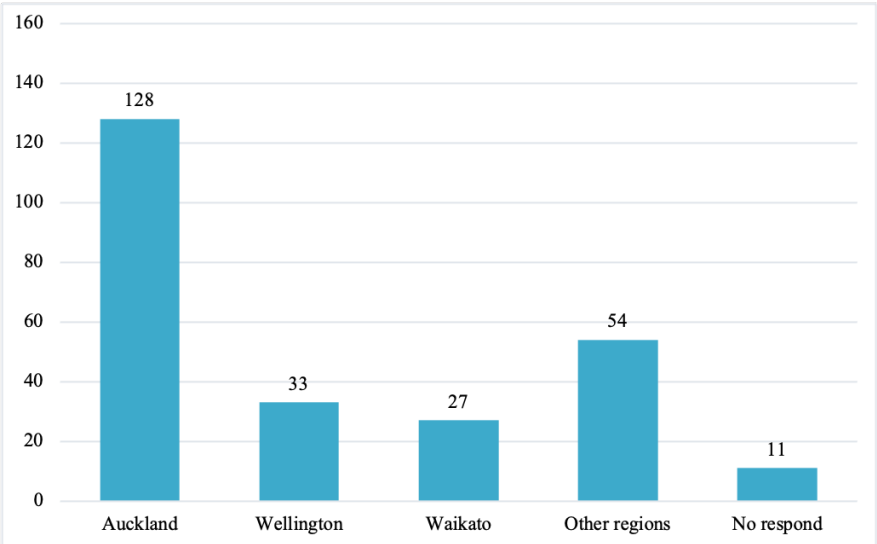

Figure 4.4: Participants' location

Figure 4.5). In the *fourth question*, they were asked about the number of times a patient needs to be reminded; the majority of 226 said as "per the patient's prescription" and five said "twice a day", while only two participants chose to go with "one reminder a day" (see **Figure 4.6**).

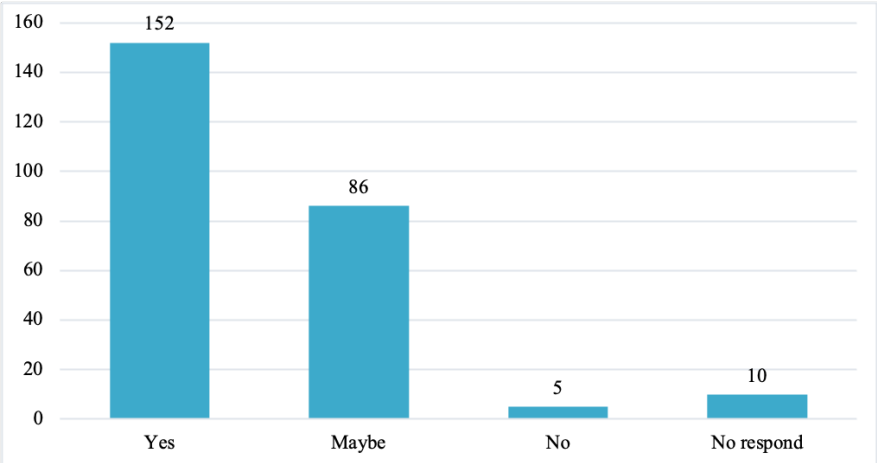

Figure 4.5: The patient needs to be reminded to take medication

The *fifth question* addressed the daily activities or diet affecting MA. One hundred eighty-two participants replied with "Yes" and 54 said "Maybe" and only six replied with "No" (see **Figure 4.7**). The majority of the respondents agreed that diet and other

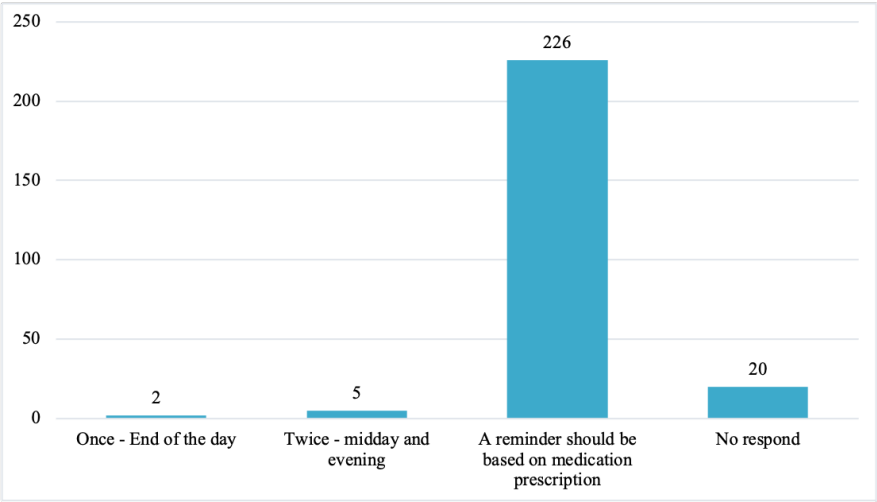

Figure 4.6: The number of reminders per medication

daily activities had an impact on MA. According to Morris et al. (2012), this can be categorised into patient-related factors. Looking at Horne et al.'s (2005) research, habits and daily activities play a big role in people's decisions, and that includes choosing whether or not to take medication.

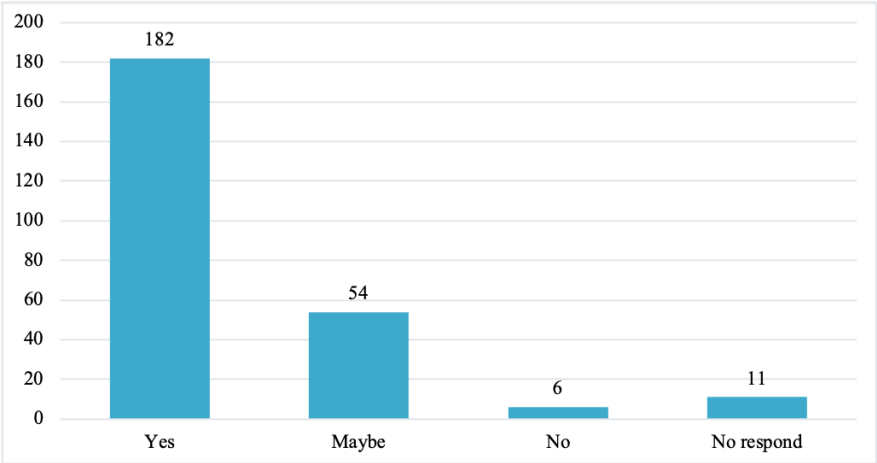

Figure 4.7: The daily activities or diet affects MA

The *sixth question* asked whether the two-way communication between the patient and health provider will improve MA. We had 187 answering with "Yes", 50 answered with "Maybe", and only four said "No" (see **Figure 4.8**). Most of the respondents agreed that communication between patient and health provider improves MA, similar

to what was reported in previous studies (Wald, Butt & Bestwick, 2015; Conn & Ruppar, 2017).

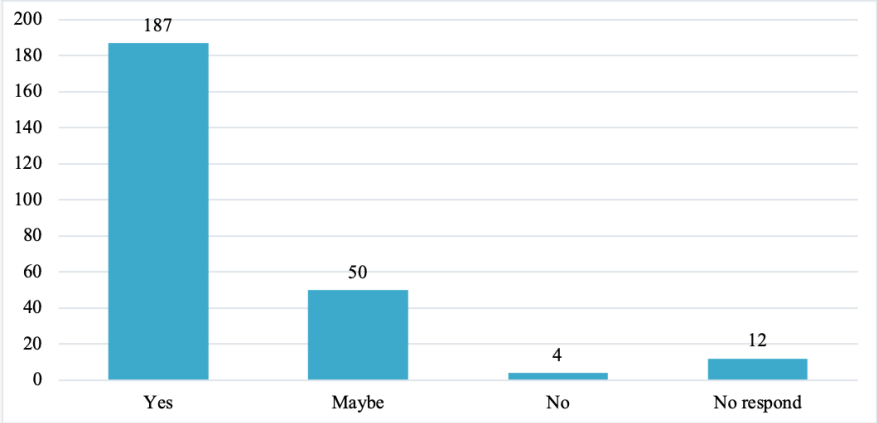

Figure 4.8: The two-way communication between the patient and health provider will improve MA

Furthermore, in the *seventh question*, to provide express feedback, they were asked: If a mobile app is designed to improve medication adherence what would be the best feature to be added other than a reminder? The most commonly noted features listed were "Educational Content" (95 times), which included health literacy and medication information, followed by "Reminders" (65), and "Ability to ask questions" (41), as shown in **Tables 4.2** and **4.1**.

4.5.4 Discussion

The questionnaire results showed that 95 participants recommended educational medication information, which they ranked as the first feature to be considered in the design. This finding is supported by Kannisto et al.'s (2015) systematic review, which showed that health literacy, medication information and educational content have direct relationships with improving MA. We also have Anglada-Martinez et al. (2015), who addressed the challenges of low health literacy in patients at pharmacies. From their research they concluded that providers should not assume patients understand

Table 4.1: Descriptive variables and their possible implementation in an app

Themes	Coded Responses (n=240)	Participants Quotes - Examples	Implementation
Health Literacy and Educational Content	95	Health literacy and educational content. The reason why the medication should be taken. What their medication is for and how it benefits them. Patient information on the importance of the prescribed medications	Educational Content
Reminder / Notification	65	Accountability from a third party - probably family or whanau (community).	Notifications
Two-way Communication	41	The ability of the app to be two-way so that the person using it can input information if they want.	Chat Feature
Compliance Matters	32	Would the reminder be audio such as an alarm? Positive reinforcement	Patient Feedback / Acknowledgment
Capturing Adherence Over Time	32	Capturing adherence data over time. An adherence tracker, i.e. knowing when a pill has been taken (or not)	Calendar
Encouragement	13	Gamification that is specific to a patient's gamification 'personality profile'. Gamification points or 'rewards' for adhering to medications.	My Points
Ability to Ask Questions	12	A contact person for queries. The phone number of their local pharmacy, doctor, and/or health line.	Contact Us

Table 4.2: Summary of features for MA mobile app

Theme	Description
Ability to ask Questions	The app should be interactive. Users must be able to communicate with health professionals via the app whenever they have any concern or worry.
Accountability	The app must be equipped with the capacity of making patients accountable by reporting them to a family member or health professional if they fail to adhere to their medication prescriptions.
Behavioural Engagement Techniques to symptoms of their medications.	The app should be able to engage its users by asking them questions related
Capturing Adherence Data Over Time	The app must be equipped with a feature that captures adherence data over time, such data can be used to understand the reason for failure.
Compliance Matters	The app should be able to remind the patient of the benefits of adherence and the consequences of non-adherence. It should also be able to remind patients of what to do before and after taking medications, such as the type of food to eat.
Encouragement	It should be equipped with some motivational content to encourage patients to adhere.
Health Literacy and Educational Content	It should help improve health literacy by displaying educational content, such as dangers of non-adherence, merits of regular check-ups, etc.
Individualised Profiles	The app should be equipped with a feature that allows for personalised customisation, such as language. Also, it must be equipped with the ability to send medication adherence data to the health provider that will be provided by its user.

medication information. Therefore, future interventions need to address medication information education, especially the issue of the limited time that pharmacists have to explain all the medication details. The second feature for consideration was medication reminders, with 65 participants suggesting that patients needed to be reminded to take their medication, due to their busy lifestyles and other priorities. This was addressed by an earlier systematic review, conducted by Vervloet et al. (2012), on the effectiveness of using electronic reminders to improve MA. Moreover, randomised control trials and cross-sectional questionnaires performed by Kannisto et al. (2015) and Garofalo et al. (2016) respectively, showed improved results when patients were reminded to take their medication.

Moreover, 41 participants agreed that improved two-way communication with health providers would increase MA. This idea was supported by previous research by Ha and Longnecker (2010), who addressed patient-doctor communication and its effects on building trust and improving health outcomes and this corresponds with the view of one participant who commented:

> *The app should be interactive. Users must be able to communicate with health professionals via the app whenever they have any concern or worry* (Questionnaire Participant).

Moreover, 32 participants suggested that patient acknowledgement/feedback and the confirmation of taking medication could help improve MA over time. It also confirms that the treatment is followed as planned to achieve the full benefits. Thirty-two participants recommended having medication intake displayed on a summary page that could be placed on a calendar or a chart. This finding is supported by Bosl et al.'s (2013) research, which mentions that a graphical representation can be quickly reviewed for missed doses. Two other suggested features were rewards (13 participants) and contacts (12 participants) for enhanced health team access. Rewards were suggested

for motivation and encouragement. Collecting points (tokens) for MA would help patients to maintain their motivation as mentioned in **Table 4.2**. The efficacy of rewards from pharmacists has been supported by previous research by (2003), in which rewards were used to reinforce new behaviours that improved MA in chronically ill patients. Pharmacist-enhanced access was suggested due to patients' need to ask questions about side effects and/or missed doses. This feature also correlates with improved medication outcomes in previous research when in-person contact has been integrated with technology-driven interventions (Granger & Bosworth, 2011).

This phase gave us an overview about NZ expert perceptions on MA and using technology to approach MA. Then, according to participants' responses and the previous evidence-based research, we generated our interview questions for a deeper investigation in the next phase.

4.6 DSR-P2.A2: Health-Technology Experts Interviews

This section details the second two activities of the quantitative phase as shown in **Figure 4.9**.

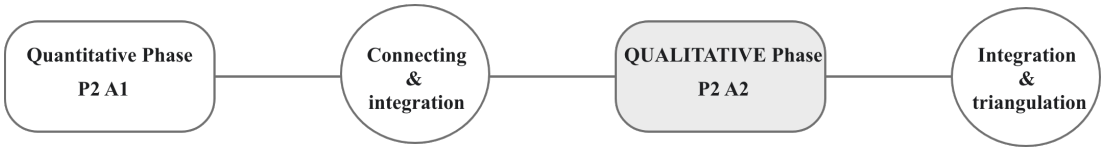

Figure 4.9: The qualitative phase in the Explanatory Sequential Mixed Methods Design

4.6.1 Instrument

Qualitative semi-structured interviews were constructed. The questions were guided by the study objectives, previous research explored in the other settings or with other research groups, discussions with professionals in research teams and the results from

the first activity (DSR-P2.A1). We constructed eight semi-structured questions that were intended to elicit views and opinions from the participants. The following documents were used to facilitate the interviews:

- Email invitation (D1.a)
- Consent form (D1.b)
- Information sheet (D1.c)
- Interview Questionnaire (D1.d)

Below are the eight questions that guided the interview structure:

Interview Questions

1. How can you describe MA?
2. What do you think about the way MA is promoted today?
3. Have you been involved in any MA initiative?
4. What do you think about technology-assisted MA?
5. What benefits could we achieve by introducing solutions for MA?
6. What challenges do you anticipate?
7. What implementation implications do you envisage?
8. Would we require wider support to make similar solutions successful?

In the *first question*, we asked how they describe MA from their perspective. It is always significant to know the participants ideas and how they see the subject discussed from their point of view, before seeking further information for better understanding (Christel & Kang, 1992). Then, in the *second question*, we asked them what they thought about the way MA is promoted today in their role or in any other programme they have been part of or heard about. Their answers to this question will give us a better understanding and an insight into the programmes or approaches available in NZ, and at the same time this will lead to more detailed answers about what worked and what didn't work, which will bring us to our next question.

In the *third question*, we asked about their involvement in any MA initiatives; if they had taken part in any initiative so we could learn from their experiences and share ideas about their approaches; what worked or what did not work and needs further investigation. From the literature review we learnt about the existing approaches worldwide to MA, however, to cater to the NZ population we had to gain further insight into what our experts thought about technology-assisted MA, which was our *fourth question*. Then, the *fifth question* asked about what benefits we could we achieve by introducing solutions for MA from their individual points of view as healthcare providers, health technology experts and health consultants. Due to the wide range of our participants' roles, answers to this question were anticipated to be rich and invaluable.

The *sixth question* asked about their anticipation of the challenges we may face in introducing those solutions. The *seventh question* was designed to elicit information about the implementation implications they envisaged. From the literature review conducted in **Chapter 2**, in preparation for a technology driven solution, the participants expressed their concern about users' acceptance of technology in the health context, stressing that including end-users' needs was critical. With poorly implemented solutions, or solutions with complicated usage, then the implementation will be at risk. Asking the end-users this question and knowing their thoughts from their perspective and settings will help us find ways to overcome those limitations. The *eighth question* was related to the previous question; having a system implemented, we asked whether it requires wider support to make similar solutions successful. Training on the use of the solution helps users adapt to changes and leads to ease of use of the solution (Sudburya et al., 2013).

4.6.2 Data gathering and process overview

Data gathering was performed using unstructured, face-to-face or online interviews. Twenty-two experts from a multidisciplinary background team in the healthcare sector, health technology design industry, and health informatics researchers participated in this study. These participants at the time of the study were working in hospitals, pharmacies, GP clinics, the technology industry, and universities. All participants showed an interest in the topic when first approached through LinkedIn based on their experience and posts. All participants sent their email addresses to enable us to provide them with more details about the study.

They were then sent an invitation email along with the information sheet and the consent form. Participants were asked to read through the information sheet and email back the signed consent form before the scheduled online or onsite interview. Recruitment and data collection continued until it became clear that there was no new information provided or that there was a repetition of information from several participants, which meant the saturation point of data had been reached for this topic. The interviews were recorded using an online tool or iPhone recorder, then saved to a local AUT laptop provided for the study. All recordings were transcribed and deconstructed for analysis, using a Word document, then uploaded to NVIVO for analysis.

4.6.3 Coding procedure

According to Strauss (1987), coding is an essential step in Grounded Theory, stating: "The excellence of the research rests in large part on the excellence of the coding". The Grounded Theory method implies data coding is an essential step. As presented in **Figure 4.10**, when coding, we look at "a bottom-up technique concerning the data, and this begins at the word or sentence level" (Urquhart, 2013). The Grounded Theory

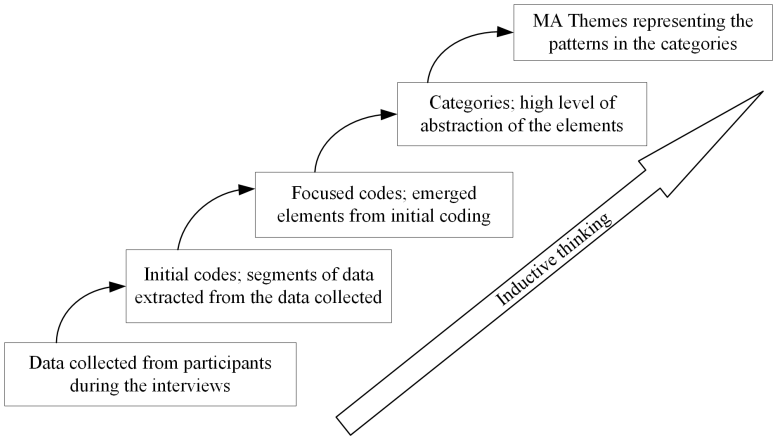

Figure 4.10: Coding procedure adapted from Glaser (Böhm et al., 2004)

method uses three stages: open coding, selective coding, and theoretical coding, as recommended by Glaser (1967), to identify, refine and integrate categories, and ultimately to develop a theory. Open coding, also known as initial coding, means going through the segments of data and attaching codes to the data while being very open and seeing what the data is telling us. Then, the open codes are grouped into larger categories in the stage of focused coding (selective coding), based on key categories that are shaping the theory. In theoretical coding, those categories are related to each other, and consider this relationship between them to achieve the expected theory from the collected data. At a later stage, the theory is engaged with existing theories and these are used to help with the densification of emergent theory.

During the analysis progression, we went from descriptive codes with little interpretation, to pattern codes to differentiate and combine the gathered data. It must be noted, however, that codes assigned at one moment of the analysis were not permanent, since they could be changed along the analysis process to achieve refinement (Urquhart, 2013). Particular attention was paid to the data contradicting the theoretical relationships to avoid research bias from the literature review. Several potential themes were identified for each interview question during the analysis phase. As they emerged, the data were clustered into categories, which then led to more specific generalised themes. From

the main themes, the theoretical relationships were postulated. **Figure 4.10** depicts the coding procedure followed in this research, which is explained in the next sub-sections.

4.6.4 Results

The participants were experts in their fields from different institutions and industries across NZ, where they were involved directly or indirectly with MA programmes. The area of expertise of the participants was expected to lead to a different perception of MA and approach to the technology that assisted MA. In fact, that was found to be generally true, as shown in the examples presented in **Table 4.3**. The health team was concerned about the consequences of not taking medication as prescribed and the risk of failing their expectations for better health outcomes at a specific time. However, the pharmacists were stressing about having the patient filling prescriptions on time and preventing medication wastage through lack of medication literacy. On the other hand, designers and researchers were interested in involving technology to solve some of the issues related to time constraints, human error, and accessibility.

From our analysis, the predominant findings were that four primary categories affected the approach of MA interventions. For the sake of simplicity and to facilitate the comprehension of the subsequent elaboration, we present our findings in reverse order. Thus, we introduce the categories first, in **Table 4.4**.

These categories are the **Patient Ability**, **Collaboration** (with the health team, placing the patient at the centre of the health circle), **Medication Use** (effectiveness and side effects), and **Technology Acceptance**, as presented in **Figure 4.11**. Examples of the interview extracts are provided throughout the analysis as direct quotes from the transcribed interviews and are used in the initial coding, which led to the construction of the focused codes, therefore to categories, then themes.

Table 4.3: Interview participant's field and their attitude towards both MA and technology-assisted MA

Roles	Attitudes towards MA	Attitudes towards technology assisted MA
GP	They assume patients are taking the correct medication they are prescribing at the correct dose, at the correct time, under the correct set of instructions. Consultation time is limited and talking about compliance and adherence while writing the prescription is not enough. The best approach is to adapt medications to their circumstances. Difficulties arise with a long-term condition, and hospital discharged patients.	Anything added to the current system will be beneficial. Knowing if the patient took the prescribed medication t o achieve the expected treatment outcome is important for the patient's health. If this information is provided then an alternative or adjusted medication plan can be suggested before it is too late to be fixed. However, multiple factors may or may not determine the effectiveness of the tech solution, and it is going to be a case-by-case scenario depending on age and physical ability.
Pharmacists	It is patient motivated, how they look after their medications, stick to taking it and many factors play into MA, and one of the main things I think is what the patient knows about their medicine. Patients stop taking medication when they do not see any perceived difference. It is quite complex, has always been a problem and not promoted as it is supposed to be.	The most beneficial thing is to give an idea of the patient's actual medication-taking history. With the available system they can see when the patients picked up their pills, but they do not see how they are taking them every day. It is beneficial to get an idea of what is happening at each dosing interval; then they can identify the reason for missing doses and approach the patient with better alternatives to improve MA.
Consultants – Health	When medication regimen is complex, advanced interventions are needed. Also, it all depends on lifestyle when it comes to young people, as the age factor contributes heavily to adherence. Besides involving the ability of the patient, which can be the physical ability and the mental ability to comply with medication.	If the technology works and it is effective, then definitely it is needed as our end goal is about improving adherence. Because if the patients are not adhering to what was agreed, then something is either wrong or there might be a very legitimate reason why they are not taking it as prescribed. It can be a signal for something important to look at. If it allows continuous monitoring or feedback, then we can achieve better health outcomes, better patient experience, better quality of life and minimize side effects.
Designers and Health Informatics Researchers	MA is a very important and critical application that should be part of our NZ current healthcare. It is a challenging task specially with the medication that has heavy side effects and potentially used by either very young or elderly populations; they can suffer from low rates of adherence. Hospital readmissions relates directly or indirectly to MA. The discharged patients with long-term conditions or chronic conditions are given a new set of medications to take, added to the old list of medications they already have, with no follow-up on when and how they are supposed to manage all medications they have.	Merging technology and healthcare is the solution that can help the population, and it needs to be implemented within the health system to improve the process and lower the cost. Having a technology-driven solution will be valuable to the healthcare organisation, to the patient, to the caregivers, family, and community. A simple app that does the medication reminding might work, or SMS messages might also be good because they do not need to be downloaded. However, the app, it will include more functionality like acknowledgement and a history of taking medication. However, it has to be simple to use and constantly improved to have a nice-looking interface that people will accept, and not only an app developed with a strong clinical background in terms of health research.

Table 4.4: Categories, focused code with the percentage of each category and the number of occurrences in the interviews

Categories	Patient Ability	Collaboration	Medication Use	Use of Technology
Focused Codes (Number of occurrences)	Patient education (24)			
	Patient attitude (13)	Involvement (18)	Medication Literacy (71)	Accessibility (51)
	Adoption (4)	Data collection (48)	Medication effect (31)	Simplicity of Use (36)
	Affordability (8)	Health Data sharing (22)	Patient experience (21)	Time constraint (146)
	Patient demographics (16)			
Total	65	88	123	233

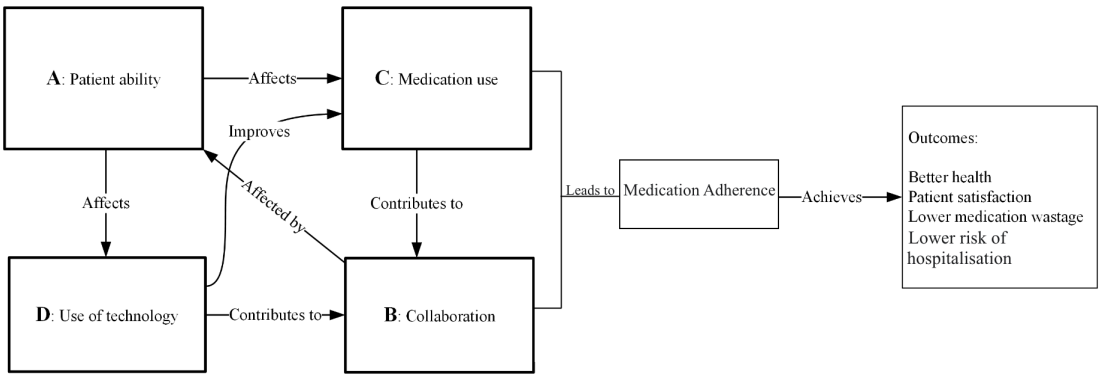

Figure 4.11: A conceptual model of patients MA dynamics

4.6.5 The construction of categories

The category construction is considered the result of moving to a higher level of abstraction when grouping the related focused codes. We had four main categories emerge from the inductive thinking process. As shown in **Table 4.4**, the number of occurrences of each code is focused under a specific category. The numbers represent the richness of each angle, and it is clearly seen that time constraints, medication literacy and technology accessibility were dominant. We have seen this as a positive sign, a successful implementation of any new technology needs time and it has to be accessible by all parties, and simple to use. Moreover, before engaging the patients to use the technology there is a need for good literacy with respect to medication aspects and goal

setting.

In the following sub-sections, we present and explain the construction of categories presented in **Figure 4.11**, from the discovery of the focused codes and their constitutive initial codes.

Category A: Patient ability

This category represents what is related directly to the patient or is within their ability, and it involves *patient education*, *patient attitude*, *adoption*, *affordability* and *patient demographics*. However, studies have proved that there are significant disparities between women and men in their intensity of medication use, their adherence to medications, and their likelihood of receiving guideline-based drug therapy (Manteuffel et al., 2014). However, unexpectedly, the gender factor is unstated in the interviews, by all participants.

Table 4.5 presents the construction of this category which constitutes focused codes and initial codes along with their analytical memo summaries supporting their link around the emergent category from the interview questions.

Examples of the interview extracts are provided to characterise the nature of the data that were used in this study:

- "I define adherence as more of an understanding of why they have to take their medication regularly."
- "Once they are educated and they know the importance of it they will continue to take it."
- "A lot of patients are defiant and don't want to admit that they have a problem."
- "I work in a pharmacy; my pharmacy is from a very multicultural area... We have Indian, Cambodian, Chinese, mainly-speaking pharmacists."
- "New Zealand is a multi-ethnic, diverse country. We have so many people from

different countries who don't speak English."

- "Maybe the elderlies will be more concerned, even adults, more concerned about privacy. Not like teenagers who don't really care."
- "All boils down to communication."
- "The only challenge would be to educate patients first."
- "Long Term Condition Funded Service involves educating them on why they're taking their medication because lack of education is one of the reasons why they don't take them."
- "Some people might be on an anti-depressant, and they want to take a herbal remedy and they shouldn't really. Adherence is a holistic thing, it's not just about when you take your medicine, it is about understanding. So, we think if there's a feature on there, which will give you some more information about what you can take, is this safe to take? "
- "Understand how to adapt medications to their own circumstances."
- "Lack of adherence wastes a lot of money."

We demonstrate next, the contraction of the focused codes around their related initial codes that build up the patient ability category. The headings of the following sub-sections represent the focused codes.

Focused code: Health education

Table 4.6 represents the construction of the focused code **Health Education** from the initial codes identified in **Table 4.5**, which in turn are grounded on the participants' quotations and observations in the previous section.

Focused code: Patient attitude

Table 4.7 represents the construction of focused code **Patient Attitude** from the initial codes identified from the data, which in turn are grounded on the participants' quotations and observations. From the interviews we noticed the concerns about the

Table 4.5: Construction of patient ability category

Initial Codes	Focused Code	Analytical memo summary
Health literacy	Health education	Medication literacy is perceived as a foundation for empowering patients and providing better health outcome.
Patients awareness		MA is not seen or considered as a priority or an issue to tackle.
Medication belief		Health education will empower the patient to take control of their medication
Acceptance of technology	Patients attitude	Patient acceptance is something to consider at the early stage of the process, as they are the main users of the system and they are the ones to be benefiting from the new approach.
Patient readiness		
Willingness to change		
Life style	Adoption	Knowing the issue from patients is the key to solving it.
Daily routine		Life style plays a crucial role in patient's adherence.
Other adherence matter		Adherence is not supposed to be only on taking medication, also adherence to anything else needs to be done.
Physical ability		Physical ability is a factor which may not be in all settings like agecare, where nurses are taking charge of the medication.
Technology cost	Affordability	Not everyone will be able to afford medication, or the MA packaging.
Healthcare cost		Non-adherence is high is in deprived communities, and they will not afford the healthcare cost nor the medication cost and the use of technology.
Medication cost		
Ethnicity	Patient demographics	Age is a key point for approaching adherence.
Social factors		Each setting has its own approach to MA.
Different circumstances		Patient's demographic plays a key role in implementing technology.
Age factor		Any new approach or settings will be challenging for elderlies 65+ who are the most users for long term medication and multiple medications.

Table 4.6: Construction of focused code: Health education

Focused code	Initial codes	Interview data
Health Education	Health Literacy	"More of an understanding of why they have to take their medication regularly." "Once they are educated and they know the importance of it they will continue to take it."
	Patient awareness	"The only challenge would be to educate patient first." "More aware of what the medication is doing for them."
	Patient belief	"Medication compliance is seen as a requirement rather than part of their health plan." "Maybe it's related to their health belief."

users' attitudes when working with technology saying

> "*...the major challenge you're gonna have is acceptance from patients. We are all used to our paper*" (Interview participant).

Focused code: Adoption

Table 4.8 represents the construction of focused code **Adoption** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.7: Construction of focused code: Patient attitude

Focused code	Initial codes	Interview data
Patient Attitude	Acceptance of technology	"The major challenge you're gonna have is acceptance from patients." "We are all used to our paper"
	Patient readiness	"We're trying to help you and not making them feel bad" "Are people willing and prepared, ready for adoption?"
	Willingness to change	"It's behavioural change" "Are you happy if you would get regular updates ... reminders or notifications on your medications?"

Table 4.8: Construction of focused code: Adoption

Focused code	Initial codes	Interview data
Adoption	Life style	"To improve their quality of life." "Something that is very used to our daily life."
	Daily routine	"You don't want it to interfere with their daily life." "It's not just the medicine. It's everything you do in your life. "
	Other adherence matter	"There's possibly other minor non-adherence that doesn't get detected." "Adherence is a holistic thing, it's not just about when you take your medicine."
	Physical ability	"But also their physical ability and their mental ability to comply with the medication." "Then particular group, were likely to have physical issues."

Focused code: Affordability

Table 4.9 represents the construction of focused code **Affordability** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.9: Construction of focused code: Affordability

Focused code	Initial codes	Interview data
Affordability	Technology cost	"Patients that can't afford a smart phone." "The phone, so financial wise they can't afford it." "The phone, so financial wise they can't afford it."
	Healthcare cost	"lack of adherence wastes a lot of money." "If you can save cost then DHB will be interested."
	Medication cost	"Not everybody can afford it." "Can't afford to fill a prescription."

Focused code: Patients' demographics

Table 4.10 represents the construction of focused code **Patient Demographics** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.10: Construction of focused code: Patient demographics

Focused code	Initial codes	Interview data
Patient Demographics	Depends on ethnicity	"We have so many people from different countries who don't speak English." "They don't speak English."
	Social factors	"They are on the go or they have got more social lives." "It's obviously a different social contract."
	Different circumstances	"How to adapt medications to their own circumstances." "Like any number of different circumstances."
	Age factor	"The age group. Like 65+ year old. Are they really happy and comfortable around using technology." "Because it's hard enough being that age to start off with and having chronic health issues is always tricky."

Category B: Collaboration

This category represents what is related to involving the patients, health teams, family members and carers in the healthcare circle. That means considering the patient at the centre of care with the privilege of empowerment to take charge of their treatment and health. That could be achieved through health data sharing from a centralised database to eliminate errors of multiple data sources. The data collection occurs where the patient can feed some information back to specific members of the health circle to support them during the MA plan and process.

Table 4.11 presents the construction of this category, its constituent-focused codes and initial codes, along with their analytical memo summaries supporting their link around the emergent category from the questions of the interview. Examples of the interview extracts are provided to characterise the nature of the data that were used in this study:

- "I think the first thing is better communication."
- "Find out why it was not taken instead of blaming the patient."
- "Know the time of the medications missed and solve that particular time frame."

- "Ask the patient if they want to be involved in MA."
- "Help us understand and detect patterns of how the patients are taking their medication."
- "I know that we have doctors in New Zealand that might be more inclined to sign their patients up to certain services like apps."
- "Patients don't remember which medication they are taking when they are admitted in the hospital."
- "First any tool has to have a pharmacist involvement and first of all find out why, and what their beliefs are. Then, put the right tool in place."
- "I definitely think clinicians should be involved, they just need to know if something is wrong and will make a note in the system... it's all about avoiding rehospitalisation."

Table 4.11: Construction of collaboration category

Initial Codes	Focused Code	Analytical memo summary
Family Involvement	Involvement	Better communication with patients results in better acceptance of any changes.
Health Team Involvement Patients' Involvement		
Patients Do Not See The Same GP	Health Data Sharing	The absence of a centralised database caused the ack of information at each level.
Multiple Prescriptions		
Better Insight For Health Team	Data Collection	Technology will help us understand and detect patterns of how the patients are taking their medication.
Identifying The Reasons for Non-Adherence		

We demonstrate, next, the discovery of the focused codes around their related initial codes that build up the individual capacity category. The headings of the following sub-sections represent the focused codes.

Focused code: Involvement

Table 4.12 represents the construction of focused code **Involvement** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.12: Construction of focused code: Involvement

Focused code	Initial codes	Interview data
Involvement	Family involvement	"The concept of involving family and friends in care is important." "It would be important to involve their family."
	Health team involvement	"The bridge between the clinician team, and the patient, and caregivers." "Can't afford to fill a prescription."
	Patients involvement	"Empower the patient and make them the centre of the health system." "Trying to make the patient-centric and make it more patient focused."

Focused code: Data collection

Table 4.13 represents the construction of focused code **Data Collection** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.13: Construction of focused code: Data collection

Focused code	Initial Codes	
Data collection	Better insight for heath team	"The concept of involving family and friends in care is important." "It would be important to involve their family."
	Identification of non-adherence	"It's really great as far as trying to help us understand and detect patterns of how the patients are taking their medication and also help us to identify if they're gonna be any, how the outcomes are gonna be in all those sort of things." "If I can identify that a patient is having issues."

Focused code: Health data sharing

Table 4.14 represents the construction of focused code **Health Data Sharing** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.14: Construction of focused code: Health data sharing

Focused code	Initial Codes	
Health data sharing	Change of GP	"I've seen their GP history reports and the GP won't have some of the information that I have." "They will go and they will see a different GP."
	Multiple prescriptions	"So somebody that's on multiple medication might have different issues with remembering which ones to have when" "Each person is giving them a prescription."

Category C: Medication use

This category represents what is related to medication or medication use: medication literacy, medication effect, and patient experience with medication.

Table 4.15 presents the construction of this category, its constituent-focused codes and initial codes along with their analytical memo summaries supporting their link around the emergent category from question one of the interview. Examples of the interview extracts are provided to characterise the nature of the data that were used in this study.

- "Where people with mental health clients, medication adherence, or medication compliance is seen as a requirement rather than part of their health plan."
- "There's probably not as much focus on specifically taking them the right way or at the right time."
- "It's about reducing the number of medications... That's called medicine therapy assessment."
- "We've done blister packing for at least over 20 years."
- "SafeRx which contains a lot of paper-base."
- "It's still not going to work on the person that does not want to take their medicine for a certain reason."

We demonstrate next, the discovery of the focused codes around their related initial codes that build up the individual capacity category. The headings of the following sub-sections represent the focused codes.

Focused code: Medication literacy

Table 4.14 represents the construction of focused code **Medication Literacy** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.15: Construction of medication use category

Initial Codes	Focused Code	Analytical memo summary
Patients still using stopped medication Avoid polypharmacy	Medication literacy	Each medication is different, the one solution will not fit all medications. A better understanding is needed of medication use and the risk of using stopped medication.
Conflict of medication Each medication is different Medication review	Medication effect	A medication review is part of the treatment plan and the patient is required to understand the effect of each medication. Not all medications are the same and that requires multiple approaches to different groups.
Side effects Medication history	Patient experience	Patient history with medication will affect the way of dealing with medication. Some of the patients stop the medication due to side effects and that requires the health providers' notice.

Table 4.16: Construction of focused code: Medication literacy

Focused code	Initial codes	Interview data
Medication literacy	Using stopped medication	"They have been prescribed medications, which they have brought it from home. The next day, transpires that these medications have been stopped." "Always if there's medication, I check with the patient first. If they're supposed to be stopped."
	Avoid polypharmacy	"Then it's a matter of looking at the whole collection of medications they're on trying to, you know, utilise is one medication that will do too." "We were the first pharmacy to instigate MUR, which is a medication review service."

Focused code: Medication effect

Table 4.17 represents the construction of the focused code **Medication Effect** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.17: Construction of focused code: Medication effect

Focused code	Initial codes	Interview data
Medication effect	Medication difference	"Different medications a day and if you have multiple conditions." "More than five different types of medication they need to take at different times, and different quantities."
	Medication review	"If it involved a medication change, now that's different." "That's an upgrade treatment plan"
	Medication conflict	"Patients on an expensive treatment and even then they're not doing it ideally."

Focused code: Patient experience

Table 4.18 represents the construction of focused code **Patient Experience** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.18: Construction of focused code: Patient experience

Focused code	Initial codes	Interview data
	Side effects	"What are the side effects, and what if they don't take it." "Address variants to adherence, whether it's side effects or just convenience."
Patient experience	Medication history	"History about medication if I refilled it or not." "The medication history is a very telling sign."

Category D: Use of technology

This category represents what is related to accessibility in terms of the ability to easily access technology by all the circle members, and which must be compatible with the available systems used and must also reach the right people who want to be part of the process. Also, there is simplicity, so the technology needs to be simple to use and acceptable to the end-user. Then, there is the time constraint, which is part of any software development process or any new project, and the treatment time, which also affects the results of the technology use or the treatment outcome.

Table 4.19 presents the construction of this category, its constituent-focused codes and initial codes along with their analytical memo summaries supporting their link to the emergent category from the interview questions. Examples of the interview extracts are provided to characterise the nature of the data that were used in this study.

- "People who have problems remembering their medication, they can use an intervention of texting and phone calls to remind them about their medication."
- "May have more use for people who are already engaged."
- "They might be busy when they receive the notification."

- "The consumers will tell if they are willing to use the technology."
- "Sixty percent of our patients are rural."
- "Patients use nicknames for medication... it was making him very sleepy during the day."
- "The most beneficial thing about introducing this is to give an idea of the patient's actual medication-taking history."
- "Nowadays everyone is using phones and even the elderly population are but it's a matter of them being able to access it... so if it's very complex it might not be worthwhile and it might not actually do anything."
- "Not everyone has a phone, well not everyone has a computer, so how are they going to access it?"
- "Why is this being used? How is this going to be used? What are the benefits of using something?"
- "Definitely you'll have to train the pharmacist and you'll have to train clinicians."
- "A large proportion of people just don't like using health apps because they're ugly and terrible to use."
- "I would say that the app itself serves as a measure of motivation and encouragement, so personally I would say they'd be two different approaches, though the idea that the app is one strategy and then family and friends is another one."
- "The pharmacy, you sign up, and they can all see if the patient has been double dipping in other pharmacies."

We demonstrate next, the discovery of the focused codes around their related initial codes that build up the individual capacities category. The headings of the following sub-sections represent the focused codes; the initial codes are in brackets and italics, following the instances that support their labels.

Table 4.19: Construction of use of technology category

Initial Codes	Focused Code	Analytical memo summary
Not all have access to broadband	Accessibility	Ease of use will help in supporting our first analysis of patient acceptance. The system has to support multiple languages.
Compatibility with other systems		
Reaching the right people		
Training	Simplicity	Educating patients is important, they cannot use something they do not understand while they are using it.
The benefit of using new solutions		
Implementation time	Time constraint	Period of treatment is one of the reasons patients stop the medication, they get bored and frustrated when it is long-term used and complex. Any new system will take time to get used to. The output will need longitudinal data collection to be able to conclude the benefit of it.
The period of treatment		

Focused code: Accessibility

Table 4.20 represents the construction of focused code **Accessibility** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.20: Construction of focused code: Accessibility

Focused code	Initial codes	Interviews data
Accessibility	Broadband access	"It's a matter of them being able to access it." "Access to broadband is very difficult."
	Compatibility	"If it involved a medication change, now that's different." "That's an upgrade treatment plan"
	Medication conflict	"Patients on an expensive treatment and even then they're not doing it ideally."
	Reaching the right people	"They might be a particular age group of people who might become comfortable with using technology." "But if the slightly younger group, teenagers or early 20s, for them health is not a main issue."

Focused code: Simplicity

Table 4.21 represents the construction of focused code **Simplicity** from the initial codes identified, which in turn are grounded on the participants' quotations and observations.

Focused code: Time constraint

Table 4.22 represents the construction of focused code **Time Constraint** from the

Table 4.21: Construction of focused code: Simplicity

Focused code	Initial codes	Interview data
Simplicity	Training	"Patients that can't afford a smart phone." "The phone, financial wise they can't afford it."
	Benefit of using new solutions	"Not everybody can afford it." "Can't afford to fill a prescription."

initial codes identified, which in turn are grounded on the participants' quotations and observations.

Table 4.22: Construction of focused code: Time constraint

Focused code	Initial codes	Interview data
Time Constraint	Implementation time	"I think there might be a short time period of getting adjusted to it." "It's only sustained for a short period of time."
	Period of treatment	"The treatment is still pending for the original one and then they turn back to hospital. So that is one of the major things which I see long-term in my private practice."

4.6.6 Building a Conceptual Model of Patients' MA Dynamics

According to the principles of GT, we have four categories postulated from our analysis, which were constructed by grouping conceptually linked focused codes, as shown in **Table 4.23**.

From the four categories as show in **Figure 4.12**, we now conduct an analytical process at a higher level of abstraction in order to find the conceptual relationships between the categories. Indeed, we are looking for patterns or underlying meanings.

Although the four emergent categories are strongly linked to one another because they emerge from the same data, which in turn were purposefully collected around a common research question – *How can digital technology improve patients' medication intake*? – there are traceable characteristics that allow us to group them under a particular arrangement. As explained earlier, the categories cannot be completely detached from one another. Indeed, when breaking the data apart during the initial coding, we split

Table 4.23: Summary of the categories, focused codes, initial codes and their number of occurrences

Categories (Total Occurrence #) Cross-Reference	Focused Code Reference	Initial Codes	Referencing initial codes	Occurrence #
Patient Ability (65) A	Patient education A1	Health literacy	A1.1	24
		Patients' awareness	A1.2	
		Medication belief	A1.3	
	Patients attitude A2	Acceptance of technology	A2.1	13
		Patient readiness	A2.2	
		Willingness to change	A2.3	
	Adoption A3	Life style	A3.1	4
		Daily routine	A3.2	
		Other adherence matters	A3.3	
		Physical ability	A3.4	
	Affordability A4	Cost of technology	A4.1	8
		Healthcare cost	A4.2	
		Medication cost	A4.3	
	Patient demographics A5	Depends on ethnicity	A5.1	16
		Social factors	A5.2	
		Different circumstances	A5.3	
		Age will affect the way of approaching	A5.4	
Collaboration (88) B	Involvement B1	Involve family and carers	B1.1	18
		Involve health team	B1.2	
		Involve patients	B1.3	
	Data sharing B2	Patients don't see the same GP	B2.1	48
		Multiple prescriptions	B2.2	
	Data collection B3	Better insight for health team	B3.1	22
		Identifying the reasons for non-adherence	B3.2	
Medication use (123) C	Medication literacy C1	Patients still using stopped medication	C1.1	71
		Avoid polypharmacy	C1.2	
	Medication satisfaction C2	Conflict of medication	C2.1	31
		Each medication is different	C2.2	
	Patient satisfaction C3	Side effects	C3.1	21
		Medication history	C3.2	
Use of technology (233) D	Accessibility D1	Access to broadband	D1.1	51
		Compatibility with other systems	D1.2	
		Reaching the right people	D1.3	
	Simplicity D2	Training	D2.1	36
		Benefit of using new solutions	D2.2	
	Sustainability D3	Implementation time	D3.1	146
		Period of treatment	D3.2	

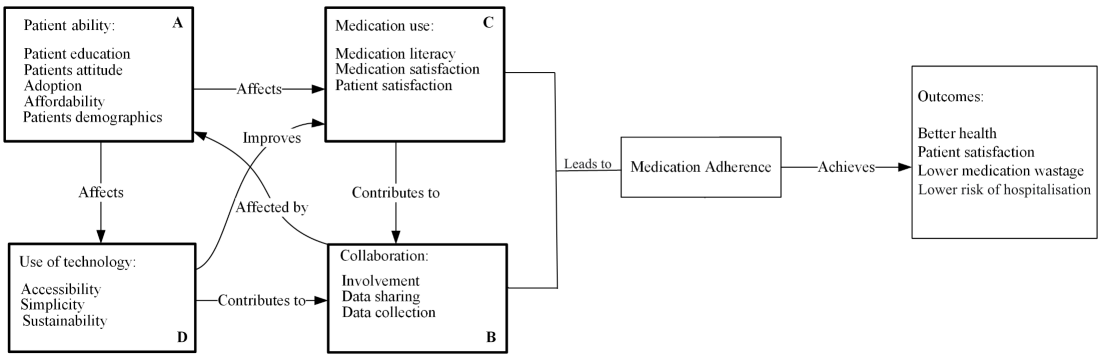

Figure 4.12: Detailed conceptual model of patients MA dynamics

distinctive but still related pieces of information, which afterwards were joined to some others according to their degree of conceptual similarity under the focused codes. In turn, the focused codes yielded the categories. Certainly, moving up from the focused code level to the category level was a zoom out, in which only the theoretical connections were considered, leaving behind the low-level concrete connections. As a result of grouping the emergent categories following an inductive thinking path, two core themes were revealed, which we explain next.

The appearance of the ***first theme*** derives from the first and the third emergent categories, *patient capacity* and *medication use*, both focused on the individuals' education, experiences and attitudes toward the whole MA process, regardless of the tools used or external involvement. While we recognise that collaboration is part of the patients' experiences with medication, it was made explicit during the interviews that the patients' ability and experiences with medication were to be solved at the patient level.

The appearance of the ***second theme*** derives from the second and the fourth emergent categories, *collaboration* and *use of technology*, which are both focused on the use of resources as either a tool or data, in addition to accessibility and data sharing, which applies to both categories. From the collected data it was clear that standalone systems would not serve the patient as needed. However, the use of technology allow reaching the required data and simplifying the collaboration to serve the patient. **Figure**

4.13 presents the high-level technology-driven MA model constructed from the themes representing the patterns in the four categories.

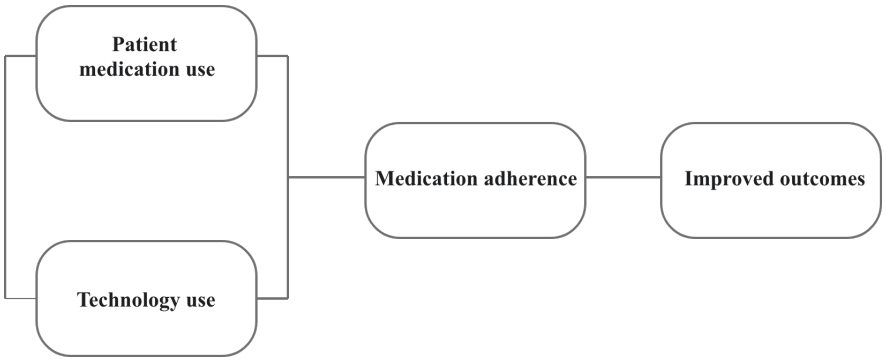

Figure 4.13: High level conceptual model of patients MA dynamics

As shown, the qualitative phase consisted of deconstructing and interpreting the data gathered from the interviews then reconstructing the participants' thoughts into clusters of similar ideas into categories then themes. After that we looked at the relationship between the themes for a better understanding of what affects patients' health outcomes positively.

4.7 DSR-P2.A3: Results Integration and Visual Interpretation of RE via a Wireframe

This activity presents the integration and interpretation of the quantitative results from activity **P2.A1.2** and the QUALITATIVE results from activity **P2.A2.3** as shown in **Figure 4.14**. From the previous sections we summarise our findings below which will then be interpreted into functions in an app wireframe.

- **Patient ability:** The first category is the patient's ability, which is related directly to the patient or their ability, and it involves patient education, patient attitude, adoption, affordability and patients' demographics in terms of age and ethnicity

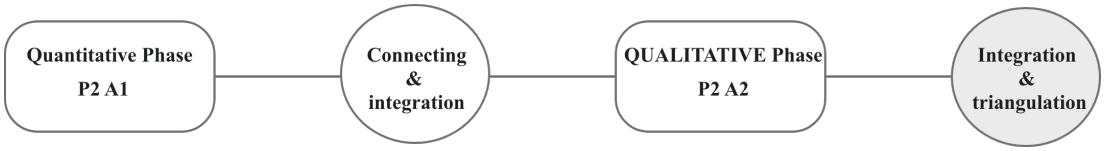

Figure 4.14: The integration and results triangulation phase in the Explanatory Sequential Mixed Methods Design

only. Studies proved significant disparities in the intensity of adherence to medication between women and men, and their likelihood of receiving guideline-based therapy for using their medication (Manteuffel et al., 2014). However, unexpectedly, the gender factor was not mentioned in the interviews by any of the participants. Moreover, the healthcare consultants regarded involving the ability of the patient, which can be a physical ability or a mental ability, to comply with medication, as being extremely important and contributing to MA. Therefore, if technology will allow continuous monitoring or feedback, they can achieve better health outcomes, better patient experience, a better quality of life and a minimising of side effects.

- **Collaboration:** This category represents the collaboration of family members and carers in the healthcare circle, while considering the patient as being at the centre of the circle with the privilege of empowerment to take charge of their treatment. Health data sharing has a centralised database to eliminate errors of multiple data sources, and data collection where the patient can feed some information back to specific members of the health circle to support them during the MA plan and process. A related study found that patient-driven healthcare can be characterised as having an increased level of information flow, customisation, collaboration and responsibility-taking, as well as predictive and preventive facets (Swan & Melanie, 2009).

- **Medication use:** This category represents what is related to medication use: medication literacy, medication effect and patient experiences with medication. According to Health Consultants, the medication regimen is complex, and advanced interventions are needed to support patients with their medication. However, they were certain that results depend on lifestyle when it comes to young people, as the age factor contributes heavily to adherence.

- **Use of technology:** This category covers the patients and healthcare teams' use of technology, which represents its easy accessibility by all the circle members and its compatibility with the available systems used, and also by reaching the right people who want to be part of the process. Also, there is the simplicity aspect, so the technology needs to be simple to use, and acceptable to the end-user. Then, there is the time constraint which is part of any software development process or any new project and the treatment time, which also affects the results of the technology use or the treatment outcome.

4.8 Wireframe Design and Evaluation

"*The greatest value of a picture is when it forces us to notice what we never expected to see.*" - John Wilder Tukey

The proposed solution is a wireframe that is equivalent to a skeleton or the simple structure of the app. It is used to describe the functionality of a product as well as relationships between views: what will happen when you click a certain button? The decisions on what (content/features) and where to include them on the app are usually made during the wireframe stage (Huang, Wang & Hsu, 2013). Although the background research included some useful examples of MA apps, it confirmed that an MA app needs to be proposed to meet the specifications suggested by healthcare

experts in NZ. Following the initial background research and the features extracted from experts' feedback as shown in **Table 4.2**, we proposed a wireframe. Its components were chosen based on frequency, novelty and importance to end-users using Adobe Experience Design (Xd) (2017) for a better visual to communicate both abstract and concrete ideas with the end-users.

The wireframe consisted of seven screens (see **Figures 4.16 - 4.22**), as described in **Table 4.24**, in addition to the home screen as presented in **Figures 4.15**.

Figure 4.15: Home screen

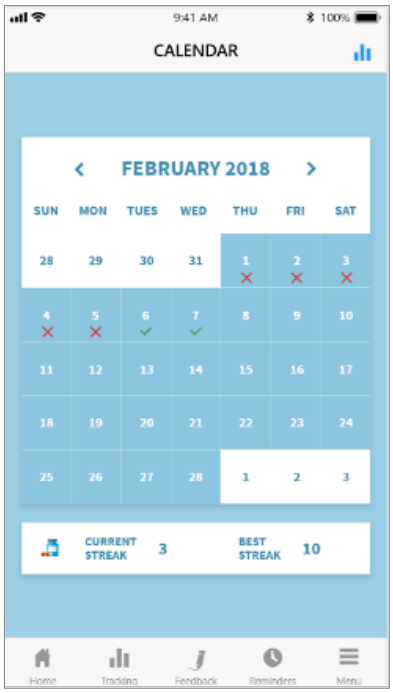

Figure 4.16: Calendar screen

The participants provided their initial feedback on the features implemented in the wireframe. Most participants agreed that, overall, the wireframe was good saying:

> *The wireframe seems great and we feel if we were to introduce such a thing into NZ, we could greatly improve medicine compliance* (Wireframe evaluation participant).

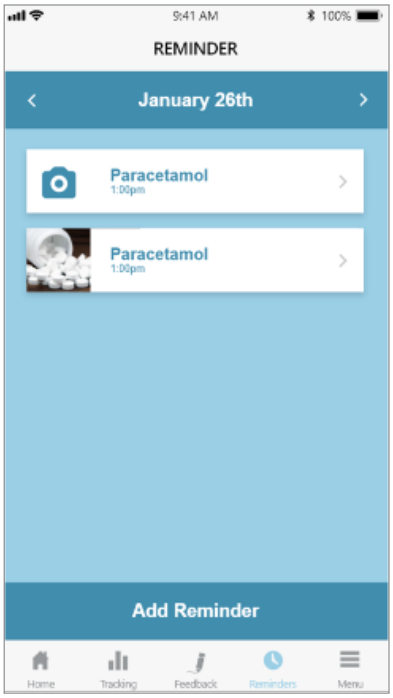

Figure 4.17: Reminder screen

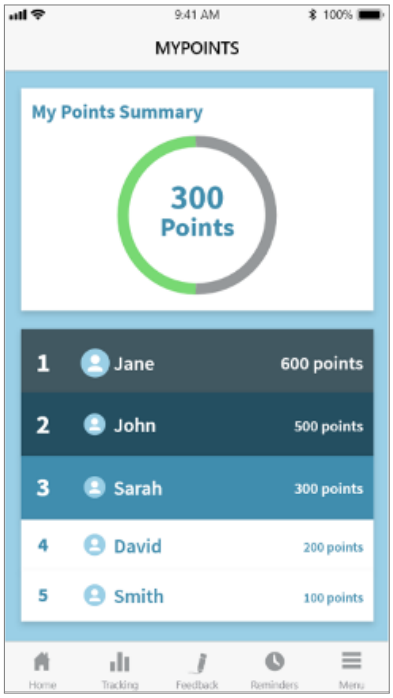

Figure 4.18: My points screen

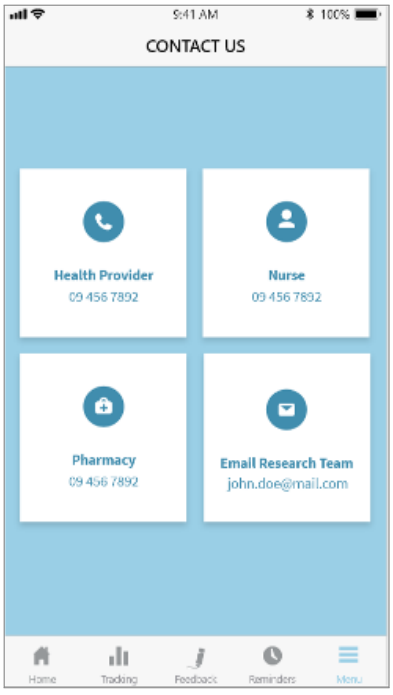

Figure 4.19: Contacts screen

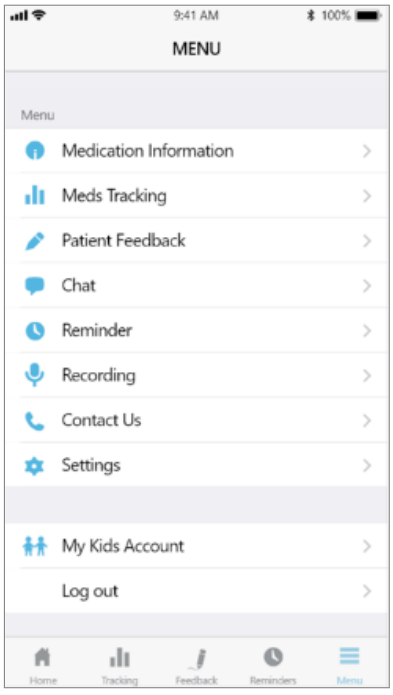

Figure 4.20: Menu screen

Below we provide the feedback given by the wireframe evaluation participants:

Figure 4.21: Chat screen

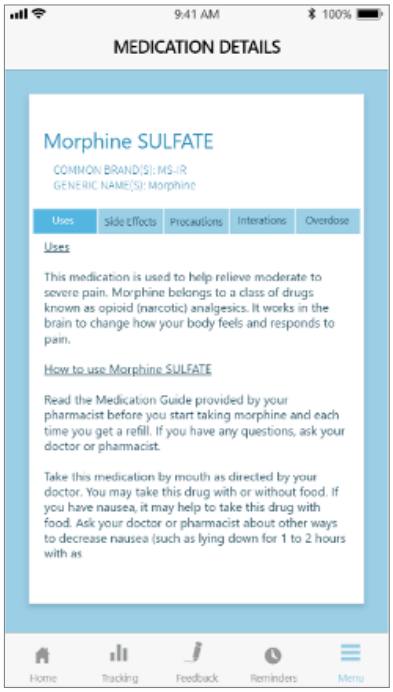

Figure 4.22: Medication literacy screen

- **Reminder/notification screen:** It was suggested to make the content more inspirational, by having the question posed in a less emphatic tone to avoid the possibility of it being perceived as nagging.

- **Acknowledgement/patient feedback screen:** It was suggested that the page name be changed to "My goals" rather than "Feedback", as the users may believe that the Feedback tab would be for providing feedback on the app and they may not utilise it. Also, the free text options should be limited to one, e.g., can be a drop-down menu/multiple-choice rather than free text to type in. Moreover, it is good to know if the user took some of the medication but not all, and the text method would not give a clear picture of that. However, writing two things could be free text, but how much data is expected or should be inputted? They liked the idea of promoting the users' awareness and suggested looking for a way to make it fun to do by re-framing it into something more personal and directly related to the users' immediate benefit.

- **Calendar screen:** A calendar can also be used to show upcoming events, appointments, and goals for taking medications in cases of patients with multiple medications. Also, the way to represent whether someone has taken their medication by using blocks of colour may work better. Moreover, care needs to be taken with the potential for people to overdose. Medication instructions should be strictly followed and reflected in the reminders/regime.

- **Contact Screen:** Having all of the patient's contacts grouped on one screen is a nice touch and likely very convenient. However, the provider's availability and operating hours are important points to consider. Also, when would it be appropriate for a user to call (e.g., when experiencing side effects, mood changes, the need to renew a prescription)? From a business point of view, it would be good to have a plan for dealing with these types of scenarios early on. Also, in establishing the contacts for each user, is a dataset available? Or could one be produced that would allow the user to select their provider? Another suggestion was having multiple language options, which was a good idea for reaching a wider audience, due to the demographic variation and multicultural nature of the country.

4.9 Summary of Chapter 4

In this chapter, we covered **Activity 2** of the DSRM introduced in **section 3.3.2**. Here we used the Mixed Methods Sequential Explanatory Study design (Creswell, 2003). We also showed that before starting the implementation of this method we looked at establishing the priority between the quantitative or qualitative approach. Depending on the phase, we preferred to start with the volume of the data to be collected during each phase, and the rigour and scope of the data analysis within each phase. Our sequence of

Table 4.24: Wireframe screens description

Screen Name	Description
Notification	The user receives two types of notifications after creating an account and adding the prescribed medication. The first type is to be reminded of medication intake and the second type is an auto-notification at the end of the day, to check whether he medication was taken as scheduled.
Acknowledgement/ Feedback	By swiping the notification message, an acknowledgment screen comes up with three parts for the user to answer: first, if medication has been taken; second, entering a reason for not taking medication; and third, to write two things done that may affect the treatment.
Calendar	The user is able to see a summary of their medication intake per month; also, it can be represented in a chart view through a toggle button on the top right corner of the screen.
Contact	The user can enter the healthcare team's (GP clinic or nurse or pharmacy) contact numbers.
Chat	The user can interact with the healthcare team in case of no response when calling.
Educational content	The medication details will provide the user with information like the use of medication, side effects, precautions, interactions and overdose.

the quantitative and qualitative data collection was determined by our study purpose and research questions. We prioritised the quantitative phase in the sequence because our study goal was to seek an in-depth explanation of the results from the quantitative method.

From our *first phase* – quantitative – we gathered the requirements for MA App features through a questionnaire that was completed by 253 participants, from health-care experts to health systems designers. The top recommended features included "Educational Content" suggested by 95 participants, "Reminders and Notifications" suggested by 65 participants, "Chat/Communication" suggested by 41 participants and "Patient Feedback" and "Calendar" suggested by 32 participants. The results from this phase needed an in-depth explanation, which then took place within our next phase.

The questionnaire included a question asking the participants if they were keen to be contacted in the further requirements elicitation phase. Here our *first mixing and integration* between both phases occurred. We built phase two – qualitative – questions according to the results of phase one, and purposefully invited participants for further elaboration of their answers.

In *phase two*, we developed a conceptual model based on healthcare professionals and health technology designers' insights into poor MA, and a method for improving MA by using mHealth. The 22 participants interviewed in this study were concerned about poor MA, which, according to them, prevents patients from fully benefiting from their prescribed medications. The healthcare professionals expressed concerns about the consequences of not taking medication as prescribed and the resulting risk of failing to achieve the expected improvements in health outcomes within a specific period. The pharmacists stressed the importance of having patients uplift prescriptions on time and preventing wastage of medication through medication literacy. The technology designers and researchers were interested in utilising technology to solve some of the problems related to time constraints, human errors, and accessibility.

The interviewees suggested many ideas to mitigate the problems caused by a lack of MA. Some key insights included: (1) the patients' ability to engage in their courses of treatment; (2) collaboration among members of healthcare teams; (3) medication use; the potential effectiveness and side effects of prescribed medications; and (5) acceptance and simplicity of technology usage.

The strength of this phase was our comprehensive sampling of the participants, which included healthcare professionals in direct contact with patients, and health technology designers experienced in developing technological tools for patients. The interviews were analysed to define the underlying themes and categories. Moreover, we continued participant recruitment until the data reached saturation. These findings will contribute to improving our understanding of the complexity of MA.

Our *second mixing and integration* occurred while discussing the outcomes from this activity and building our MA model, then designing the wireframe based on the most highly recommended features. Such mixing of the quantitative and qualitative aspects results in a higher quality of conclusions (Schoonenboom & Johnson, 2017). We also considered checking the reliability and validity of the proposed wireframe by evaluating it through a subset of the participants from the two phases. We needed to validate the results and make sure the features and functions we designed and implemented into the wireframe were well translated and reflected the participants' input.

Now, with the vision of the expected end product in mind it will help us to identify and prepare what questions to ask in the FG session in the next chapter. The wireframe from this phase was developed into a working prototype prior to the FG sessions, however, for the flow of the thesis we present the co-design with end-users in **Chapter 5**, then MAMA system development in **Chapter 6**. The limitation of this activity was that all participants were selected from limited sources. Therefore, there might be more healthcare professionals and health technology designers who are interested to share their experiences in approaching MA or designing MA tools. However, we believe our findings from this stage have contributed to an increased understanding of the complexity of MA and our research study as a whole. To complement the input from this activity we conducted an FG in the next chapter, which considered artifact refinement and evaluation to highlight potential pitfalls (Tremblay, Hevner & Berndt, 2010).

The next chapter presents our working prototype to end-users in FG sessions to investigate new ideas and collect feedback and reviews on the user interface. This will be done in three iterations, back and forth from design to development and incorporating the feedback from each iteration. This will also cover the design part of MAMA which is embedded in the third phase in the DSRM – Design and Development as shown in **Figure 4.23**.

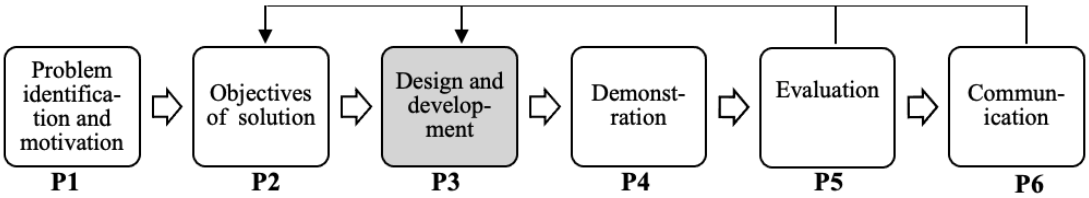

Figure 4.23: The third phase in the DSRM – Design and Development

Chapter 5

Co-Designing MAMA with End-Users

"A snapshot in time shows that we are moving from the design of categories of 'products' to designing for people's purposes." - Elizabeth B.-N. Sanders and Pieter Jan Stappers

This research aimed to investigate the use of digital technology in addressing MA by involving multi-disciplinary experts and end-users to understand their perspectives. The main research question of this study is: *How can digital technology improve users' medication intake?* We collected requirements for managing MA and an MA MVP is developed and piloted with end-users in NZ.

In this chapter, we present co-designing MAMA with end-users, through FGs, in an iterative process. Each iteration feedback improves MAMA to better serve the users' needs. MAMA is presented to the FG participants as a *working prototype*. For the purpose of a clear presentation of RE, we have organised the chapters in an order that gives our readers a better understanding of the features implemented in MAMA. This chapter presents the following main outcomes:

- Results of three iterations of the FGs
- Discovery of features to achieve sustained usage of MAMA

- MAMA MVP built through an iterative design and implementation process
- Updated version of MAMA incorporating the co-design results.

The remainder of this chapter is structured as follows: **Section 5.1** presents the introduction. **Section 5.2** describes the methodology and research methods followed. **Section 5.3** illustrates the focus groups' iterations. Then, **section 5.4** detailed the focus groups' iterations and discusses the data analysis and findings. Finally, **section 5.5** summarises the results and presents the strengths and limitations of this activity.

5.1 Introduction

The literature has suggested that the initial adoption of technology is related to its acceptance when exploring an innovation, such as perceptions of compatibility or visibility, and the relative advantage (Gücin & Berk, 2015). However, in spite of the growing adoption of the mHealth apps, their sustainability and users' low retention rate are of concern to researchers, and few studies have addressed this matter (Druce, Dixon & McBeth, 2019; Adu, Malabu, Malau-Aduli, Drovandi & Malau-Aduli, 2020; Lin et al., 2020). Users may become attracted to the available new technology, but this attractiveness may be temporary unless they develop ways of using it to benefit from their past practices (Sudburya et al., 2013). Here we aim to ensure MAMA achieves sustained usage by involving end-users in the design, given their position of being an 'expert of their experience', who plays a large role in knowledge development and the generation of ideas. One of the most useful novel features postulated from the FG is the multi-channel notification detailed in **section 5.4.1**.

5.2 Focus Groups Methodology

As stated earlier in **section 3.2.3**, following a complex mixed method approach we will be benefiting from multiple methods of data collection based on our study needs. The work conducted in this chapter adapted the CeHRes road-map for eHealth design and development which contains not only technological but also human and contextual factors (van Gemert-Pijnen et al., 2011). The CeHRes road-map recognises that eHealth development requires continuous iteration and evaluation, stakeholder participation that spans the entire development process, and the identification of implementation, as described in **Figure 5.1**.

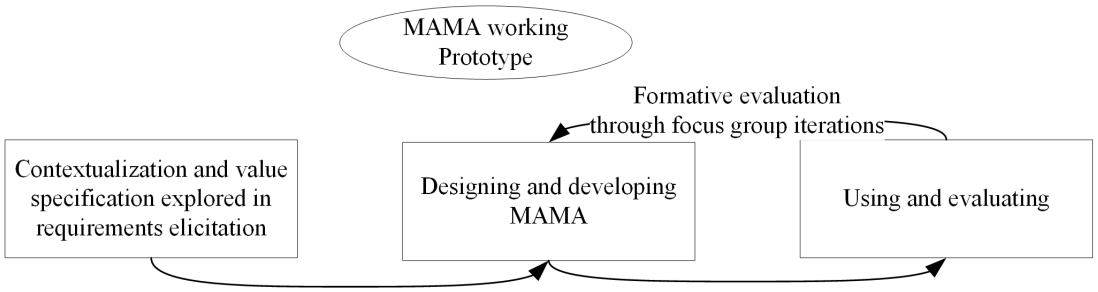

Figure 5.1: The development process of eHealth technologies, adapted from the CeHRes road-map (van Gemert-Pijnen et al., 2011).

For an effective user experience the key considerations are *design*, *development iterations*, and *evaluation* (Traynor, Lee & Duke, 2017). So, if we identify several issues with the prototype, it can be then fixed with an updated design in one of our FG sessions. In Gracey et al.'s (2018) research, they discussed how likely an app is to be successful by proposing ways to foster creativity and to further develop ideas for its design and features from the end-users. They suggested that developers and users of the app are to be consulted, and their feedback should be incorporated into the design. Here, we consulted our FG participants and benefited from using the knowledge and expertise of those who have an authentic experience of the issues or needs being investigated.

The co-design process places the 'user' as 'an expert' of their experiences (Burkett,

2016). It involves redesigning a prototype through FGs that can be sustained beyond the scientific evaluation. Following the CeHRes road-map, our process will require continuous iterations and evaluation with users, across the entire development.

In this phase, each FG session was considered an iteration for feedback and evaluation. The outcomes of each iteration were added to the design to obtain feedback from the next iteration, as shown in **Figure 5.2**. The process included users, who contributed to an in-depth understanding of their needs. Their perceptions helped us identify what needed to be changed to improve the interface of our original prototype. The data collected from each of the FG sessions were analysed using content analysis, a flexible method for qualitative analysis that allows the identification of patterns of responses within the data (Vaismoradi et al., 2013). This analysis is considered suitable as it provides a detailed description of data sets and generates insights into participants' perspectives on specific topics, which depended on our need to explore the data and form our understanding into a meaningful output. Moreover, this analysis type gave us the common trends in the data, to be interpreted and applied to the prototype screens.

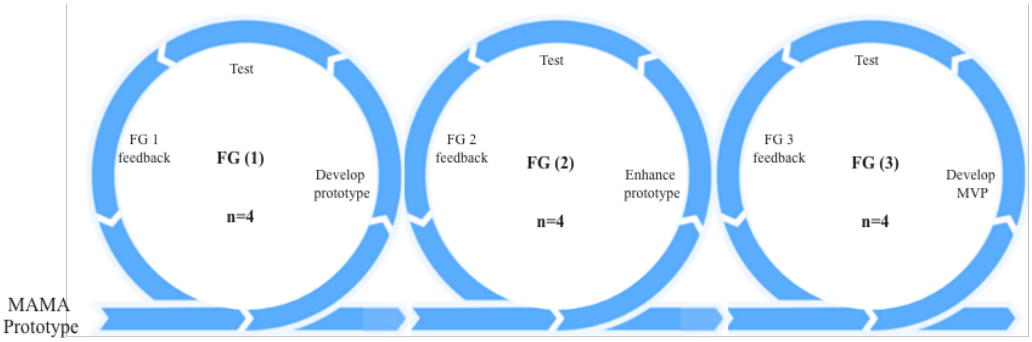

Figure 5.2: Co-designing MAMA through FG iterations

5.2.1 Ethics considerations for focus groups

A separate ethics application was prepared for the co-design FGs with end-users. It was considered as a new application, separate from the initial ethics approval due to

the nature of this phase, which involves interaction with medication users. Collecting participants' details and their health conditions through sharing their experiences required additional justification and further resources. Our application was approved by AUTEC on 13/09/2019. *AUTEC Reference # 19/343: A focus-group co-design and evaluation of an mHealth medication adherence application*. The consent forms were electronically stored in the researchers' AUT password-protected computer. Consent forms are stored for six years then destroyed through AUT's confidential documents system according to AUT guidelines.

5.2.2 Sample selection and participants

Purposive sampling was used in this study (M. Martin, 1996). Participants for the FGs were previous participants from the RE phase, who agreed to be contacted to participate in addition to personal contacts who showed interest in participating either as users of medication reminder apps or consumers of medication. We invited both individuals with and without prior knowledge or experience with medication apps. After their response of being keen to participate, we sent through the information sheet, consent form and evaluation form. Potential participants were asked to email the consent form before attending the FG. For those, we sent the app link to download on their phone (MAMA version for IOS users only) before they attended the session. The non-IOS users were informed they would have an iPhone device provided for them during the FG, with the app installed. A total of 12 individuals participated as shown in **Table 5.1**, with four participants in each FG.

Table 5.1: FG participants across the three sessions

Group	No	Group Letter	FG Username	MA Apps Experience	Meeting Date	Participation accepted	Invitation Sent	Consent form	Download app	Mobile Type	Record	Evaluation Form	Sketched	Transcribed	Analysed	Implemented
FG(1)	1	**A1**	S	Yes	2-Dec	Yes	Yes	Yes	Yes	iPhone 8Plus		Yes				
	2		J	Yes		Yes	Yes	Yes	Yes	iPhone 8Plus	Yes	Yes	Yes	Yes	Yes	Yes
	3	**B1**	P	No		Yes	Yes	Yes	Yes	iPad		Yes				
	4		MN	No		Yes	Yes	Yes	Yes	iPhone 6s		Yes				
FG(2)	5	**A2**	T	Yes	27-Feb	Yes	Yes	Yes	Yes	iPhone 6s		Yes				
	6		B	Yes		Yes	Yes	Yes	Yes	iPhone 7	Yes	Yes	Yes	Yes	Yes	Yes
	7	**B2**	M	No		Yes	Yes	Yes	Yes	iPhone 6s		Yes				
	8		N	Yes		Yes	Yes	Yes	Yes	iPhone 7		Yes				
FG(3)	9	**A3**	R	No	3-Mar	Yes	Yes	Yes	Yes	iPhone 6s		Yes				
	10		B	Yes		Yes	Yes	Yes	Yes	iPhone 6s	Yes	Yes	Yes	Yes	Yes	Yes
	11	**B3**	E	Yes		Yes	Yes	Yes	Yes	iPhone 6		Yes				
	12		SH	No		Yes	Yes	Yes	Yes	iPhone 6s		Yes				

5.2.3 Focus group procedures

The three FG sessions took place at one of the meeting rooms at AUT as shown in **Figure 5.3**. Participants were welcomed and given a participation package, which included a copy of the consent form, FG provision of a protocol for recording consent, the evaluation form and recording consent form, in accordance with our session plan (see **Appendix D.2**). The participants who had not already submitted the signed forms were asked to complete them before the start of the session.

Figure 5.3: FG session settings

After acquiring the participants' consent for recording the discussion, a printed copy of the evaluation form was distributed, along with iPhones (for the ones who did not bring an iPhone), A3 white sketch-paper, sticker notes, coloured markers, and candy (used as a pretend medication to take during the session). We answered the participants' concerns and questions, then started our session with an overarching introduction about the study and its purpose. We presented the workflow of the expected future use of the proposed app, as illustrated in **Figure 5.4**.

Next, the participants were asked about their overall understanding of health apps, their experience with medication apps, and their reasons for liking or disliking them. Participants freely shared their experiences (if any) without prompting. Then, we went

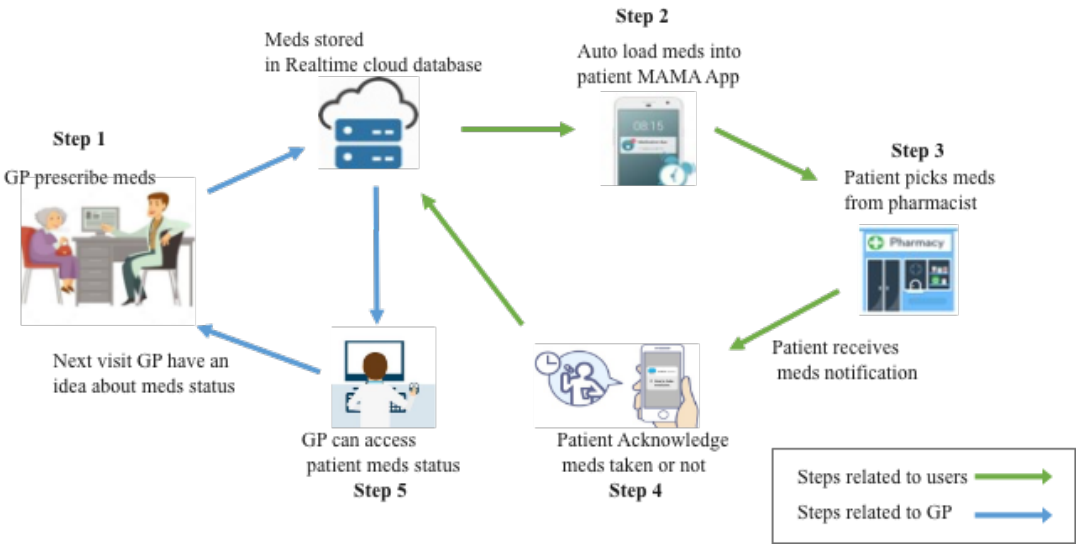

Figure 5.4: Proposed patient-healthcare provider workflow for MAMA

through a demonstration of the MAMA prototype. After that, participants were given mobile phones, with the MAMA installed, to use and explore (as a discovery tour) and fill the evaluation form they were given at the start of the session. They were asked to create an account and start navigating its screens. We went around the participants and answered their questions. Then, the four participants were put into two groups (to allow the discussion between peers and sharing of ideas) and asked to use the A3 white paper for sketching and drawing/or writing their thoughts as shown in **Figure 5.5**.

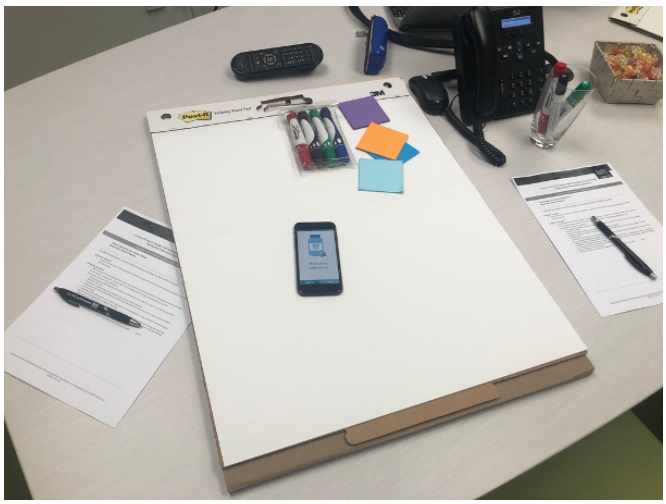

Figure 5.5: A3 Sketch paper, testing phone and forms package

The same procedure was implemented for all three FGs. The researcher took the role of moderator and note taker. We did not have prior knowledge of the participants' views of the medication apps nor of their health conditions. We had a positive attitude towards health apps but remained neutral in the conversation with the participants. Each FG session took place in the same meeting room and ran for 60 to 90 minutes. All participants were provided with a NZ$25 gift voucher and a thank-you card for their time. All FG discussions were audio-recorded and then transcribed verbatim.

5.2.4 Focus group instruments

We used four instruments for the data collection during the FG. There was an open discussion, which was audio recorded when the participants started the discussion, and the recording remained switched on until the discussion ended. The sketches made by participants were collected as supplementary material. All questions and answers were recorded for better understanding of their concerns and feedback. At the end of the session the data collected were: (1) evaluation forms; (2) notes of questions asked during navigation of the app; (3) sketches; and (4) group discussion recording. In summary, these four forms of data gathered during the FG sessions are detailed below:

- **Evaluation form:** The participants were given the time to discover the prototype screens. A form was given to them to collect their feedback on the prototype. They were also given the option of including further views and comments after each main section of the evaluation form (see **Table 5.2**).

- **Note taking:** The researcher took notes of all the questions and feedback given while participants were navigating the prototype and answering the evaluation form sections. Furthermore, any ambiguous sections were noted for detailed explanation and clarification.

- **Sketching/drawing on A3 white paper:** After completing the form, the participants were asked to include all that they considered missing from the prototype. Also, to further express this as a visual representation of the prototype screens according to where they saw improvements were needed in terms of visuals, content and functions.

- **Group discussion audio recording:** The participants' drawings were discussed among the team and these discussions were audio recorded to make sure details were not missed and would be included in the discussion section in detail.

Working prototype

The screens presented in **Figures 5.6 to 5.9** are the four main screens of the working prototype, designed and developed in consultation with healthcare experts and health technology designers, resulting from the RE phase. The prototype content was designed to include the main features that remind users to take medication at a scheduled time. Colour and graphics were included to enhance the prototype's visual appeal, and the prototype was given the name "MAMA".

Evaluation form

The evaluation form consisted of six main areas we wanted to acquire users' feedback from, as shown in **Table 5.2**. The questions in each section were adapted from the mobile health app's testing tools used in previous research (Levine et al., 2020). Also, embedded in the questions were the points related to app users' complaints (Khalid, Shihab, Nagappan & Hassan, 2014). Including these would help us better understand what may contribute to users' dislike of the apps, thus discontinuing their use.

Each section had the option of further comments and suggestions, for elaboration if required. **Section A** was intended to be a general question about their experience

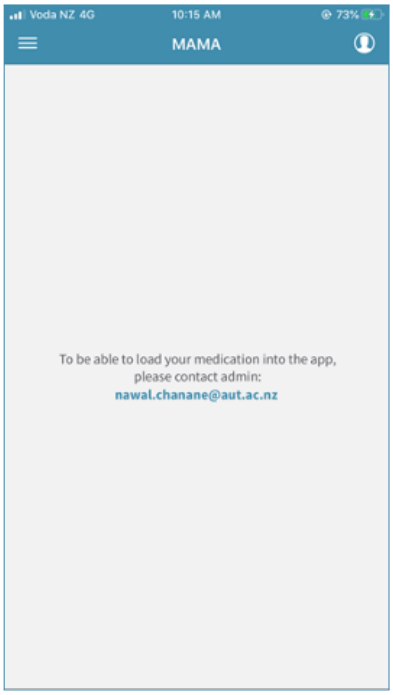

Figure 5.6: Home screen - FG1

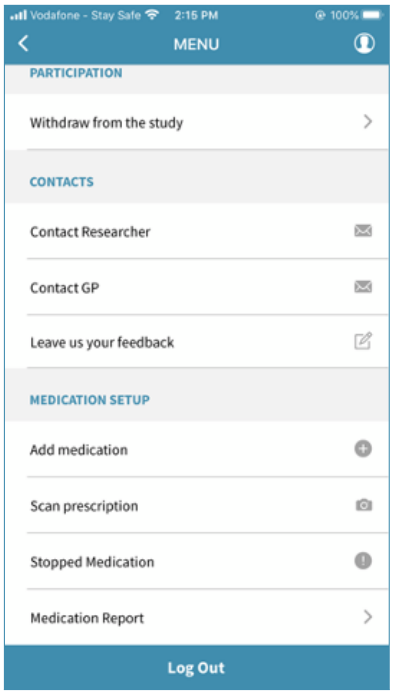

Figure 5.7: Menu screen - FG1

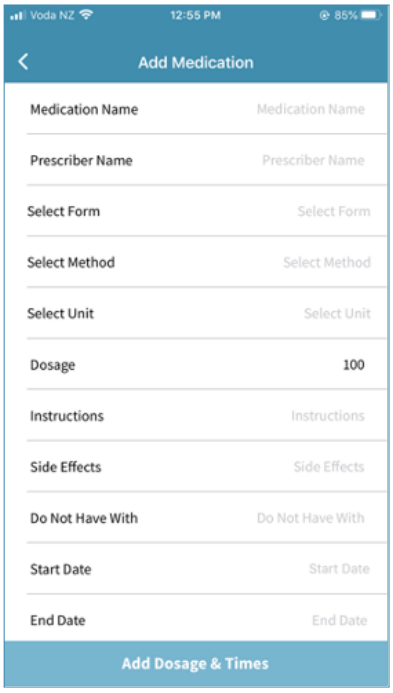

Figure 5.8: Add medication screen - FG1

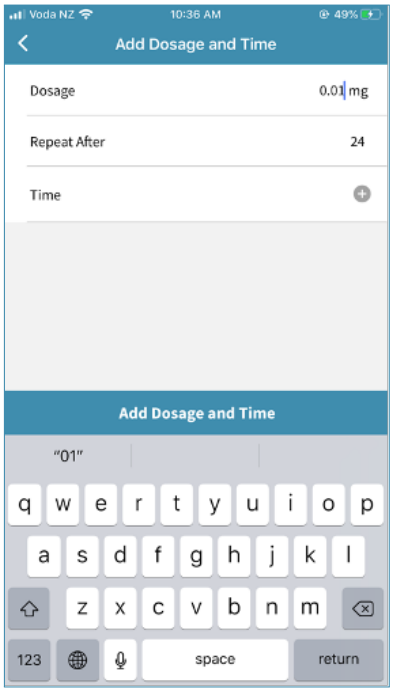

Figure 5.9: Add dose screen - FG1

with mobile apps and what features they thought should be available in an app. Then, we included the following **sections: B, C, D** and **E**, which evaluate MAMA from a

Table 5.2: FGs questionnaire

Question No	Question text
Section A: Top features that should be available in an MA App (Open-ended questions)	
Q1	What kind of feature should be available?
Q2	What kind of things would you want/need in it?
Q3	What kind of things do you think other users might need / want in it?
Q4	What would motivate you to spend time on it?
Section B: User Interface Testing ($\checkmark/\times$)	
Q1	Interface changes with change in screen direction
Q2	Labels and buttons text are clear and concise
Q3	Minimalist design- excess feature removed
Q4	Minimised user actions
Q5	Prompt display of errors and warning messages
Q6	You can recognise between inactive buttons from active buttons
Q7	Colours used provide good contrast and good readability
Q8	Speaks the user language
Q9	Tool tips on login page
Q10	Text and spelling /grammar
Q11	Number of buttons/ links is reasonable
Section C: Usability Testing ($\checkmark/\times$)	
Q1	User interface elements provide visual feedback when pressed within 3 seconds max.
Q2	Easy navigation across different screens.
Q3	When clicking on notification it opens the app
Q4	Functionality of the exit options at any point of running the application
Q5	Enabling responsive menu button
Section D: Functionality Testing ($\checkmark/\times$)	
Q1	Login page responsiveness
Q2	Functioning of redirect options
Q3	Scroll bar properly working
Q4	Compatibility on different devices, screen size, resolution and OS.
Section E: Security and Data Privacy ($\checkmark/\times$)	
Q1	The availability of authentication such as username/password
Q2	The availability of the consent form and participant information sheet in the App
Q3	The availability of the withdrawal from the study in the App.
Section F: General Feedback (Open-ended questions)	
Q1	What are your initial reactions to the prototype?
Q2	Would you use this app? Prompt: why/why not?
Q3	What do you like most/least about the app?
Q4	What changes would you make to the app?
Q5	What is the most important thing researchers should consider when developing MA mobile applications?

user's point of view. **Section B** asked about the UI, which is considered one of the most important reasons users like or dislike using the technology according to the UTAUT2 model (Sudburya et al., 2013). **Section C** checked the usability of the app in terms of ease of navigation, i.e. the user will not feel lost in the app. **Section D** asked about the functionality and responsiveness when tapping on any icon. **Section E** checked the security and data privacy, a critical point to consider with health apps, making sure the health data need to adhere to the data protection and privacy regulations (Ministry of Health, 2020). The last one is **section F** for general feedback where we included questions such as if they would use the app, what changes they would like to make to the app, and, as end users and the main beneficiaries of these apps, what they considered to be important points researchers need to address when developing mHealth apps.

5.3 Focus Group Iterations

The three FG sessions were conducted with 12 participants divided into four users in each FG as shown earlier in **Table 5.3**.

5.3.1 Iteration one

Design

The first iteration group evaluated the developed prototype from the elicitation phase. **Figures 5.6 - 5.9** present the four main screens – Home, Settings, Add Medication and Add Dose – which included features of look and feel. The users sketched their feedback and views on the A3 paper, as shown in **Figures 5.10 and 5.11**.

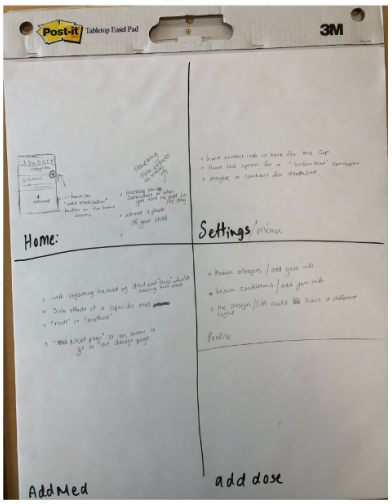

Figure 5.10: FG1 - Group A review

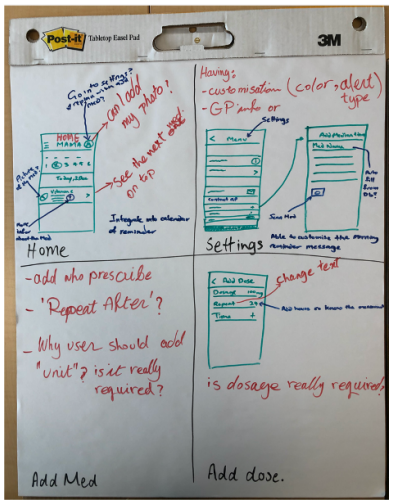

Figure 5.11: FG1 - Group B review

Evaluation

The participants were given the chance to share and explain to the group what they had on their A3 paper. These discussions were recorded and transcribed, analysed following content analysis, then summarised (see **Appendix D.4** for the full summary feedback). From the A3 sketches in **Figures 5.10 and 5.11**, we can see that users pointed out some changes to be addressed in the prototype we listed in **Table 5.3**, in addition to suggesting new features, listed in **Table 5.4**.

Table 5.3: MAMA suggested changes - FG1

Screen Name	Changes suggested in the first iteration
Menu	Name of page “Settings”
Home	Move logo (profile pic) to settings page and replace it with “Add med” (or a pic for +)
Add account	Add “GP contact/email”
Add medication	Add “prescriber name”
	Add optional fields for “Side effects” and “Do not have with:”
	Change “Route” to “Method”
	Keep the data in the input box of add medication in case accidently pressed on back button
	Change the colour of the submit button (I will provide you with the colour number)
Profile	Add “Allergies” for the user to fill

Table 5.4: MAMA suggested new features - FG1

Screen Name	New features suggested in the first iteration
Add medication	As soon as the user adds the meds the default time will be Morning: 9:00AM, Midday: 12:00PM, Afternoon: 03:00PM, Evening: 06:00PM. Then the user can change it if needed. When user clicks on medication name it will take him/her to Med Settings. User can click on the "Morning" and it will open the screen Choose Time, Same for Midday, Afternoon and Evening (add a toggle on/off beside each time) Scan prescription to add medication
Settings	Summary page for the med taken/not taken/snooze
Medication reminders	Multi-channel notification. If no med taken for the day, send email to user

5.3.2 Iteration two

Design

The second iteration group evaluated the enhanced prototype from the first FG session. Participants had the four main screens – home, settings, add medication, and create account screen – with the added features of look and feel, as shown in **Figures 5.12 to 5.15**. These were the enhanced prototype screens presented to the participants. The users sketched their feedback and views on the A3 paper as shown in **Figures 5.16 and 5.17**.

Evaluation

The participants were given the chance to share and explain to the group what they had recorded on the A3 paper. The recorded discussions were transcribed, analysed following content analysis, then summarised (see **Appendix D.4** for the full summary feedback). Users suggested having the following points in the app:

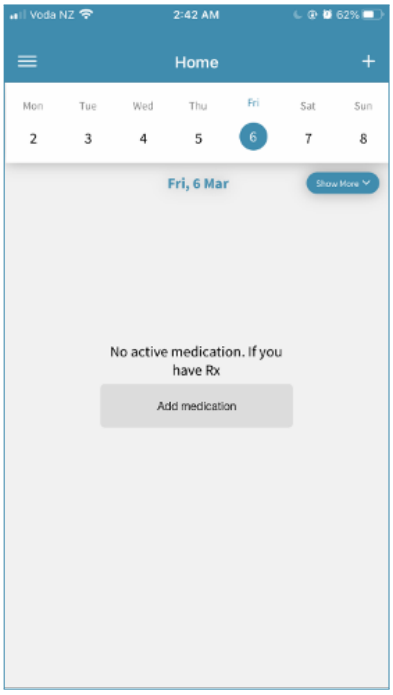

Figure 5.12: Home screen - FG2

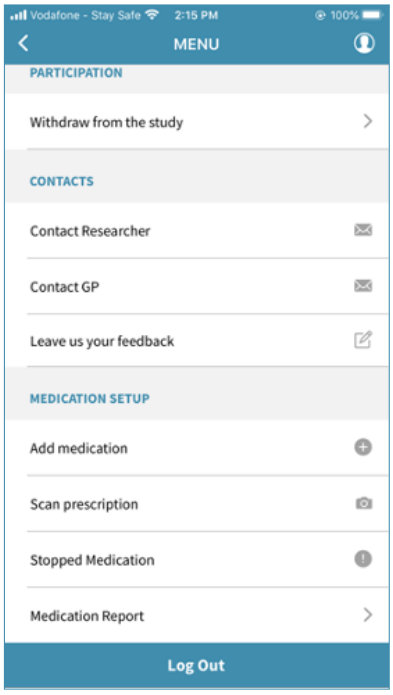

Figure 5.13: Menu screen - FG2

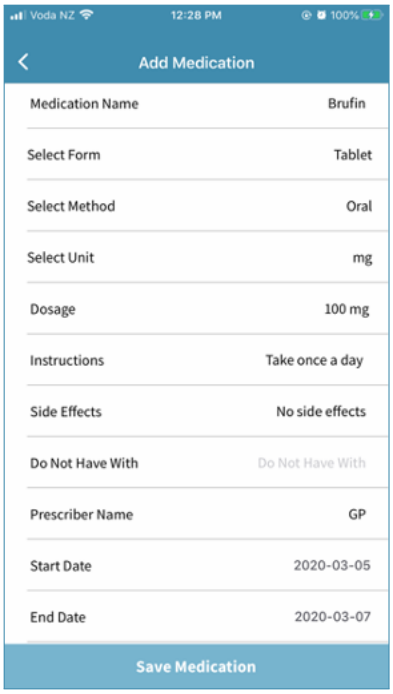

Figure 5.14: Add medication screen - FG2

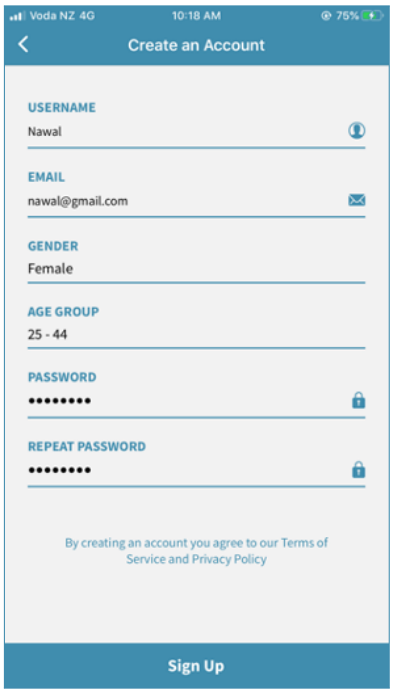

Figure 5.15: Create account screen - FG2

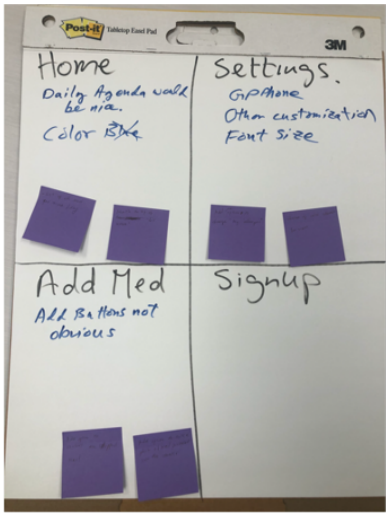

Figure 5.16: FG2 - Group A review

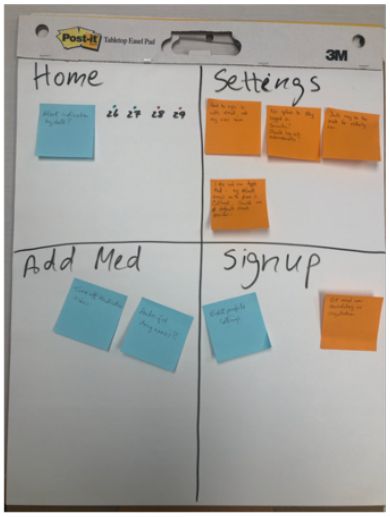

Figure 5.17: FG2 - Group B review

Table 5.5: MAMA suggested changes - FG2

Screen Name	Changes suggested in the second iteration
Signup	Caregiver number in signup screen
Med Settings	GP Email is mandatory field – would not complete registration until I had entered it on "Med Settings" page – medication name should appear

Table 5.6: MAMA suggested features - FG2

Screen Name	New features suggested in the second iteration
Menu	In MENU add toggle on/off for multi-channel notification
Feedback	A place for feedback/comments on how the medication is/is not working
Contact GP	Quick, reliable way to ask the doctor a question
Call reminder	A voice saying "Hi, you didn't take your medications today."

5.3.3 Iteration three

Design

The third iteration group evaluated the enhanced prototype from the second FG session. The four main screens – home, settings, add medication and create account screen – with the added features of look and feel as shown in **Figures 5.18 to 5.21**. The enhanced prototype screens were presented to the participants. The users sketched their feedback and views on the A3 paper as shown in **Figure 5.22** and **Figure 5.23**.

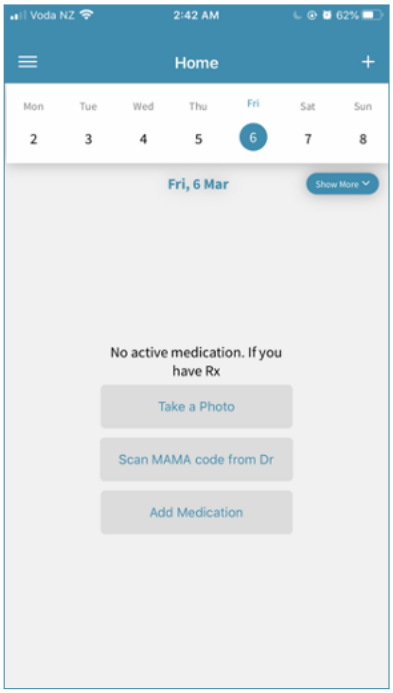

Figure 5.18: Home screen - FG3

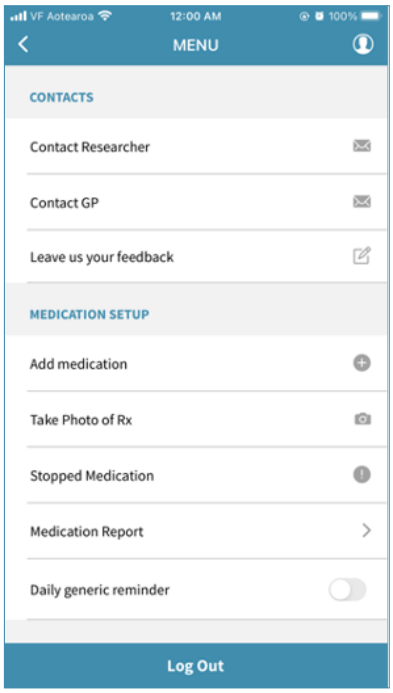

Figure 5.19: Settings screen - FG3

Figure 5.20: Add medication screen - FG3

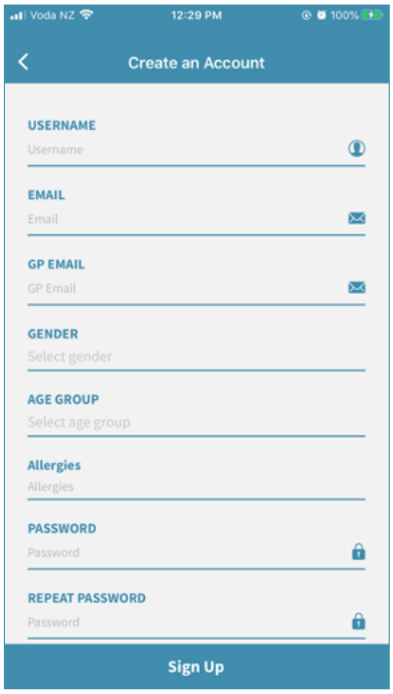

Figure 5.21: Sign-up screen - FG3

Evaluation

The participants were given the chance to share and explain to the group about their suggestions recorded on the A3 paper. These discussions were recorded and transcribed,

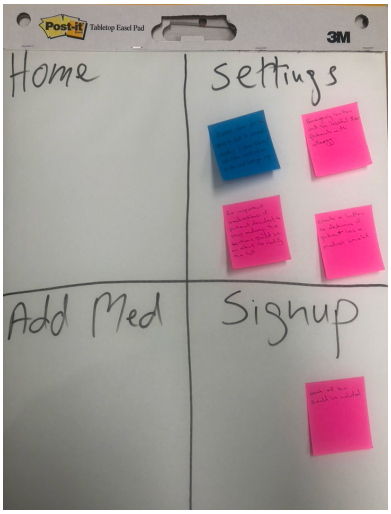

Figure 5.22: FG3 - Group A review

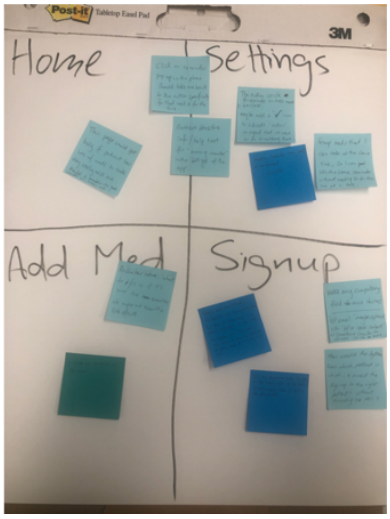

Figure 5.23: FG3 - Group B review

analysed following content analysis, then summarised as below (see **Appendix D.4** for the full summary feedback). Users suggested having the following features in the app:

Table 5.7: MAMA suggested changes - FG3

Screen Name	Changes suggested in the third iteration
Signup	Add to Signup Screen “Next of Kin number” (optional)
Menu	Add to MENU “Medications History”; it will display a screen with all (meds names/ status/ start and end date)
Add medication	“Prescriber name” in Add medication screen should be (Optional)
Home	In HOME screen, Display “Dose” under the medication info

Table 5.8: MAMA suggested features - FG3

Screen Name	New features suggested in the third iteration
Home	If all meds taken the date showing in HOME screen will be circled green, if all not taken circle is red, if one or more not taken then circle is orange
Medication Reminders	Maybe a joint partner in the app, so they can act as a human reminder
Profile	Patient should be able to see the list of their allergies
Menu	Maybe add button for family member support, just like the emergency support in GP

5.4 Focus Group Data Triangulation

Data were separately analysed after each FG iteration, as presented in the previous sections. The drawings on the A3 papers were compared and evaluated according to the evaluation: visual, navigation, purpose, content and layout. The output of the first iteration was implemented in the prototype design to be presented to the second FG. During the analysis of the feedback, our rationale behind choosing the suggestions to be implemented in the prototype was according to its feasibility and two other aspects we regarded as significant in making a decision: (1) if what was suggested was made by all participants or if they agreed on it during the discussion; and (2) if what was suggested matched or supported any of the data collected in the RE phase (**Chapter 4**). Applying this gave us a more solid reason for including or excluding suggestions made by the participants. At the end of the third FG, we did another round of reviewing the data as a whole, trying to intersect the main features identified within the data from the three iterations as presented in **Figure 5.24**.

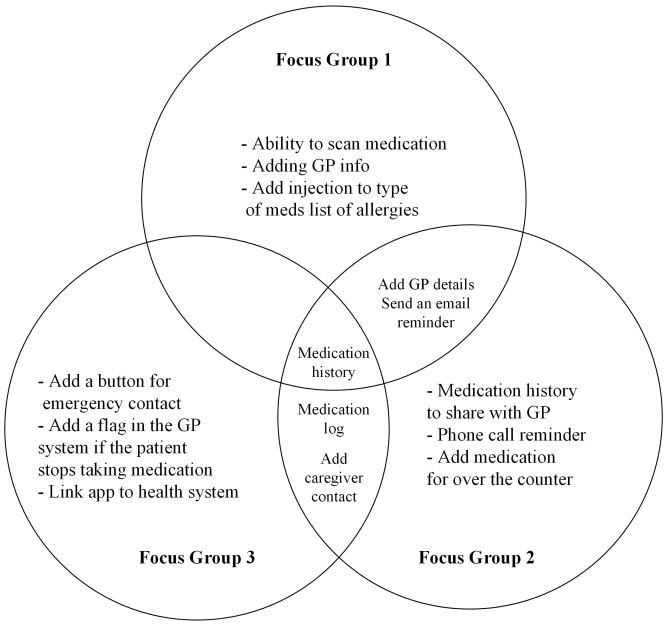

Figure 5.24: High-level findings from FGs with unique and intersected features

In addition to analysing the data collected from the three FGs' discussions, we

looked at the questionnaire findings. The feedback to sections B, C, D and E was amended in the prototype design after each FG, to make sure the issues pointed out were resolved prior to the next iteration. Then, the feedback from sections A and F were rationally studied and merged with the data from the group discussion, in addition to the notes taken during the three sessions. To make sense of all the data, we grouped them into categories, which were then given a general theme. We then translated these themes into an equivalent functionality in the prototype to support the main ideas and thoughts shared during the sessions. The three main features were identified as: (1) *simplicity and ease of use*; (2) *reporting*; and (3) *integration*, as presented in **Table 5.9**, along with a sample of selected participants' quotes across the three FGs.

For the rest of this chapter, we will be highlighting the translated features into functions – (1) *multi-channel reminders*; (2) *medication intake acknowledgement*; (3) *medication reporting*; and (4) *connection with the health system* – and examining how each function serves the purpose of helping users to take their medication on time.

Table 5.9: A Sample of selected participants' quotes across the three FGs

Original Features	Participants' Quotes
Simplicity/ Ease of use	"It's not the sort of app that you need people to spend time using." "The reminder should be very lightweight." "Other apps are super crowded and annoying. For example, from a running app to do a simple job to trying to sell me shoes." "I don't want to play candy crush in the app!! Just keep it simple. It has a job to do." "Lots of people do not email tech, so a phone call will be more useful for them."
Reporting	"If I get the med from the pharmacy only, good to have it added to the app also." "It doesn't have to be only when the GP prescribes it." "Good my GP will see what I am taking."
Integration	"The alert to GP if stops medication is important because there are medications that patient can't just stop them." "It's good to link this app to HEALTH365 so I can check my medication history that will make it even easier for record-keeping." "It can be used in a rest home, where the nurse will receive a notification."

5.4.1 Multi-channel reminders

The multi-channel reminders mean that end-users will be able to receive notifications in different ways (i.e., app push notifications, emails, automated phone calls, and SMS) to remind them to take their medication on time. With the availability of multiple channels the app can accommodate users who,

- miss their dose as a result of not checking their mobiles frequently during the day, but do access their emails;
- and/or users who consider phone call reminders more practical than an email, which may be sent to their overloaded inbox;
- and/or users who consider an in-app notification one of the things they do not even look at due to the number of notifications they receive from all the apps they have on their phones;
- and/or users who like to be reminded multiple times to remember and take their medications.

According to Stawarz et al. (2016), reminders are important for people in remembering a specific task in their busy schedule. Moreover, older medication users are more likely to forget a dose when they are taking more than one medication, especially if this is taken over a long period, as patients tend to forget over time. This feature has been added to accommodate a variety of users with busy schedules, who are more likely to forget their medication during the day, even if they have all sorts of medication apps on their phones.

In Shubber et al.'s (2016) research, it was reported that forgetting medication was the most frequently cited barrier to adherence across all age groups. Challenges relating to timing of medication, including being asleep, could be overcome through text messaging, individual counselling and reminder devices that seek to modify medication

taking in a way that fits one's daily activities. Another study conducted by Shin et al. (2015) reported from interviews that participants mentioned occasions when they did not take medications on time as prescribed because they simply forgot to do so during working hours.

This novel feature will allow users to receive reminders in multiple ways according to their response to the app push notification. The reminders are based on workflow, as presented in **Figure 6.4**. MAMA will thus provide four channels of notifications: (1) *app push notifications*; (2) *email notifications*; (3) *automated voice call reminders*; and (4) *SMS notifications*. The four channels are implemented according to the notification workflow and processed based on the information provided by the user during the sign-up. Providing this is a step forward in designing to accommodate individual needs and to deliver medication notifications in a way that is best and most convenient for the individual. Below we list and explain the channels in sequence according to the FG participants recommendations and preferences:

1. **App push notification:** This is the default and first form of reminder; the user will receive an app notification to take medication at the chosen time (the users will have the ability to choose the number of times to be reminded during the day). This is an ideal way to remind the user, as it is non-intrusive and in accordance with the system-wide notification preferences of the mobile phone. According to medication administration research, the users of medications have between a 30-minute and one-hour time window to take their medication before it is considered a late dose (Furnish et al., 2020). Therefore, the user will take the medication and log it in the app as taken. If the medication is not taken 30 minutes after the first dose time, the second channel (emails) will be triggered.

2. **Email notification:** The user will receive an email notification to a specified email address (see **Figure 5.25**). The user will be reminded to take the medication

and prompted to log it in the app. In the case that acknowledgement is available for any of the scheduled medications during the day, the third channel will be triggered, which is the automated voice call.

3. **Automated voice call:** This type of notification depends on the availability of the user's mobile number. This function will make the acknowledgement of medication intake simpler, especially for those who do not check their mobile phones frequently. It is anticipated that phone calls will attract their attention, reminding them of their medication even if they did not have the chance to check the phone for any SMS or push notifications. According to research conducted by Hasvold and Wootton (2011), telephone reminders have an improved hospital attendance rate compared with SMS reminders. Therefore, this functionality will further explore and confirm whether automated voice calls will impact medication intake rate in comparison with other types of notifications provided.

4. **SMS notification to caregiver:** The SMS alert will be sent to the caregiver number registered when signing up in the app (see **Figure 5.26**). However, in case no caregiver mobile number is registered, this feature is not processed. An advanced feature could be to flag the user's username in the healthcare provider's database in case multi-notification has been used more than twice during the week and still no medication has been logged.

5.4.2 Medication intake acknowledgement and reporting

One of the main elements that arose in the FG sessions was the ubiquity of logging their medication intake in the app and having it handy to show their healthcare provider during their appointment. The availability of this kind of medication reporting over time, and its accessibility through the health system, is a bonus for an enriched medical

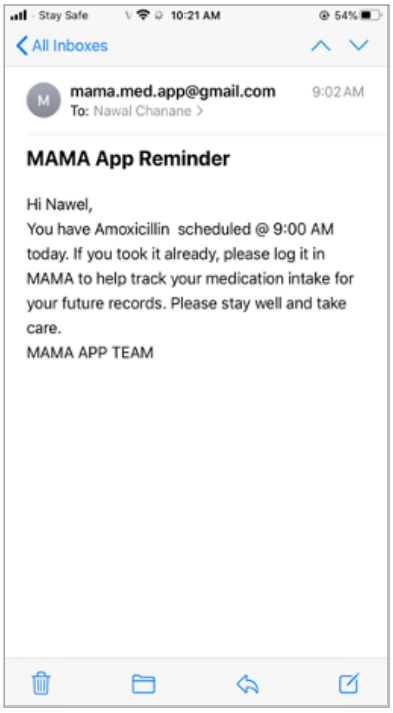

Figure 5.25: Email medication reminder

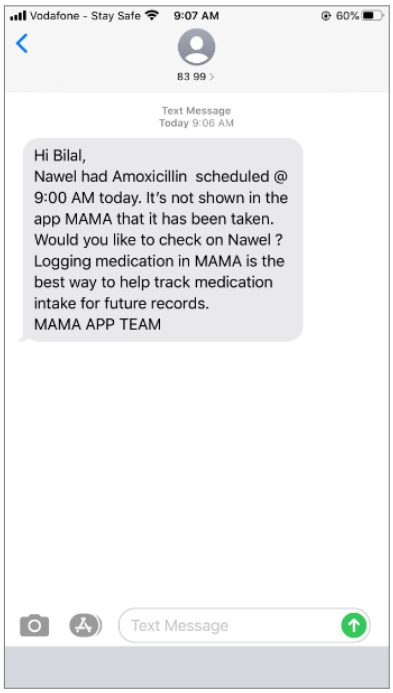

Figure 5.26: SMS to caregiver

record. MAMA provides a streamlined design with a quick way of checking their medication intake status.

In a recent study by Park et al. (2016), they discussed a number of features available in MA apps, including reminders to take medication, reminders to refill, and storing medication information and logs, but none of the existing apps focused on feeding the data back to the health system. This feature is anticipated to fill gaps in the treatment record, knowing that adhering to the medication prescribed is one of the main elements of improving health conditions (Eimear, Monica, Liam G., Jane C. & Gerard J., 2018). In saying that, the following two sub-features were integrated to serve the purpose of keeping track of medication:

1. **Medication intake report/history:** This allows users to see their history of medication intake with the status of what was taken, missed or discontinued (see **Figure 5.27**). The patient can share the report with the healthcare provider and/or

pharmacist. Medication history is important for keeping an up-to-date list of all medications, including the prescribed dosage, the dosing frequency, and the reason the drug was prescribed. Also, it will allow reporting of the patient's dietary restrictions necessitated by a specific medication (Saljoughian, 2019). Moreover, the patient's consultations with different doctors make it difficult to keep the medications list up to date because of the various health systems in primary and secondary care and in private healthcare (Kvarnstrom et al., 2018). Furthermore, being able to track the treatment regimen is considered a struggle for all ages, but especially for older adults, which leads to concerns about double dosing (Schneider, Baum, Amy & Marisa, 2019). Therefore, including this function in the app will allow the user to keep all medication history and the latest medication list at hand for his/her record and, if needed, for any emergency situation.

2. **Flagging stopped medication:** This feature will allow users to flag discontinued medications on their app when stopped for any reason; otherwise, patients will still be taking them or their healthcare provider will assume they are still taking them (see **Figure 5.28**). Having patients changing the drug regimen or stopping any medication or replacing one medication with another will greatly affect the treatment outcome. It will be beneficial to keep a record, so it can be shared with the healthcare provider, with the possibility of reducing the frequency of administration, introducing combination medicines or even deprescribing some medication. Moreover, patients who engage in their healthcare perform a significant role in an informed and patient-centred way of treatment (Eimear et al., 2018).

It is anticipated that patients engaging with mobile app technologies may have the potential to record all the medication intake and make the data available to GPs

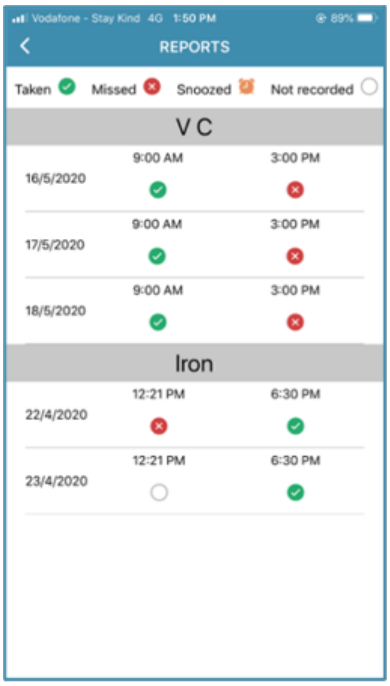

Figure 5.27: Medication status report

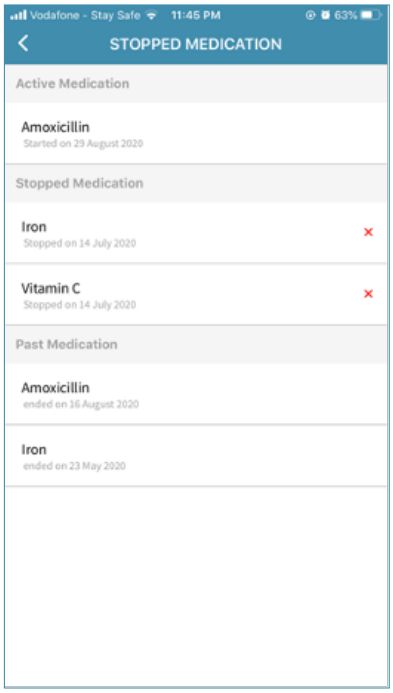

Figure 5.28: List of stopped medication

at the point of care. This corresponds with a randomised controlled trial conducted by Vasilevskis et al. (2019); they examined the impact of medication reduction on adherence by deprescribing, and it was concluded that incorporating patients' preferences into the decision-making is significant to the treatment process. Furthermore, preventing polypharmacy while keeping track of which medication is on the list to be taken, what medication has been stopped, and which drug to watch out for to avoid a drug interaction, which can also lead to nonadherence to the prescribed medication, are also very useful functionalities (Brinton, 2018).

5.4.3 Smart loading of medication to MAMA

One of the most important distinctions between the existing medication reminders' apps and MAMA is the auto-loading of medication through a webform for ease of use, which can be integrated with the health system as a future work. The theme of smart loading of medication is one of the features that represents the connectivity with the health

system through the app. This includes: (1) *automatic loading of medication* from the health system to the app users' account (this function is out of the scope of this study); (2) *semi-automatic loading of medication* into the app through MAMA webform (see **Figure 5.29**), where the end-user will receive an SMS notification when Rx is loaded into their MAMA account (see **Figure 5.30**); and (3) *self-adding medication* through the app using the 'add medication' function screen (see **Figure 5.31**).

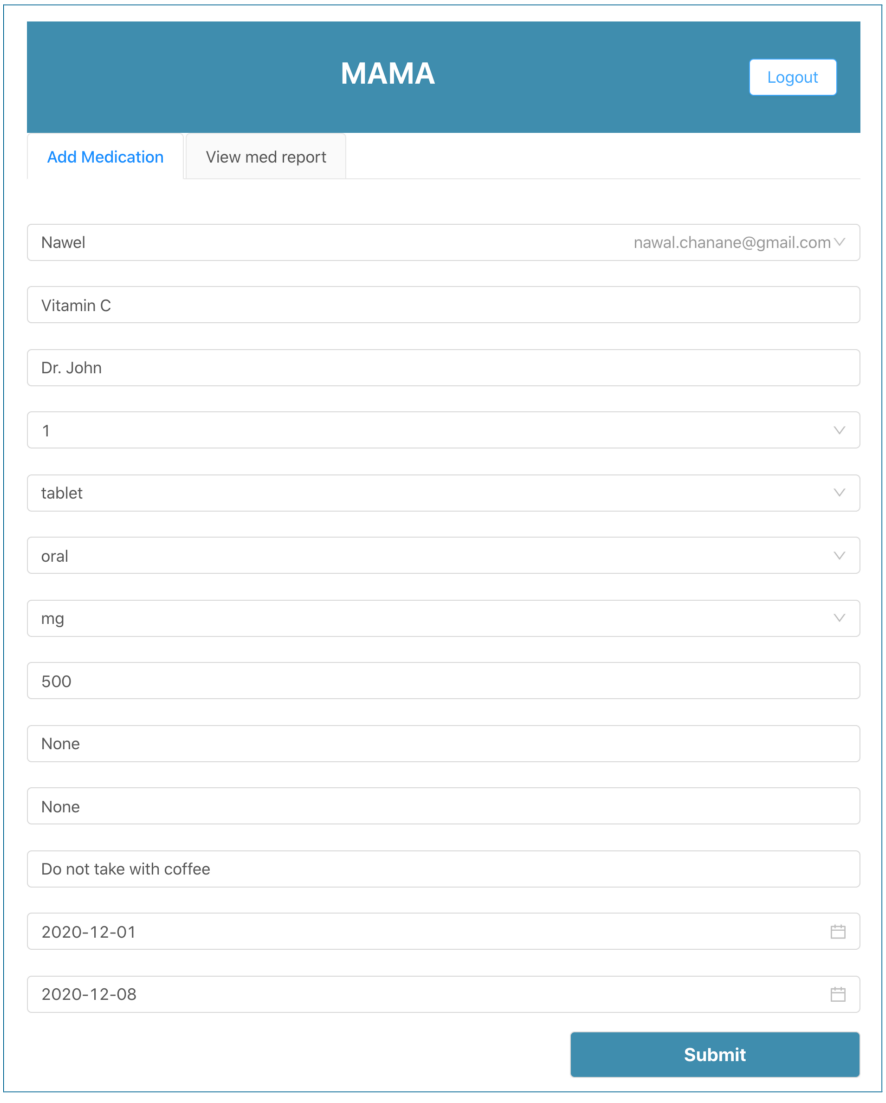

Figure 5.29: Webform for auto-load of medication

MA and polypharmacy – 'the use of multiple drugs or more drugs than are medically necessary' – are significant public health concerns worldwide and are an important

focus of integrated care (Maher, Hanlon & Hajjar, 2014). Also, older people relying upon community pharmacies frequently have difficulty managing their medications (Beuscart et al., 2019). A recently published study by Saljoughian (2019) report-ed that approximately 44% of men and 57% of women older than 65 years take five or more nonprescribed and/or prescribed medications per week. They concluded that technology-driven systems and electronic medical records would help prevent harmful drug effects and interactions.

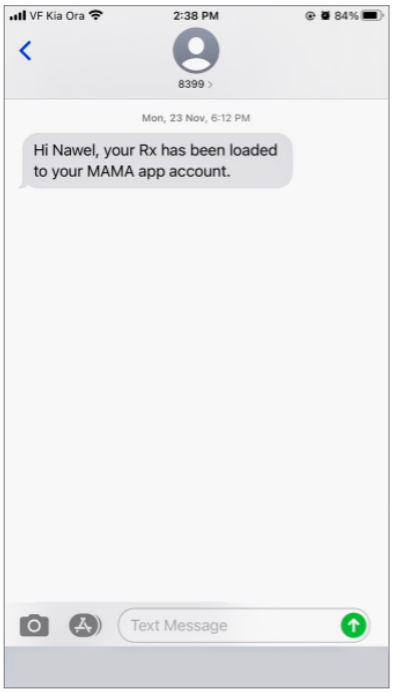

Figure 5.30: Medication notification

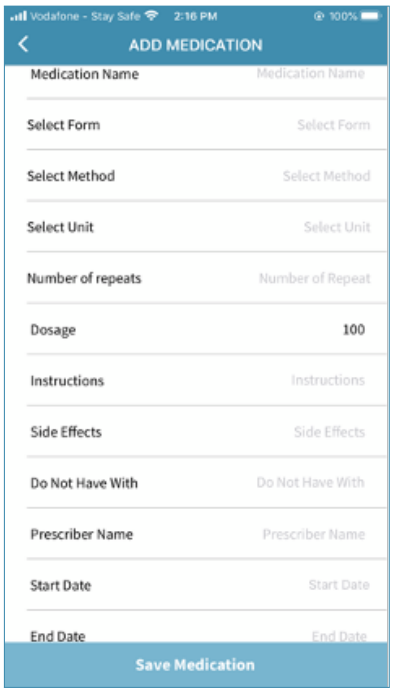

Figure 5.31: Add medication screen

We also found in Shah et al. (2012), that the increasing use of multiple medications has been associated with an increased risk of unfavourable drug reactions, drug-to-drug interactions, medication nonadherence and greater healthcare costs. We proposed this as a function in MAMA for ease of use, by providing auto-loading of medication to prevent any error in the details of Rx entry when adding medication to the app. This requires almost no effort from users when scanning their prescription using the feature 'scan prescription' (see **Figure 5.32**), then sending it through the app to the Rx Data

Entry Team (DET) for medication loading using the webform. After the medication is loaded into MAMA, an SMS notification is sent to the end-user, asking to open MAMA and change the reminders time from default to the treatment plan (see **Figure 5.33**).

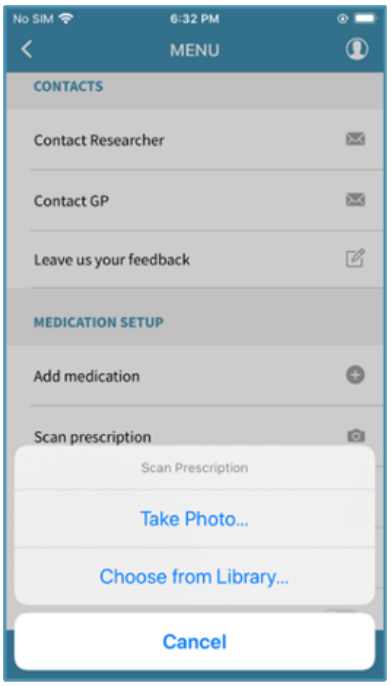

Figure 5.32: Scan prescription screen

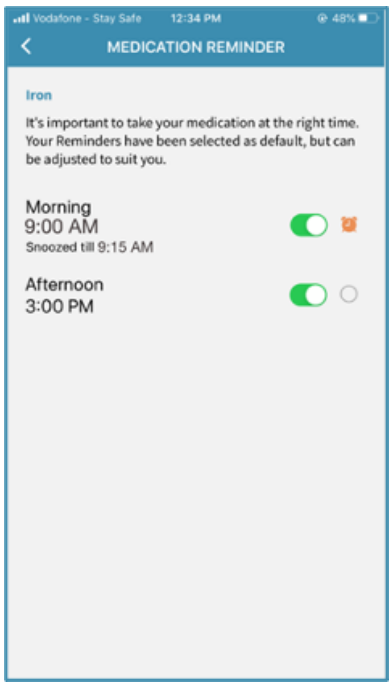

Figure 5.33: Medication reminder screen

In a real case scenario this could be done by the pharmacist when dispensing the medication to the patients, or by the health provider when prescribing the medications as presented in the **MAMA storyboard** in **Figure 5.34**.

According to research, an easy-to-use app with minimum purposeful functionalities, which is responsive and useful to the patient, is more likely to be used (Kenny, Dooley & Fitzgerald, 2014) and that corresponds to our participants views about medication apps saying:

> *It's not the sort of app that you need people to spend time using... The reminder should be very lightweight... Other apps are super crowded and annoying. For example, from a running app to do a simple job to trying to sell me shoes* (FG participant A).

Another participant commented when discussing ways to make the app more engaging for end-users and to make sure they like it so they use it:

> *I don't want to play candy crush in the app!! Just keep it simple. It has a job to do.* (FG participant B).

In **Table 5.10**, we list all the features discussed and suggested in our RE Phase including questionnaire, interviews and the iterative FG sessions. The implemented features in MAMA were tested and evaluated by the FG participants, development team and research team prior to piloting with end-users.

Figure 5.34: MAMA storyboard

Table 5.10: MAMA features and other apps features

Medication reminder apps features	Novel features postulated from RE	MAMA Implemented features
Different medication data entry (scanning, taking a picture of the package, and voice entry)	Smart loading of Rx (adding medication to MAMA user account through the healthcare provider system)**	Smart loading of Rx (adding medication to users account through a webform)
Medication history	Multi-channel reminder system	Multi-channel reminder system (app notification, email reminder, automated call reminder)
Manually adding tracking medication	Medication intake history (Webform report for health provider access)	Medication intake history
Reminder with personalized voice	Stopped (discontinued) medication report	Stopped (discontinued) medication report
Medication reminder	Prompting healthcare provider	Webform report for health provider access**
Goal setting	Multiple languages*	Reminders with no connectivity
Education content	Emergency icon that's linked to the health emergency service**	Caregiver SMS notification
Snooze option	Reminder noticing the change of time zone	Contacting healthcare provider
Flexible scheduling	Warning if safe dosage exceeded	User profile
Visual aids	Safety plan for acute situations	Medication list
Customisable alert sounds	Contacting healthcare provider	Data privacy and Data security
Multiple users support	Voice acknowledgement for medication intake using Alexa *	Snooze option
Data exporting / sharing	Integration with the health system or with Health365	Scan Rx
Multilingual	Integration with rest-home system	Allergies list
Refill reminders		
Reminders with no connectivity		
Data privacy and Data security		
Data security		
Adherence statistics and charts		
Medication database		
Time zone support		
Adherence rewards		

*feature not implemented due to cost, lack of resources, time constraint
**feature not fully implemented due to complexity and third-party involvement

5.5 Summary of Chapter 5

From our RE phase we have learnt that MA apps are one of the most effective methods to remind patients to take medication on time. However, reminders via apps are overwhelming today, so consumers often stop using them after a brief period of initial usage, and eventually view them unfavourably, or do not use them at all. In this chapter we presented our working prototype to end users. These users either had experience with medication reminder apps, or they take medication and were keen to participate in one of our three FG sessions, to give their insights on our proposed prototype. The feedback gathered informed our final MAMA MVP design that resulted in the outcome of this chapter. The participants suggested several ideas to resolve the challenges of medication reminder apps' usage and discontinuity. The feedback from each iteration was examined and amendments applied to the prototype accordingly. Moreover, the feedback from the three iterations was triggered and categorised based on its relativity. Categories that were similar were then grouped into general themes, which helped us translate those themes into functions to implement in the prototype. The implemented features identified from the data collected for the prototype were: (1) *multi-channel reminders*, (2) *medication intake acknowledgement and reporting*, and (3) *smart loading of medication into the app*, as important elements.

The strength of this activity was our inclusive sampling of the participants, which included the main users of the app, in order to have a complete view of the reasons for using or not using medication reminder apps. The FG results were analysed to define the underlying themes. These findings showed positive perceptions of this approach and provided us with insights into possible improvements to our prototype. This in turn counted as an important strength of this research, where the design of the key elements from the user's perception and building the MVP, followed an iterative design process among a diverse set of users.

The limitation of this activity was the limited number of participants, which could be addressed by recruiting more users in each group. However, reaching participants was not simple. From the 140 individuals who showed interest in participating, only 12 replied during the given period, and others got in touch after we completed the sessions. In the next chapter, we will develop the MAMA system (MAMA and MAMA Webform), which is the ***Third phase*** in the DSRM – Design and development as shown in **Figure 5.35**.

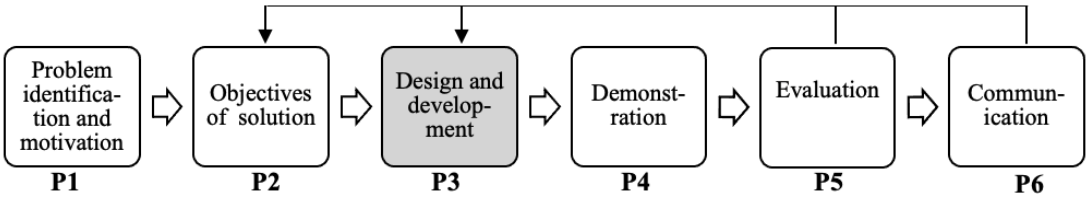

Figure 5.35: The third phase in the DSRM – Design and development

Chapter 6

System Development

"The value of an idea lies in the using of it." - Thomas Edison

This research aimed to investigate the use of digital technology in addressing MA by involving multi-disciplinary experts and end-users to understand their perspectives. The main research question of this study is: *How can digital technology improve users' medication intake?* We collected requirements for managing MA and an MA MVP was developed and piloted with end-users in NZ.

In this chapter we present the work conducted to fulfil the requirements gathered from multiple phases of RE, including the iterative FG sessions. The solution was developed via several iterations and here we demonstrate the entire system development including incorporation of feedback from the FG iterations. There are several medication reminder apps detailed in **Chapter 2**. However, our objectives will be achieved by customising our own solution due to the limitation of modifying the existing stores apps. MAMA is different from the available apps as presented in **Chapter 4**, not only in functionality but it has unique features as presented in **Table 5.10**. This chapter presents the following main outcomes:

- Translation of requirements into a working prototype

- Three iterations of user feedback, development and testing
- The effective tools and functions used to achieve the final product.

The subsequent sections of this chapter are structured as follows: **Section 6.1** presents the introduction and **section 6.2** introduces the methodology followed in building MAMA. In **section 6.3** we describe the system development and in **section 6.4** we present the tools used in the iterative development process. In **section 6.5** we give an overview of our testing during and after MAMA development. In **section 6.6** we present the user manuals developed for end-users as an explanatory guide for MAMA. Finally, **section 6.7** summarises the work done and lessons learnt during the development process.

6.1 Introduction

With the rise in mobile apps for health and well-being across all age groups, mHealth apps for MA are increasingly used (Petersen et al., 2020). However, if they are poorly designed, they may contribute to the challenges users face (Schnall et al., 2016). According to Sudbury et al. (2013), poor design may also intensify the issues for users with low technology literacy. This has a noticeable effect on the acceptance of technology in the health context as presented in Nordhoff et al.'s (2020) research. We believe a well-designed and carefully developed app is more acceptable and sustainable (Sudburya et al., 2013). With this in mind, we had to ensure the solution we deliver to users, although unfinished and with minimum features, is nevertheless stable and relatively bug-free. That way, users can focus on the features and benefits without being constrained by technical issues. We believe that medication reminder apps have the potential to improve the quality of health, leading to better treatment outcomes.

6.2 Development Methodology

We adopted the Agile methodology for the development process of MAMA. Building through the iteration, Agile software development refers to a group of software development methodologies based on iterative development, where requirements and solutions evolve through collaboration between cross-functional teams. The use of Agile methods has grown rapidly in Information Systems Development (ISD) (Duc & Abrahamsson, 2013). A dominant idea in Agile development is that the team can be more effective in responding to change (Cao, Mohan, Xu & Ramesh, 2009). Research on related studies indicates that Agile methods have a good level of suitability for the development of mobile applications (Rahimian & Ramsin, 2007). The fast releases, with an iterative and incremental approach, shorten the time from conception to production (Duc & Abrahamsson, 2013). Due to our need to be able to adapt to changes from the iterations with our users, Agile development was the most viable for that process.

Following the process of the Agile model in **Figure 6.1**, the first build requirements were extracted from analysis of the questionnaire, interviews and experts' evaluations of the wireframe in the first phase of DSRM presented in **Chapter 4**. We developed the first version of the build to be deployed to the first FG for review and feedback. The outcomes were requirements from the first iteration for the second build, then tested by the developers and the research team. After that, we deployed it to the second FG for review and feedback. Then we developed the third build to be deployed to the third FG for feedback and review. The fourth and final build incorporated the input from the last FG, which resulted in the MAMA MVP. The MVP was tested by the research team and approved for deployment (see the testing devices list in **Appendix D.4**).

MAMA (2020) included the features of multi-channel notifications, scanning prescription to add a medication, adding medication function, stopping medication, and a medication history list with status, in addition to other functions like creating account,

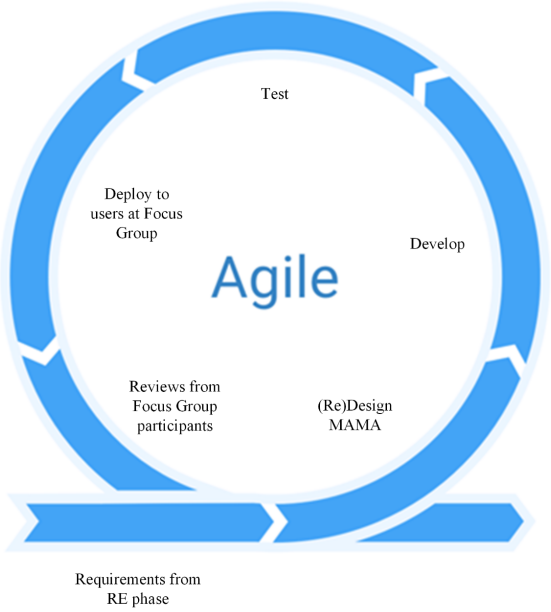

Figure 6.1: Agile development model

resetting password, adding medication and modifying reminders timing as presented in **Table 6.1**.

6.3 The MAMA System

6.3.1 System overview and workflow

The MAMA system is composed of three parts: (1) mobile application, (2) webform, (3) Firebase real-time database, as shown in **Figure 6.2**. The mobile application synchronises with the Webform using the Firebase real-time database, where data transfers from the MAMA Webform to the Database then to MAMA. This system enables scanning Rx and sending it to the healthcare provider, adding medication, logging medication status and stopping the medication. The system works according to the workflow in **Figure 6.3** and **Figure 6.4**.

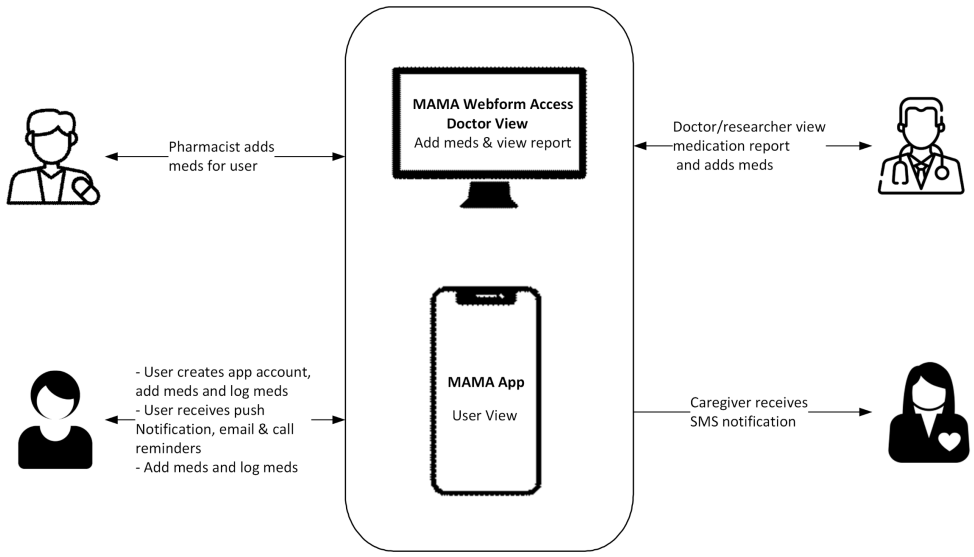

Figure 6.2: MAMA system overview

6.3.2 System architecture

As presented in **Figure 6.6**, the system architecture of MAMA consists of both IOS and Android apps built using React Native. React Native is a framework of JavaScript, which is a bridge between native components. It helps create both Android and IOS using a single language. The Firebase real-time database stores the data entered by the end user and researcher. Firebase acts as a serverless database that stores and retrieves data from the database. Then, according to the data stored in Firebase, the third party services will be functioned.

Twilio is a service used for sending Auto voice call reminders based on the medication reminders scheduled by the end user, and the SMS reminders to caregivers. For us to be able to build, deploy, and manage our applications entirely in the Cloud, we used Heroku, which served as a container-based Cloud Platform as a Service. We have included the future potential integration with our system with the likes of ACC, health systems, insurance companies, pharmacy systems and research teams.

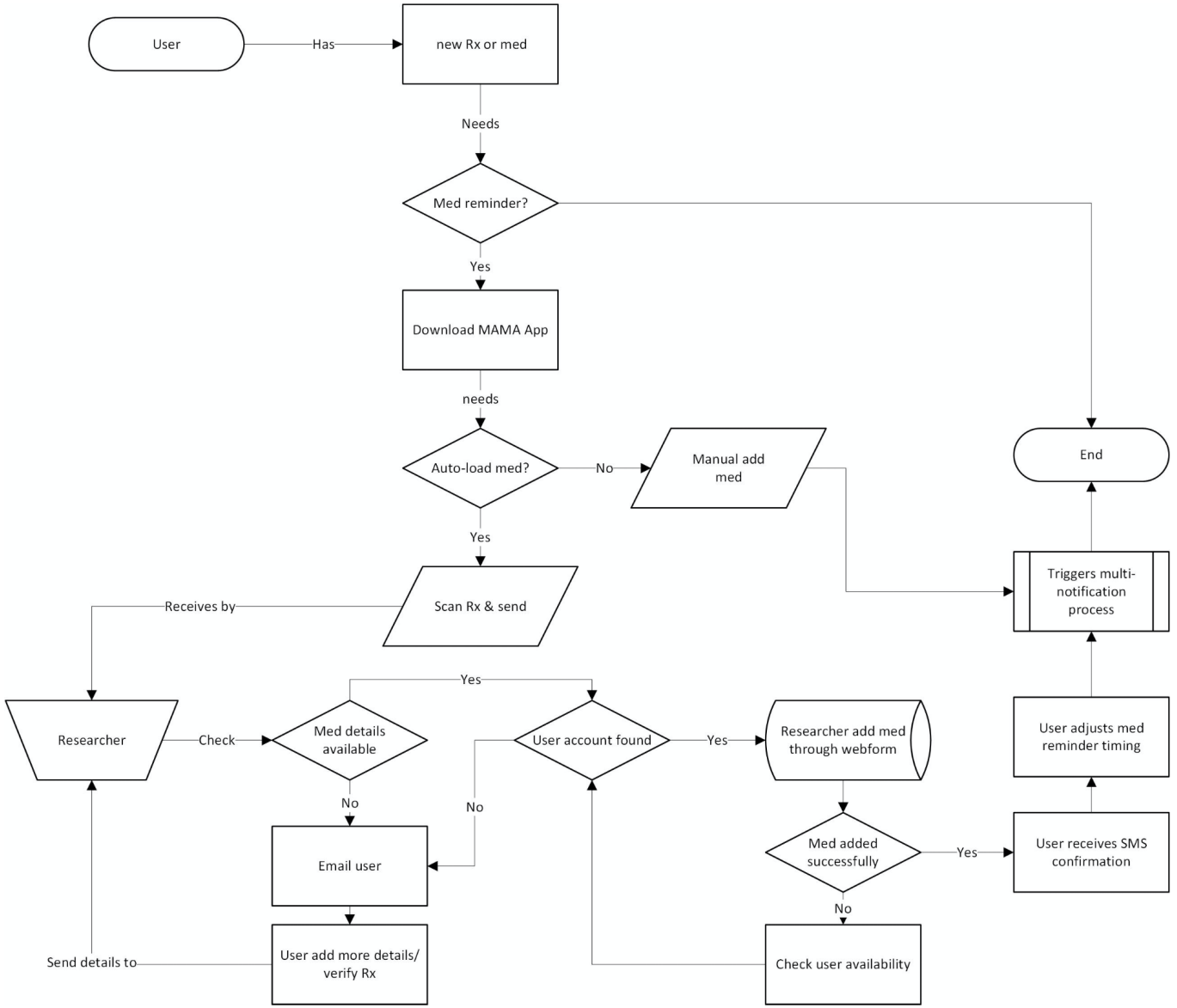

Figure 6.3: MAMA system workflow - loading Rx into users account

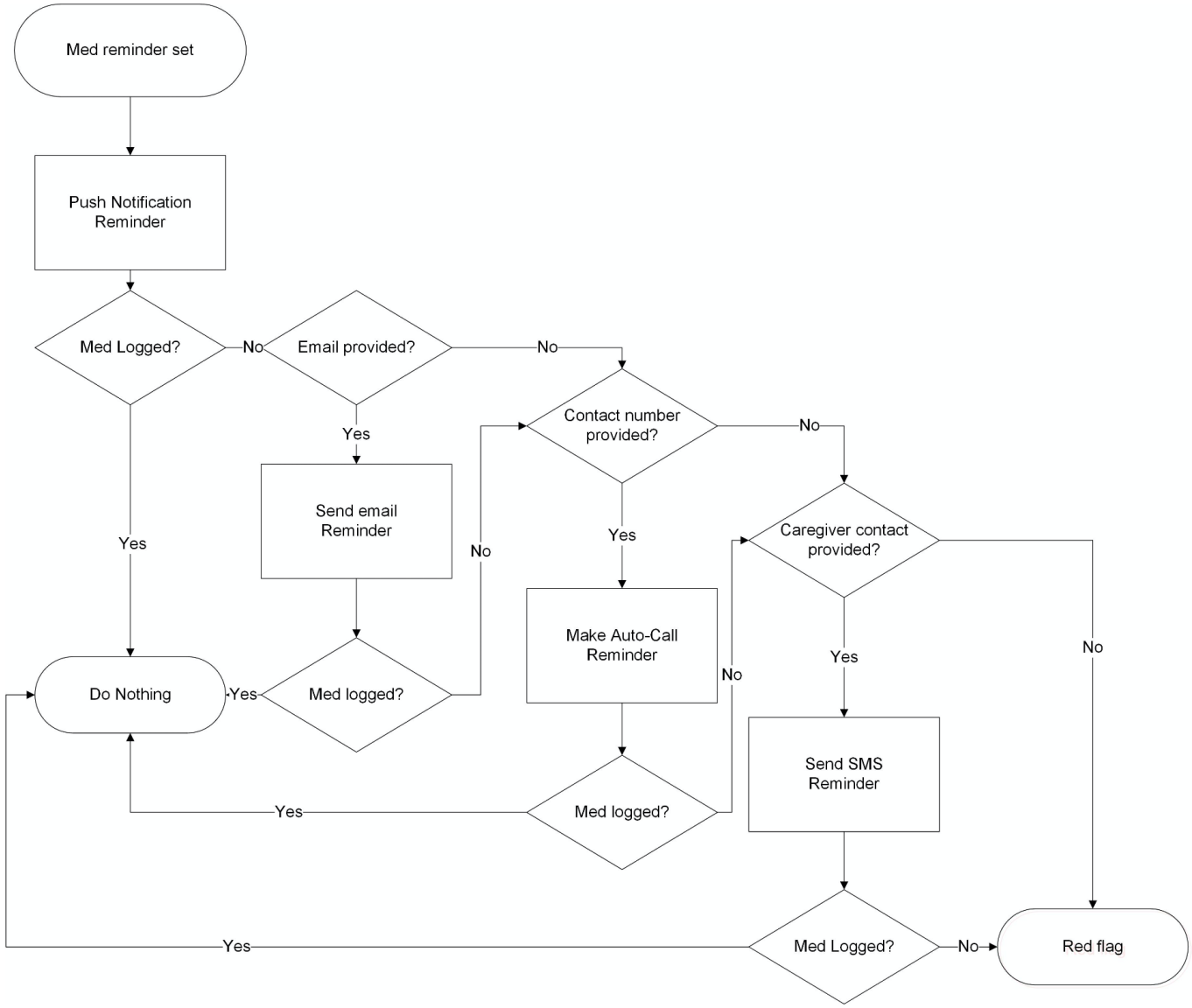

Figure 6.4: MAMA system sub-process workflow (triggered multi-notification process)

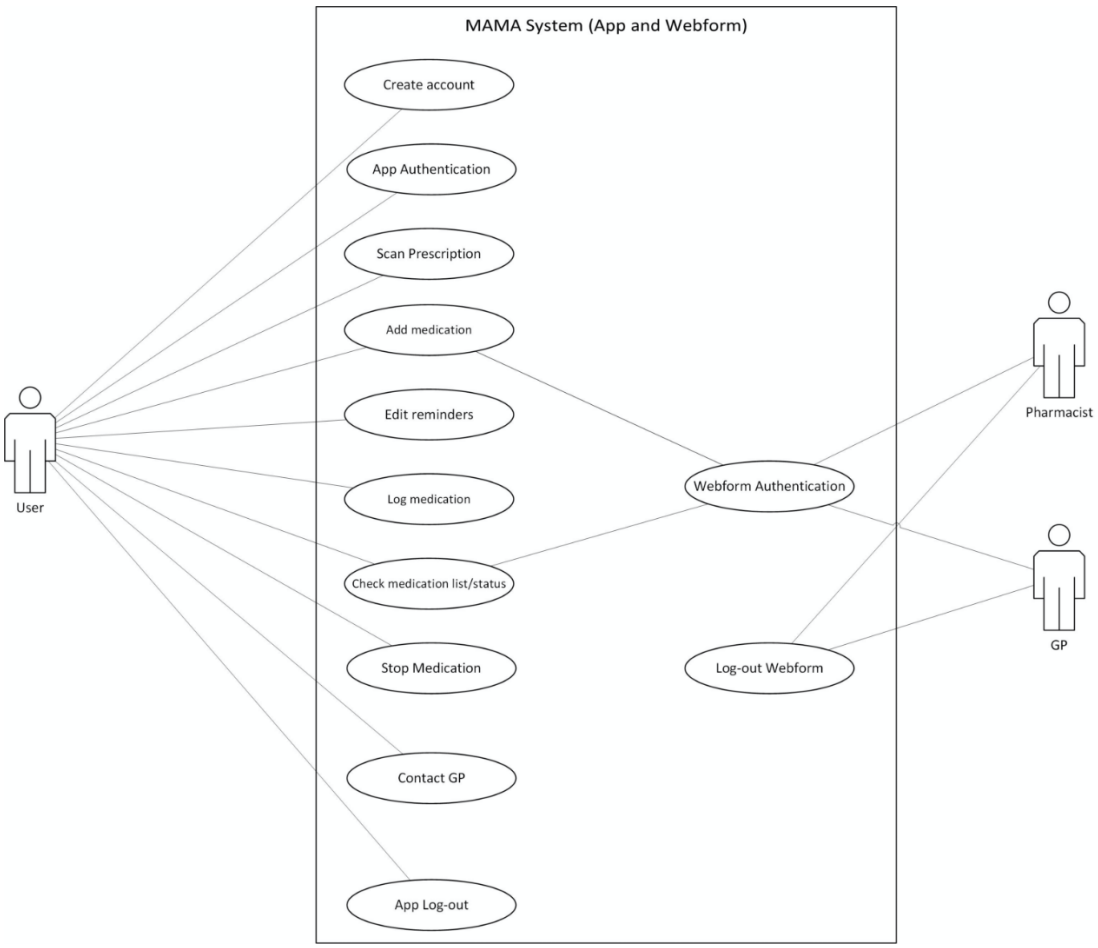

Figure 6.5: Use case diagram for MAMA system; App and Webform

In **Figure 6.7**, we present the end-to-end sequence design for a typical scenario. The user will create a MAMA account through an IOS or Android device that will enable the Firebase Authentication and store the information in the Firebase Database to create a user record in the database. Then, the user will be able to add medication into MAMA and add dose or scan Rx. The DET will load Rx through the Webform into the user's account and store it in the Firebase Realtime Database. App push notifications will be stored locally on users' devices. The Heroku server acts as a container for all the third party services required for scheduling medication reminders for the auto-call, email and SMS. The Nodemailer utilises the email reminders, and Twilio for the auto-call and caregiver SMS.

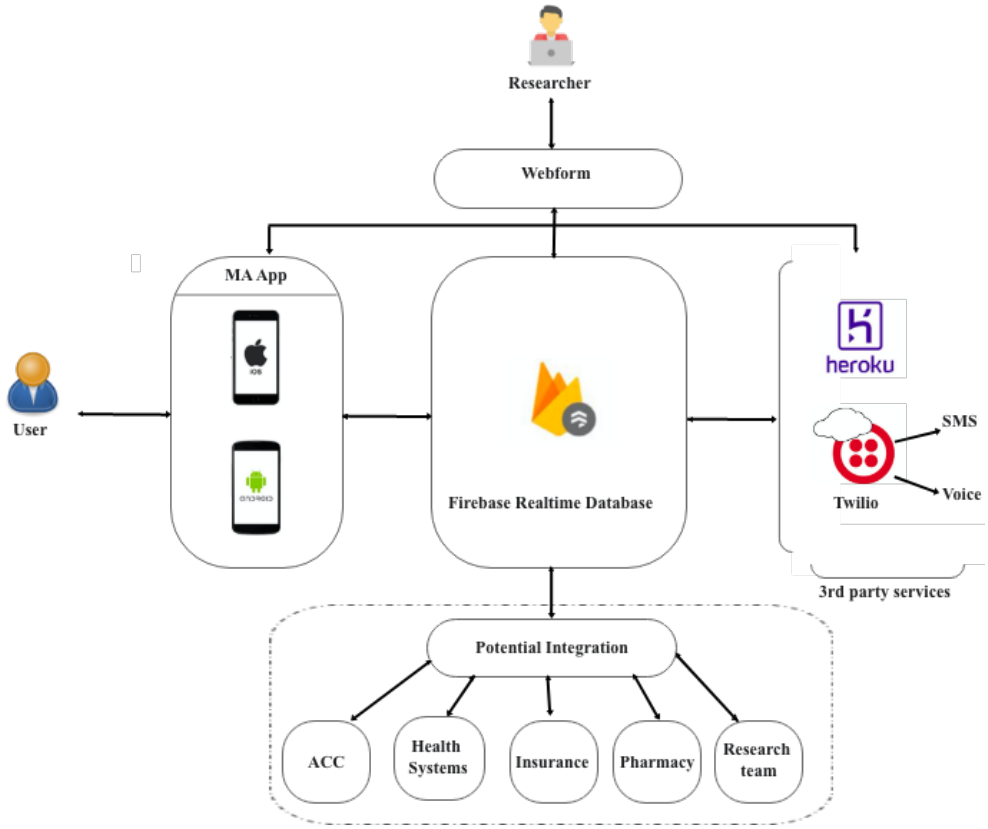

Figure 6.6: High level system architecture for MAMA

6.3.3 Use case diagram

Actors

MAMA is a medication management and reminder app which can be used both by users having challenges with keeping track of medication and for timely complex regimen medication intake, and healthcare providers to overlook the medication status of the planned treatment and adjust the plan as required. **Figure 6.5** shows the actors in a use case diagram for the MAMA system.

Use cases

User

- Log-in: User enters credentials and logs into the MAMA personal account.
- Medication management: User can add medication, scan Rx, edit reminders,

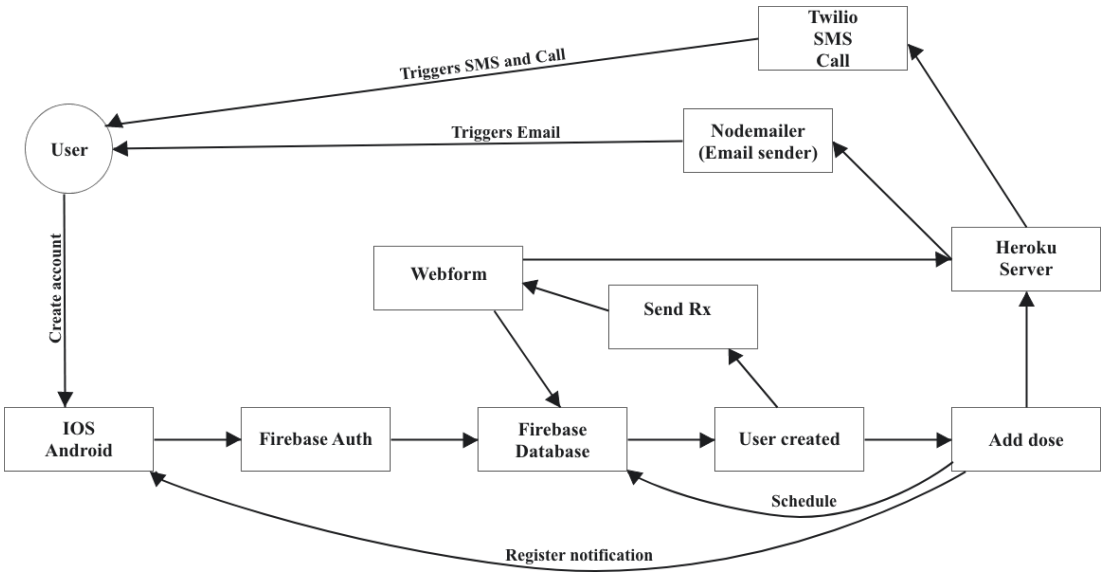

Figure 6.7: End to end sequence design for a typical scenario

discontinue medication, contact GP, manage the medication list and log in medication intake.

- Sign-out: User logs out from the account.

Admin (GP and/or Pharmacist)

- Log-in: The healthcare provider enters credentials and logs MAMA Webform account.
- Medication management: Add medication and check medication log history: The healthcare provider adds medication for patients and can see the medication history of the user.
- Sign-out: The healthcare provider logs out from the account.

6.3.4 Application interface

Due to the increase in the number of interfaces and the variety of users, the need for an effective interface design increases (Blair-Early & Zender, 2008). Therefore, when building an application, it is essential to keep in mind the effectiveness of good

interaction. No matter how good the functionalities or the program, if it is not user-friendly, it will not be considered an effective application (Sudburya et al., 2013). Therefore, to build a friendly interface for MAMA, we conducted rigorous inductive research and detailed discussions with experts and end-users as presented in the previous chapters. Accommodating MAMA with all the functionalities proposed was a complex and challenging task. However, after conducting the design iterations, we were able to include the minimum yet highly recommended features within a minimal and user-friendly design.

6.3.5 MAMA main screens

Figure 6.8 presents the MAMA screens' structure. Below we explain several of the screens (see **Appendix D.4** for all the screens).

Home screen

From the Home screen shown in **Figure 6.9**, you can access four functions:

- Scroll between the calendar days
- Access the Menu screen, by tapping on the three lines
- Two ways of adding medication:
    1. Self-add medication by tapping on the plus icon or on the icon Add Medication
    2. Scan and send prescription to the Rx DET to load the medications to the user account, by tapping on Scan Prescription

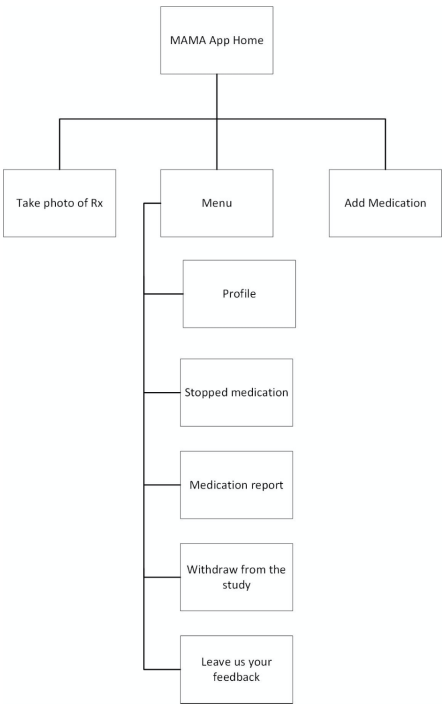

Figure 6.8: MAMA main screens structure

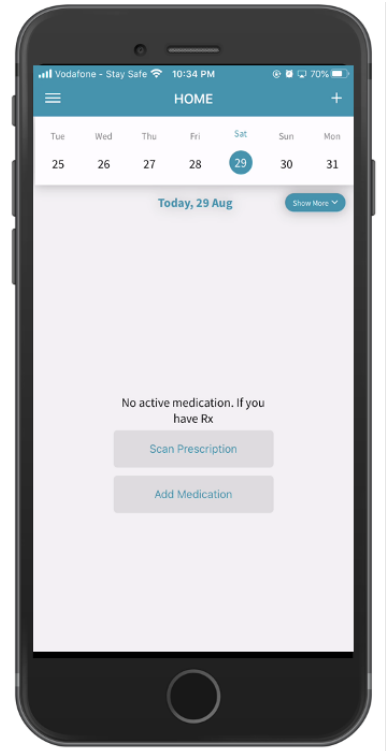

Figure 6.9: MAMA home screen

Add medication screen

As shown in **Figure 6.10**, this will allow the users to add medication manually into their account:

- Enter your medication details according to your Rx or over the counter medication details.
- Tap Save Medication.
- Tap on medication name to setup medication reminders.

Automated loading of medication

The automated loading of medication screen in **Figure 6.11** will allow you to Scan Rx and Send for auto-load of medication into the MAMA account:

- Tap Scan Prescription from the Home screen or Menu.

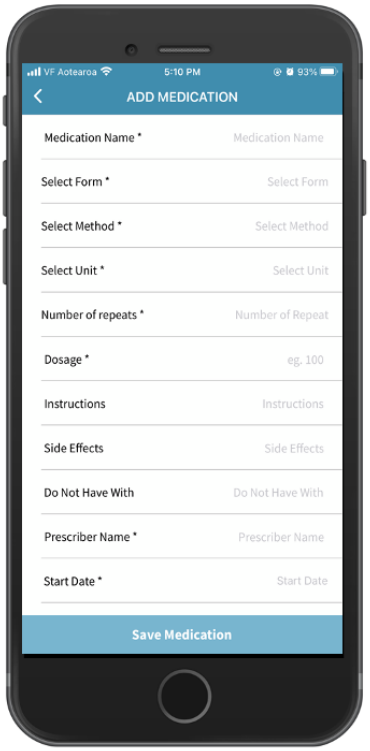

Figure 6.10: Add medication screen

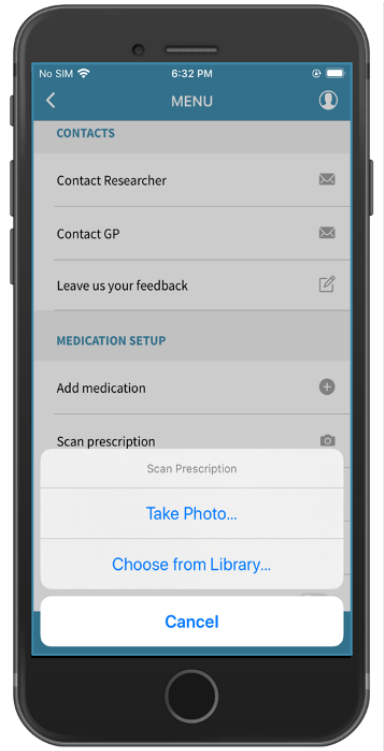

Figure 6.11: Auto-load of medication

- Tap Take Photo or Choose from Library.
- Take prescription photo, then tap Use Photo.
- A popup box will appear “Are you sure you want to send email of your prescription”, if yes, tap Proceed, otherwise tap Cancel.
- If the user chooses to proceed with sending prescription, a popup box will appear “Your prescription is sent to the Rx DET to have your medication loaded into your MAMA account”.
- Tap OK.

Note: In the pilot study presented in the next **Chapter 7**, we ask the users to allow 30 minutes to have their medication loaded into their MAMA account, after sending their prescription.

Stop medication screen

Figure 6.12 lists all medication; active, discontinued or past. This screen will allow the users to stop the medication they wish to discontinue, and that will stop the scheduled reminders for that particular medication:

- From the Menu, tap Stopped Medication.
- You can see the Past medications, Stopped medications and Active medications (that you are still taking).
- If you wish to discontinued an Active medication, tap on the medication name.
- A popup box will appear "You want to stop this medication? If yes! This medication will no longer be available on medication list", if you wish to proceed tap Stop, otherwise tap cancel.

Medication report screen

Medication report screen in **Figure 6.13**, allows the users to check their medication intake status report:

- From the Menu, tap Medication Report.
- On the top of the screen you can see the legend for each status.
- Scroll up and down to check status of each medication dose for your medication.

6.4 MAMA Development Tools

6.4.1 Technologies used

Here we listed the tools we used for development, integration and to manage the MAMA system.

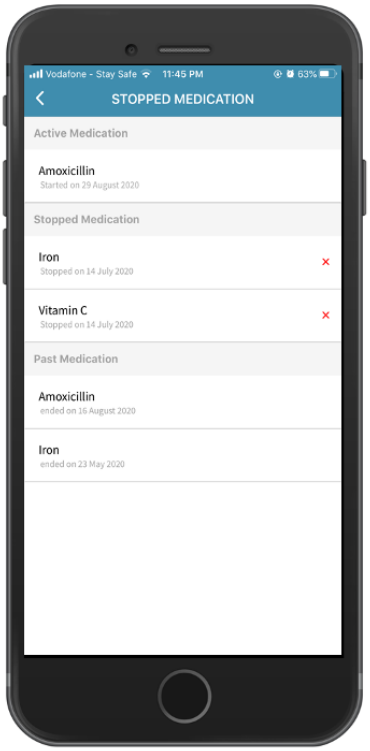

Figure 6.12: Stop medication screen

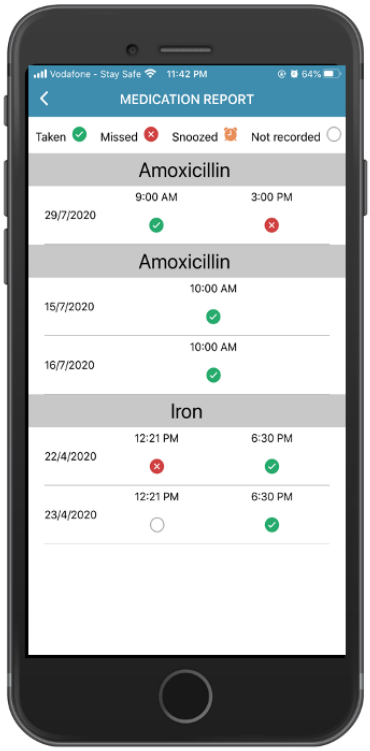

Figure 6.13: Medication report screen

- **Firebase Database:** The Firebase Real-time Database is a cloud-hosted NoSQL database that lets you store and sync data between your users in real-time (Google Firebase, 2018).

- **Firebase Authentication:** Most apps need to know the identity of a user and Firebase Authentication aims to make building secure authentication systems easy. While improving the sign-in and on-boarding experience for end-users, it provides an end-to-end identity solution, supporting email and password accounts, phone authentication and more (Firebase Authentication, 2021).

- **Heroku**: This is a Platform as a Service (PaaS) that enables developers to build, run, and operate applications entirely in the Cloud. We used it as a dedicated server to deploy the node.js server that handles the scheduling of notifications (Heroku, 2021).

- **Firebase Hosting**: This provides fast and secure hosting for web apps, static and dynamic content, and microservices. We have used it to deploy the MAMA Webform (Firebase Hosting, 2021).

- **TestFlight**: This is an Apple product that makes it easy to invite users to test iOS apps, app clip experiences and collect valuable feedback before releasing the apps on the App Store. We used it to deploy the IOS application to our testing participants (TestFlight, 2021).

- **FCM (Firebase Cloud Messaging)**: This is a cross-platform messaging solution that lets you reliably send messages at no cost. We used it to send notifications to both android and IOS (Firebase, 2021).

- **Visual Studio Code**: This is a code editor redefined and optimised for building and debugging modern web and cloud applications. We used it for real-time compiling of code (Visual Studio, 2021).

- **Android Studio**: This is the official integrated development environment for Google's Android operating system, which was designed specifically for Android development. We used it for our Android build (Android Studio, 2021).

- **Xcode**: This is Apple's integrated development environment for macOS. We used it to code our IOS app build (Apple, 2021).

- **Redux**: Redux is an open-source JavaScript library for managing application state. It is most commonly used with libraries such as React or Angular for building user interfaces (Abramov & Redux documentation authors, 2021). We used it for internal state management to build the MAMA interface.

- **React Native**: React Native is an open-source mobile application framework created by Facebook, Inc. It is used to develop applications for Android, Android

TV, iOS, macOS, tvOS, Web and Windows by enabling developers to use React's framework along with native platform capabilities (React Native, 2021). We used it to create a native MAMA for Android and iOS using React. React is an open-source, front end, JavaScript library for building user interfaces or UI components. React can be used as a base in the development of single-page or mobile applications.

6.4.2 Development of MAMA

We developed the mobile application using React Native. React helped us develop both Android and IOS with JavaScript. The mobile app is synchronised with the Webform through Firebase Real-time Database. The Firebase Authentication is used to authenticate users (Firebase Authentication, 2021). The Node.js server is used to schedule notification reminders to remind users of their missed or snoozed medications (Refsnes Data, 2021). The mobile app is synchronised with the Web Application through the Firebase Real-time Database.

6.4.3 Development of MAMA Webform

The Webform application was designed using React.js Framework (React Native, 2021). Firebase is used as a centralised database for communication between both web and mobile applications. Firebase Authentication is used to authenticate web form, and Firebase Database functions are used to store data from the webform. Registration of notifications is handled with Rest APIs (Restfulapi, 2020).

6.5 MAMA Testing

We tested MAMA throughout the development process using emulators: Android Pixel with Android 7, 8, 9, 10, and iPhone 8+, iPhone 11 pro with IOS 12, 13, 14. Also, different types of mobile devices were tested as a team and individuals by the development team then the research team. Some of the devices used for testing were the iPhone 6, 7, 8 Plus, iPhone X and 10. We also tested on Android devices like Galaxy 10 (see the full list of devices used for testing and the challenges that occurred in **Appendix D.4.d**).

We also recorded each function separately and presented it to the research team for assessment and feedback before the approval to start the pilot with end-users. **Table 6.1** presents MAMA functions and the recorded videos (click on the links from the table or scan the QRCode to access all videos, if you are reading this thesis from a paper copy).

6.6 User Manual

For the purpose of the pilot study, we created a user manual for both MAMA and Webform explaining the functionalities of each feature available and the benefit of using it. Here we list some examples from **Figures 6.14** to **Figure 6.23** (see the detailed manuals in **Appendix D.4.e**).

6.6.1 Installing MAMA

On an Android device, click on the link you will receive in the invitation email to download the app. On an IOS device you will receive an email invitation from Apple TestFlight, follow the three steps listed in the invitation or go through the steps below if

Table 6.1: MAMA functions in mini videos

No	MAMA functions	Sub-functions mini video
1	Download MAMA	Download App- from invite link
2	Create account	Create account
3	Login	Login- with correct password
		Login- with wrong password
4	Reset password	Reset password
		Reset password - create new password
5	Add medication	Add medication - through the app
		Scan prescription
		Rx DET receives prescription
		Add medication from Webform
6	Set reminders	User Change medication reminder
7	Multi-channel notifications	Push Notification received - log Snooze
		Push Notification received - no action
		Email reminder received - no action
		Call reminder received – reply but no action
		Caregiver SMS notification
8	Medication acknowledgement	Log medication – missed
		Log medication – taken
9	Medication report in-app	View medication report
10	Stop medication reminder	Stop one medication – Medication no longer in the Home
11	Contacts	Contact researcher
		Contact GP
12	Medication report Webform view	GP view report - Webform
13	Feedback form	Leave us your feedback
14	Logout	Logout from account
		Account Disabled when Login to account with wrong password multiple times
15	Study participation status	Withdraw from the study
16	Login after withdraw	Login
17	Generic reminder	Daily generic reminder

you are using the public link to install the app.

Note: The steps were articulated for the pilot participants, who were invited and received the MAMA app link to download on their devices (for both IOS and Android versions).

Installing TestFlight

- Install TestFlight on the iOS device that you will use for testing.
- Open your invitation email or tap on the public link sent to you, on your iOS device.
- In TestFlight tap Install or Update for the app.
- When the app is installed/updated, tap open.

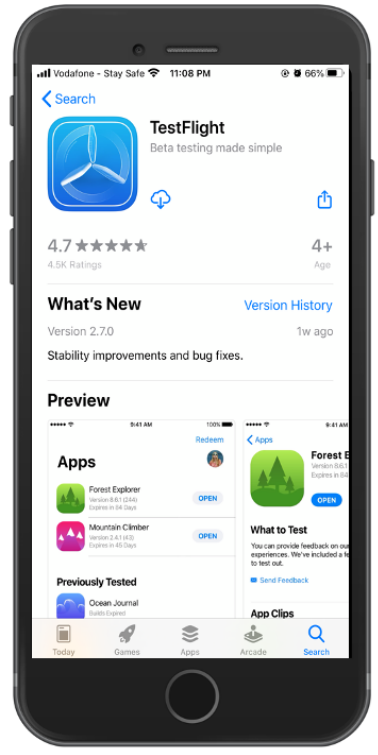

Figure 6.14: Installing TestFlight

Figure 6.15: Installing MAMA

6.6.2 Create an account

- Enter a username - you can use any preferred username and it does not have to be your National Health Index (NHI) number.
- Enter an active email address that you use/check most frequently, to be able to receive the email reminder.
- Add your cell phone number to activate receiving the auto-call reminder.
- Add the caregiver cell phone number to activate the caregiver SMS notification (only if the caregiver is involved in the treatment).

The entered information will be loaded into the database to activate the notifications/reminders and more. You can choose which information you would like to enter if the field is not required (identified with *).

6.6.3 Login / Reset password

- Enter your email and password to login.
- If you forgot your password, click on “Reset here” to reset password.
- The reset password link will be sent to the email you have provided when creating the account.
- Tap Login.

6.6.4 Setup reminders

From the medication reminder screen shown in **Figure 6.18**, tap on the medication name. The number of reminders (repeat medication) will be loaded according to your prescription. Then, you will be able to edit the time according to the time of your first dose.

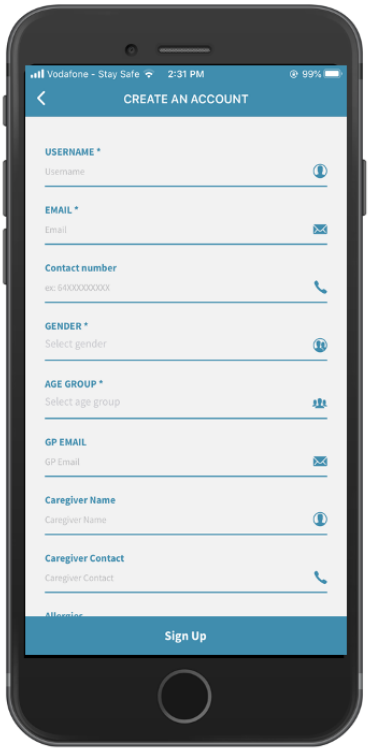

Figure 6.16: Create account screen

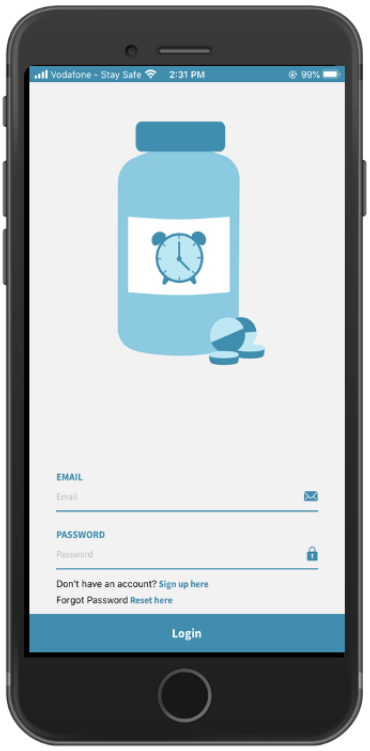

Figure 6.17: Login screen

Note: The default times will be 9:00am, 12:00pm, 3:00pm and 6:00pm. If you change the toggle to Off, then you will not be receiving any reminder for that scheduled time. It is not recommended to change the number of medication repeats before consulting with your GP/prescriber.

- To change the time, tap on the default time and scroll to preferred time.
- Tap Done.

6.6.5 The multi-channel notifications

There are three types of notifications which the user will receive if the scheduled medication is not logged into the app, as presented earlier in **Figure 6.4**. The fourth notification is sent to the caregiver if the contact number is provided by the user when

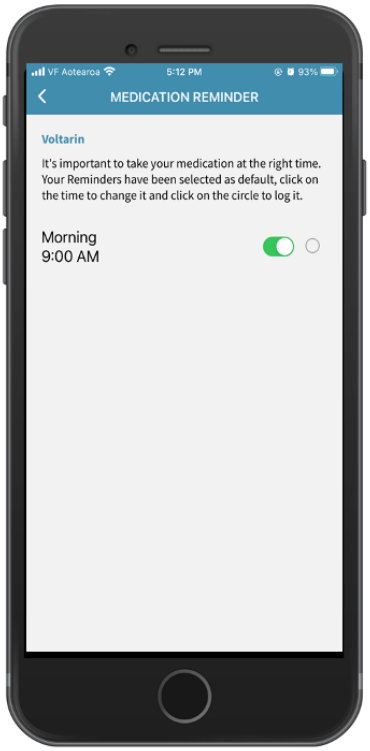

Figure 6.18: Schedule reminders screen

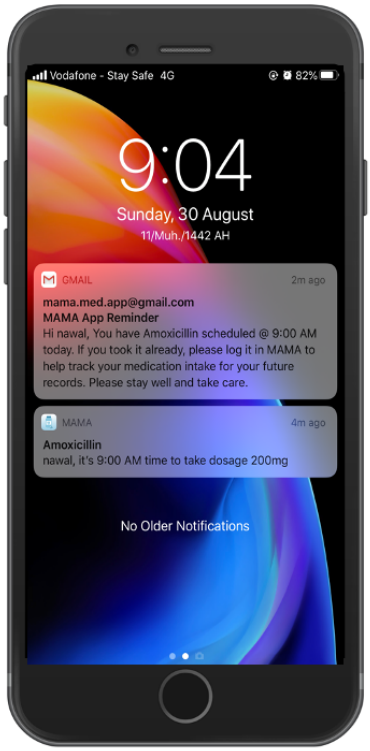

Figure 6.19: Multi-channel notifications

creating the account. Here are the scenarios of receiving the reminders and logging your medication intake:

- If you take your medication before the scheduled time and log it in the app as taken or missed, then, you will not receive notification for that logged time.
- The first notification you will receive is the app notification and by tapping on it, you will be directed to the log medication popup screen.
- If you missed logging your medication when receiving the app notification, you will be sent an email reminder 15 minutes after the scheduled time.
- If you missed logging medication after receiving the email reminder within the first 30 minutes from the scheduled time, you will receive an auto-call reminder as shown in **Figure 6.20**.
- If you missed logging medication after receiving the auto-call and did not log the med as Taken, or Missed anytime during the day, then an SMS will be sent to

your caregiver to check if you need any help.

Note: All notifications will be received through Apple Watch if you mirror your iPhone alerts from the Watch app.

6.6.6 Menu and logout

Figure 6.21 allows you to access all functions of MAMA.

- Tap the profile icon in the top right-hand corner to view your details and medication list.
- Tap Withdraw from the Study if you do not wish to continue.
- Tap Contact Researcher if you wish to email any question regarding the app use/functionality during the trial period.
- Tap Contact GP if you wish to email your GP. (This app is for research purposes only at this stage and not integrated with your GP system.)
- Tap Logout if you wish to exit the app.

Note: You do not need to logout each time from the app. If you logout, you will need to login again with your credentials to access your account.

6.6.7 Webform access

The MAMA Webform shown in **Figure 6.22** is connected to the Google cloud Firebase database. This will allow instant loading of medication into the users app when medications are added through the Webform (see the detailed manuals in **Appendix D.4.f**).

- **Add medication tab**

  When users create a MAMA account, their data will be saved in the database. This will allow the search for their username through the Webform shown in

Figure 6.20: Call reminder

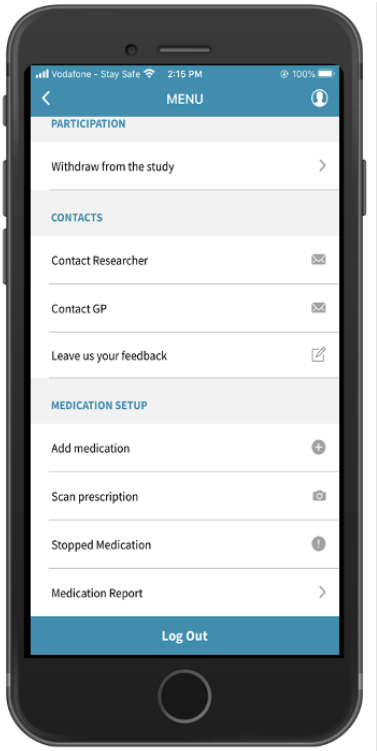

Figure 6.21: Menu screen

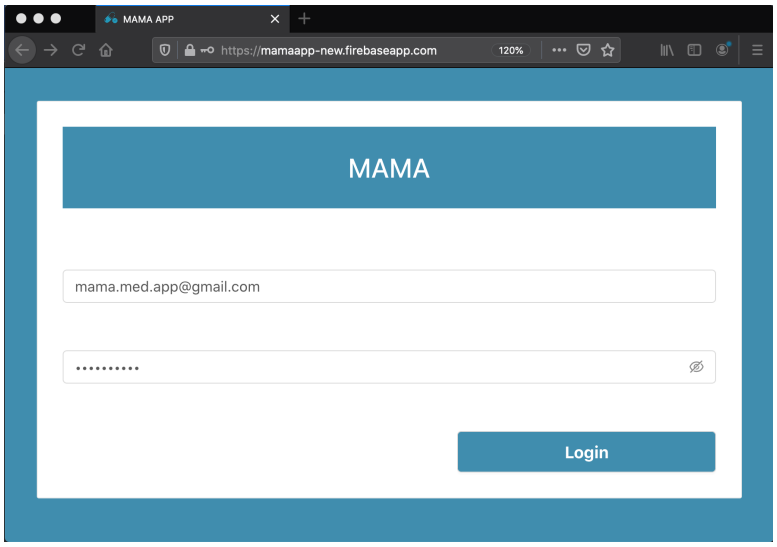

Figure 6.22: MAMA Webform - Login page

Figure 6.23, to be able to add their medication. To load medication on the user's account through the web form, the below steps are followed:

- Log in into the Web form.

- Click on the drop-down menu for the usernames.
- Look for the username matching the full name in the prescription received through mama.med.app@gmail.com.
- Click on the username.
- Add the details of medication in the form according to the prescription.
- Click Submit.
- An SMS will be sent to the user confirming the loading of medication on MAMA count.

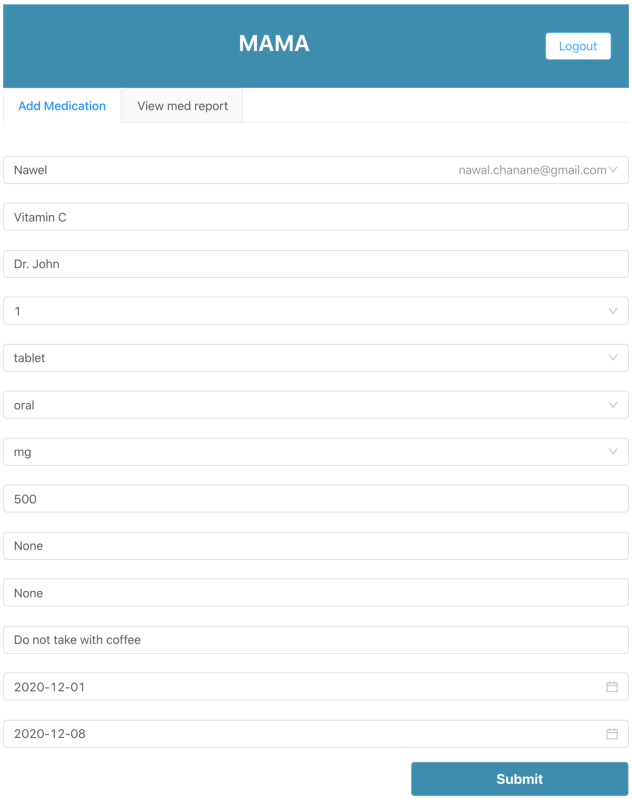

Figure 6.23: MAMA Webform – Add medication page

- Medication report

The medication report view shown in **Figure 6.24** allows the healthcare provider to view the medication intake status for a particular user with health concerns.

- Click on the View Med report tab.
- Look for the username matching the full name in the prescription received through mama.med.app@gmail.com.
- Click on the username you are looking for.
- View medication status report.

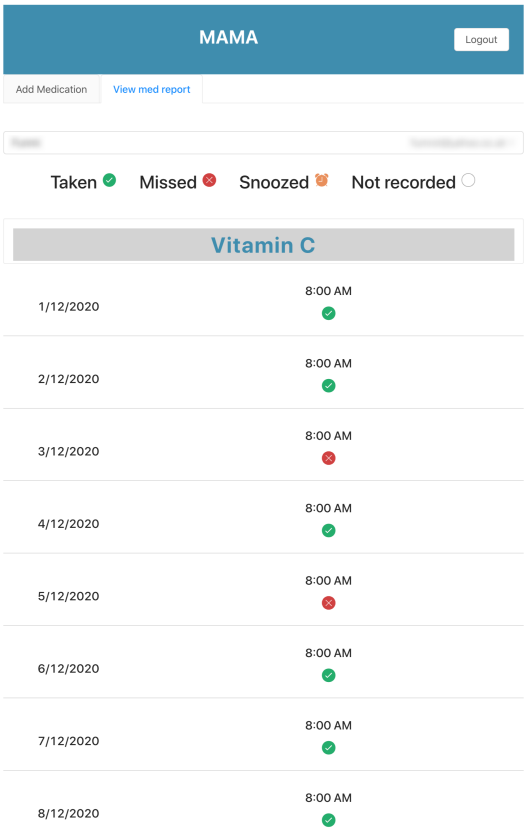

Figure 6.24: MAMA Webform - Medication report screen

6.7 Summary of Chapter 6

This chapter explained the development of the MAMA system based on the feedback from end-users through multiple iterations, first from the RE phase, then the feedback from the FGs' iterations with end-users. While developing the app, we kept in mind

that it should not only provide value to users but also should be technically sound. We ensured these two equally important elements must both be present when building MAMA to be successful.

Although the development is done for an MVP which is a minimum version of the final solution, its quality was a priority for gaining acceptance from end-users. It was important to keep the end-users in mind to make sure their feedback was not primarily concerned with bugs and other flaws in the solution's underlying code. The development was one of the challenges faced in this study. The support of experts and their technical work and advice were appreciated and highly regarded.

The following planned activity in the next chapter, guided by the DSRM, is to pilot MAMA with end-users for a period of two weeks. This will be conducted to evaluate MAMA's feasibility and acceptability, and the effectiveness of the multi-channel reminders on improving medication intake. It will be the Demonstration and Evaluation of MAMA, which is the fifth phase in our study design process, as shown in **Figure 6.25**.

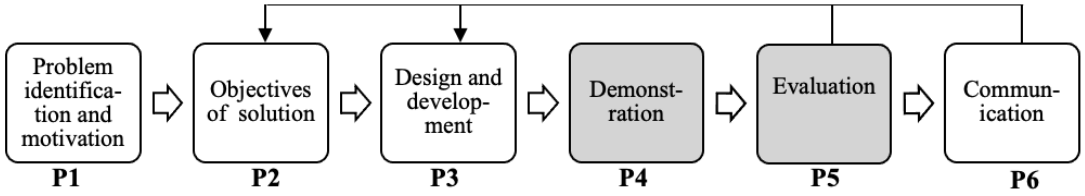

Figure 6.25: The fourth and fifth phase in the DSRM – Demonstration and Evaluation

Chapter 7

Piloting with End-Users: MAMA's Feasibility and Acceptability

"Drugs don't work in patients who don't take them" – C. Everett Koop

This research aimed to investigate the use of digital technology in addressing MA by involving multi-disciplinary experts and end-users to understand their perspectives. The main research question of this study is: *How can digital technology improve users' medication intake?* We collected requirements for managing MA and an MA MVP was developed and piloted with end-users in NZ.

This chapter presents the pilot study phase and the evaluation of the feasibility and user acceptance of MAMA. Our MVP was designed with primary goals in mind: to address (1) *the failure of taking the scheduled medication on time*; (2) *age-related data entry errors and ease of use*; and (3) *management of multi-medication use leading to pill burden*. This chapter produces the following main outcomes:

- Feasibility and acceptability evaluation of MAMA from end-users' perspectives
- Early adopters' feedback and recommendations for future development and enhancements.

The following sections in this chapter present first the introduction in **section 7.1**; introducing the scientific research in the field and the rationale for and importance of piloting in design science research. Then **section 7.2** presents the methods covering the study settings, intervention and data analysis methods followed in this chapter. Next, **section 7.3** illustrates the results: the recruitment process, participants' flow, baseline data, and the outcome and estimations. Subsequently, **section 7.4** documents the interpretation and generalisation of the feasibility aspects of the study, and finally, **section 7.5** concludes the overall evidence of feasibility and highlights the necessary modifications proposed for future studies.

7.1 Introduction

Piloting is an essential element of good study design. In the words of De Vaus, "Don't take the risk. Pilot test first" (De Vaus, 2013). A pilot study is referred to as a feasibility study, a useful small-scale version, or a pilot run that provides the groundwork for a research study (Hassan, Schattner & Mazza, 2006). According to Malmqvist et al. (2019), pilot studies are the neglected part of the research process, although they have the potential to inform subsequent parts of the research process and can provide valuable insights for other researchers. It is presumed that we benefit from the pilot study as it provides us with ideas and clues we may not have foreseen before conducting the pilot study, or gives warnings about where the proposed tools are either inapplicable or too complicated (Woken, 2005).

From the literature review we learnt that advancements in technology and mobile connectivity have played an increasingly important role in healthcare, specifically mHealth which is consistently used to help patients struggling with adhering to prescribed medication (Steinhubl, Muse & Topol, 2015; Whitehead & Seaton, 2016).

Because of multimorbidity, patients are still facing challenges with the burden of complex Rx regimens, which often lead them to poly-pharmacy in the long-term (Menditto et al., 2019). This reduces the level of medication management and adherence leading to treatment failure (Islahudin & Hasan, 2019). To overcome this challenge, there is a need for alternative strategies that healthcare providers can recommend to patients to help manage their medication intake, especially for those patients who spend the majority of their time outside of the clinical setting.

Although reasons vary when dealing with patients struggling with MA, forgetfulness (non-disease related) is one of the most commonly reported barriers, accounting for 30% even among motivated patients (Coventry, Fisher, Kenning, Bee & Bower, 2014). mHealth technology can help patients adhere to treatment, manage medication, and monitor activity (Byambasuren, Sanders, Beller & Glasziou, 2018). Yet, the majority of reminder apps offer only one method of reminder, predominantly SMS, or a phone call or an mHealth app reminder, despite the rise of research on medication reminders using mHealth, as elaborated in the literature review chapter in **section 2.5**.

In the previous chapters we gathered insights from medication users on the optimal features to include in a medication reminder app. Using these insights, we developed MAMA to be responsive to users' preferences. Our objective here is to pilot MAMA to:

- Evaluate its feasibility and acceptance by users
- Examine how MAMA usage affects participants' medication intake
- Gather feedback on how to facilitate its use.

7.2 Pilot Study Methodology

7.2.1 Participants and settings

A purposive criterion sampling method was used to invite individuals from previous stages of this research who showed interest in participating in the pilot. Purposive sampling appears to be used most commonly in implementation research (Palinkas et al., 2015). We also adopted the ABC pathway (see **section 3.1**) to recruit external individuals who had heard about the study but did not have the chance to participate in the earlier stages. We emailed an invitation to potential participants along with the information sheet and an electronic consent form (see **Appendix D.3**). Participants were recruited according to the eligibility criteria, including being in the target group of medication consumers but not receiving treatment for a terminal illness, being aged 18 and over, finding challenges in taking medication on time, and being willing to use the app to improve medication intake for the duration of the study period. In addition, participants were required to have a smartphone to test the app and to be living in NZ. Participants were excluded if taking medication on time was not required, or they did not have a smartphone, or if they reported a terminal disease condition (e.g., requiring cancer medication). Those who met the entry criteria were enrolled in the study and emailed the app link to download for iOS or Android, according to the phone type specified in the consent form.

In addition, participants were provided with MAMA documentation explaining how to download, install and use the app, then how to create an account and add medication or scan Rxs (see MAMA explanation document **D.4**). The participants were encouraged to get in touch with us through the app if any issues occurred, or if they experienced any difficulties during the pilot. We assisted participants who needed one-on-one help with the steps to get started. They were also informed about the feedback questionnaire

at the end of the pilot period. The participants were mailed a participant gift voucher of NZ$20 after submitting the feedback questionnaire, if they chose to receive a gift voucher.

7.2.2 Ethics consideration for the pilot study

A separate ethics application was prepared for this phase of the study a 2-week pilot study with end-users. It was considered an intervention research, which has a different nature of data collection from the previous two phases (see **section 5.2.1**). Collecting participants' details and medication names required additional justification and further resources. Our application was approved by AUTEC on 02/04/2020 *AUTEC Reference 19/343 Smart reminders to improve medication intake*. The consent forms will be electronically stored in the researchers' AUT password-protected computer. Consent forms are stored for 10 years then destroyed through the AUT confidential documents destruction system.

7.2.3 Instruments

Intervention (MAMA)

MAMA is a simple-to-use medication management app that serves users by keeping records of medication lists and medication intake logs and reminding them to take medication on time, through a multi-channel notification workflow presented in **section 6.4**. MAMA targets MA failure due to forgetfulness, complexity of the medication regimen, and poor MA management. It builds on the UTAUT2 model for mobile IT in the healthcare context (Sudburya et al., 2013). MAMA, as a patient-facing tool (see **section 5.5** for the list of functions), aims to:

- Provide a semi-auto-load of medication for ease of use

- Provide a simple workflow-base reminder according to the user's scheduled time
- Allows stopping discontinued medication to keep the medication list up-to-date
- Allow the user to contact the GP if any questions are needed.

The Webform was activated through the provision of (1) loading medication into users' accounts according to the prescription scanned by the users; and (2) the timely information on the user's medication intake status.

MAMA feedback questionnaire

The questionnaire consisted of 13 questions underpinned by the UTAUT2 model (Sudburya et al., 2013). Each question fell under one of four categories: participant's characteristics, MAMA usage, MAMA rating and feedback and suggestions, as presented in **Table 7.1**.

7.2.4 Data collection

Data collection was conducted using two tools: (1) MAMA for collecting user details when creating an account/signup, adding medication or scanning prescriptions, adjusting medication time and medication status logs; and (2) feedback questionnaires as an external anonymous Qualtrics link. The responses were not linked to participants' accounts to avoid the possibility of reporting biases that may arise with the in-app assessment. The app was intended to collect users' medication intakes and the questionnaire to collect feedback from unidentifiable users' experiences. The analysis of the data after completing this study was shared with the participants who chose to receive a summary report.

Table 7.1: MAMA feedback questionnaire

Category	Questions	Type of question	Purpose of question
Characteristics	**Q1:** To help us tailor MAMA to all age groups, please specify your age.	Dropdown	Measures demographics and a component of UTAUT2 model - Age and Gender
	Q2: Did you have previous experience with medication reminder apps?	Yes/No	Component of UTAUT2 model -Experience
	Q3: What type of mobile were you using for the pilot?	Multiple choice	Component of UTAUT2 model - Performance expectancy and facilitating conditions constructs
MAMA use	**Q4:** What is the number of medications added to the app?	Dropdown	Medication complexity affects medication intake
	Q5: Did MAMA help you take your medication on time?	Multiple choice	Evaluating app efficacy
	Q6: What features did you like the most (you may choose more than one)?	Multiple answer	Evaluating user's preferences and component of UTAUT2 model - Performance expectancy
MAMA rating	**Q7:** How would you rate the Scan prescription and Auto-load of medication (if you shared the prescription with the Rx DET)?	Rating scale	Component of UTAUT2 model -Performance expectancy
	Q8: How would you rate the Multiple reminders?	Rating scale	Component of UTAUT2 model -Performance expectancy
	Q9: Which reminders were more useful to you? (you may choose more than one)	Multiple answer	Evaluating user's preferences and component of UTAUT2 model -Effort expectancy
	Q10: How would you rate the Stop medication feature?	Rating scale	Component of UTAUT2 model -Performance expectancy
Feedback and suggestions	**Q11:** Would you recommend MAMA to your friends?	Likert scale	Component of UTAUT2 model -Social influence construct
	What is the reason for your choice?	Open-ended	We paired the closed question with an open-ended question to better understand and address the quantitative data.
	Q12: Would you like your GP to recommend MAMA to patients?	Likert scale	Component of UTAUT2 model -Social influence construct (Peer influence and Practitioner influence)
	What is the reason for your choice?	Open-ended	We paired the closed question with an open-ended question to better understand and address the quantitative data.
	Q13: To make MAMA satisfy your needs, please let us know what features you would like to add or replace in the app.	Open-ended	Allowing users to offer feedback in their own words will help us uncover opportunities that we may have otherwise overlooked

7.2.5 Sample size

There are varying rules of thumb for a pilot study sample size, ranging from 12 to 35 individuals (Bell et al., 2018). For example, according to Mark Mason (2010), an ideal sample size for such studies is between 20 and 30. Also Creswell, as cited by Mark Mason (2010), recommended five to 25 participants, and Charmaz recommended 25 participants as an adequate number for small projects. In adherence to Bertaux's guidelines (Modell, 1982), 15 is the smallest number of participants for a qualitative study, irrespective of the methodology. Our recruiting process ended when the number of participants reached 26, which lies within the recommended sample range. Our sample number corresponds with past health app pilot study research, which had the number of participants ranging between 10 and 25 (Foster, Hosking & Ziya, 2010).

7.2.6 Feasibility criteria

The study's feasibility was assessed based on the participants' responses to the questionnaire (Lancaster & Thabane, 2019). The questions were designed to evaluate the usefulness of the app functions in helping them take their medication on time, and the acceptability of the technology. The study feasibility was assessed based on the participants' responses to the questionnaire. The 5-point Likert-type scale was favoured due to its response quality, as it increases response rates and reduces respondents' frustration levels (i.e. less confusing responses), in addition to the ability to compare the reliability coefficients with other studies' results using the same scale (Revilla, Saris & Krosnick, 2014; Hameed, Basheer, Iqbal, Anwar & Ahmad, 2018).

7.2.7 Analysis

Descriptive analyses of the demographics and characteristics were reported as frequencies and percentages for categorical variables and SD (standard deviation) for

continuous variables. The usability of MAMA was described using event frequencies. All statistical analyses were performed using Qualtrics (2017) and SPSS (2020). Content analysis was performed for the qualitative data to capture participants' perceptions and identify the quotes that clearly highlighted the features suggested using NVIVO (2018). The relative importance index (RII) analysis was used to rank the features according to their relative importance, based on the participants' replies. This is an appropriate tool to prioritise the features rated on Likert scales (Rooshdi et al., 2018).

Further to our analysis, we utilised the UTAUT2 to examine MAMA usage patterns and acceptability, in addition to comparing them to previous pilot results using the same method (Sudburya et al., 2013; Gatwood et al., 2016; Santo et al., 2019).

7.2.8 Questionnaire validity and reliability

To evaluate the questionnaire validity, face validity and content validity were performed by the research team. For the reliability of the Likert-scale questions in our questionnaire, a Cronbach's alpha (α), a commonly used measurement of internal consistency for questionnaires, was used for calculating the sample size (Cronbach, 1951). For research and exploratory studies, Cronbach's alpha (α) values of 0.7-0.8 are acceptable, while a value of around 0.9 is excellent (Cortina, 1993). All statistical analyses were performed using SPSS.

7.3 MAMA Pilot Results

The collected data was inductively processed from both the feedback questionnaire and MAMA logs and activities.

7.3.1 Recruitment

The recruitment of participants took place from October 2020 to December 2020. All 143 potential participants were invited to participate. A total of 117 were from previous stages of this research: 100 from the questionnaire participants and 11 from the interview participants (RE phase, see **section 4.2**), six from the FG participants (Co-design phase, see **section 5.2**), and 26 external individuals, by adopting the ABC pathway introduced earlier (see **section 3.1**). Participants were recruited according to the eligibility criteria mentioned in **section 7.2.1**. Each participant started the pilot at a different date based on their replies and availability. The start dates were between 15 November 2020 and 4 December 2020, and the end dates ranged between 29 November 2020 and 19 December 2020. Each participant was scheduled for a 2-week period from the date of the first scheduled medication for each individual.

7.3.2 Participants

Of the 143 individuals invited to participate, 42 replied to the email invitation. Sixteen of those were excluded: two did not meet the inclusion criteria, 10 declined to participate and four individuals provided different reasons (two of them had permanently left NZ and the other two reported COVID-19 related issues). The participants who experienced COVID-19 related issues, expressed concerns that this may affect their participation and they may have to discontinue at some point after they started the testing. The piloting of MAMA started with 26 participants. From the 26 participants, 24 accounts were created, and 22 of them added daily medication ranging between one to five medications per day. Eleven participants needed follow-ups during the pilot period, either when downloading the app, or creating an account, and/or completing the questionnaire. All 22 participants completed the pilot period of two weeks, then completed the feedback questionnaire. The CONSORT flow of participants is shown in **Figure 7.1**.

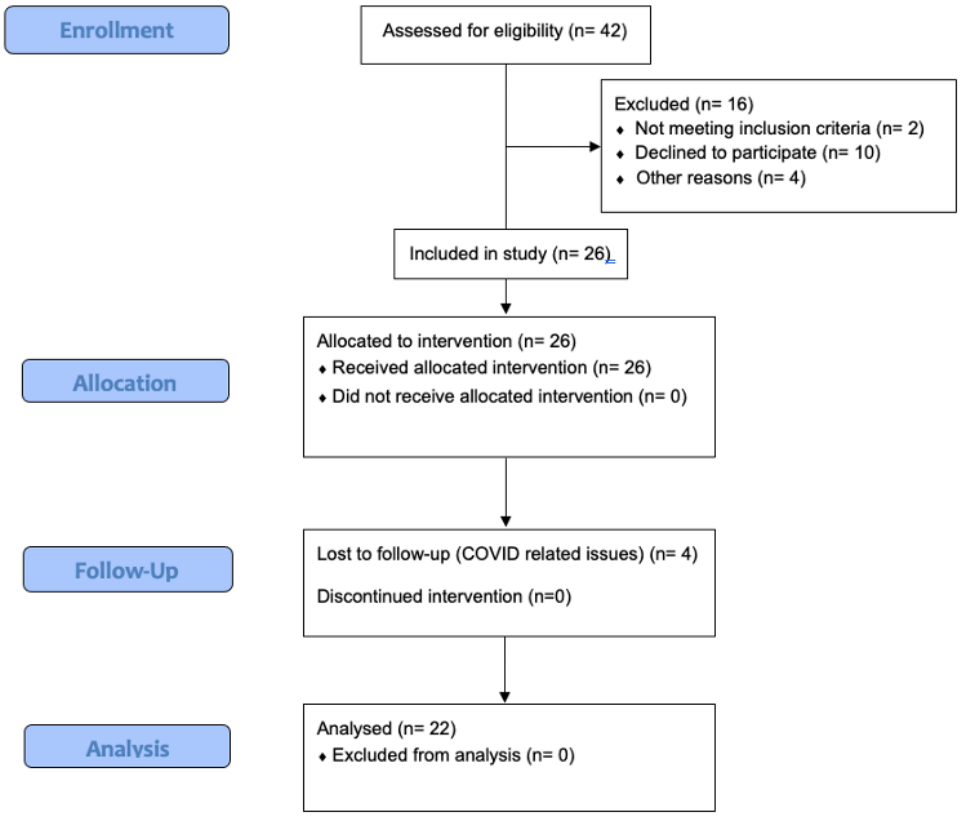

Figure 7.1: Participants flow diagram CONSORT

Some participants reported delays in submitting the feedback due to personal issues, mostly resulting from COVID19 consequences or travel, due to the timing of the pilot, which was between November 2020 and December 2020. No adverse events were caused due to MAMA use. Demographic information was gathered when app accounts were created (see **Table 7.2**).

7.3.3 MAMA usage and usability

The users' activities were plotted over time, as shown in **Figure 7.2**, which records the activity over one day, then one-week's activity and then one-month's activity. **Figure 7.3** indicates a usage peak on 22 November 2020, one week from the start date of the first participant, which shows that participants already had MAMA installed and

Table 7.2: Participants' gender and age group

Participants Characteristics	Frequency	Percentages
Gender		
Female	17	77.27%
Male	5	22.73%
Age range	1	4.55%
15-24	7	31.82%
25-44	7	31.82%
45-64	5	22.73%
65+	9	40.91%

running on their phones by that date.

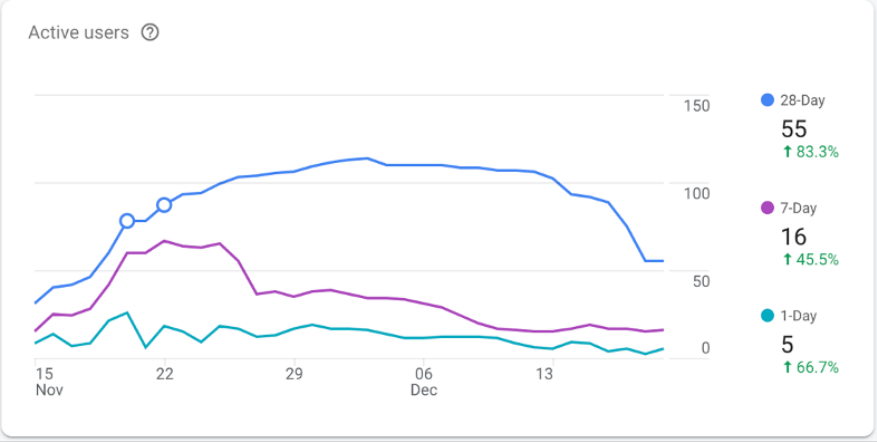

Figure 7.2: Active users plotted over time. Summary values show the number of active users as of the last day of the date range

Figure 7.4 plots the number of users who triggered the MAMA start page over the two week period to log their medication. We can see also a comparison between the daily users' engagement in **Figure 7.5**.

The participants used their personal iOS or Android phones to pilot MAMA. Ten participants used iOS and 12 participants used Android (e.g., Samsung, Huawei). Participants added medication into their accounts three to five days from the date of downloading the app. Seven users were not expected to receive the automated voice call reminder due to the unavailability of their contact number. And five users were not expected to benefit from the caregiver SMS reminder due to the unavailability of

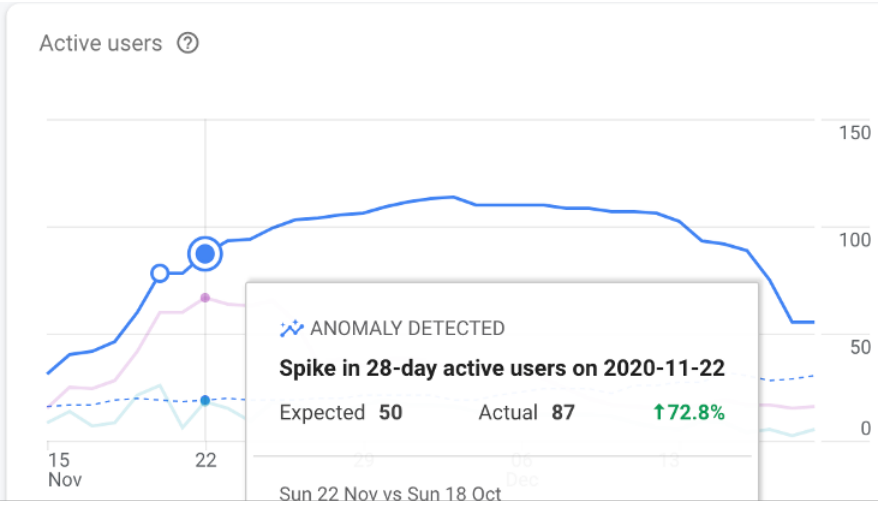

Figure 7.3: Active users engaged with the app in the device foreground and logged an engagement event

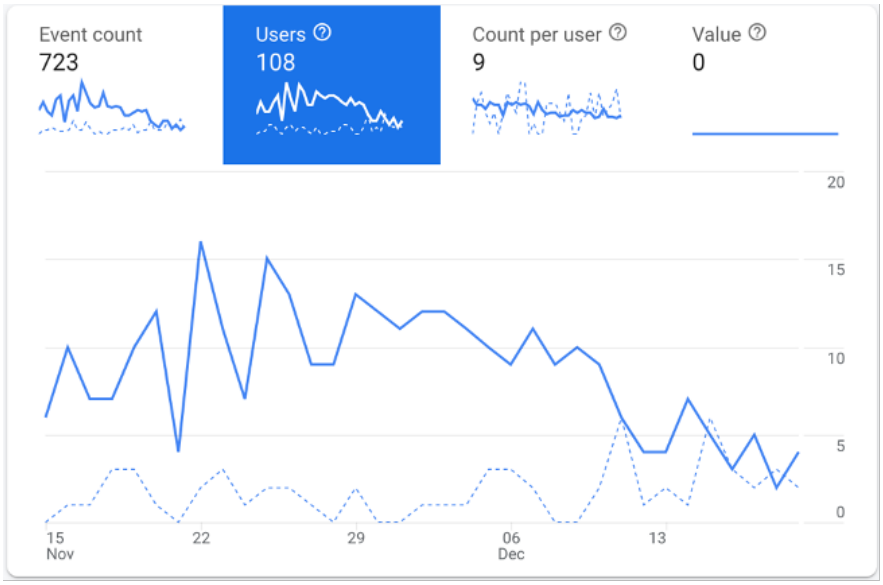

Figure 7.4: Number of users who triggered the start page

their caregiver's contact number. The auto-voice call was triggered 96 times and the SMS reminder 18 times in total during the two week period (see **Figure 7.6**). However, fewer users logged their medication as "Taken" after the push notification during the second week.

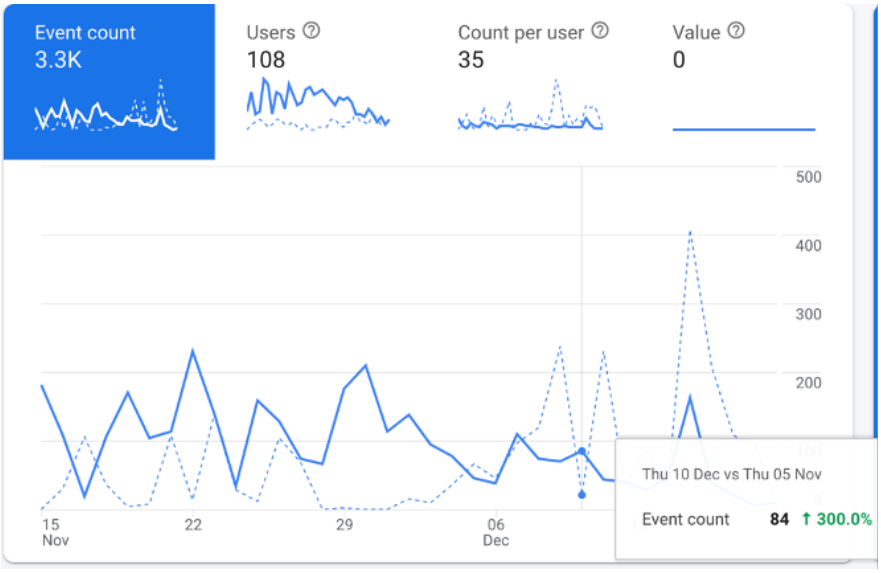

Figure 7.5: Daily users engagement during the 2-week pilot period

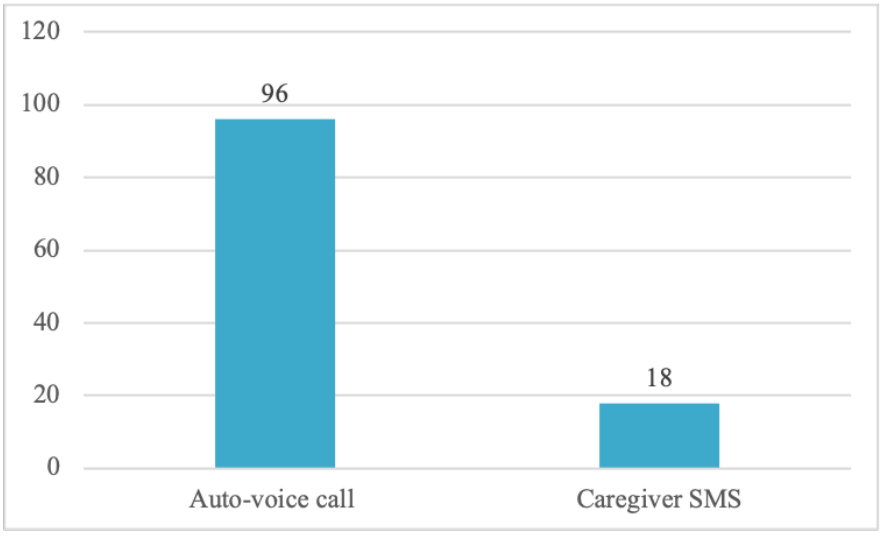

Figure 7.6: The number of times the auto-voice call reminder and the caregiver SMS reminder were triggered

7.3.4 Medication intake adherence

The medication added to the app was either prescribed or over the counter. The graphs from **Figure 7.7** to **Figure 7.10** represent the statistics summarised from the app usage over the two weeks.

If we eliminate the out-layers and participants with one medication, their adherence

rate was zero. Then, we can get an acceptable to excellent adherence with a rate around 0.8 (80%). From **Figure 7.7** it is clear that the number of pills expected to be taken is very close to the actual number of pills taken and from the graph we can see the overlap, which means the adherence rate was high for more than half of the participants.

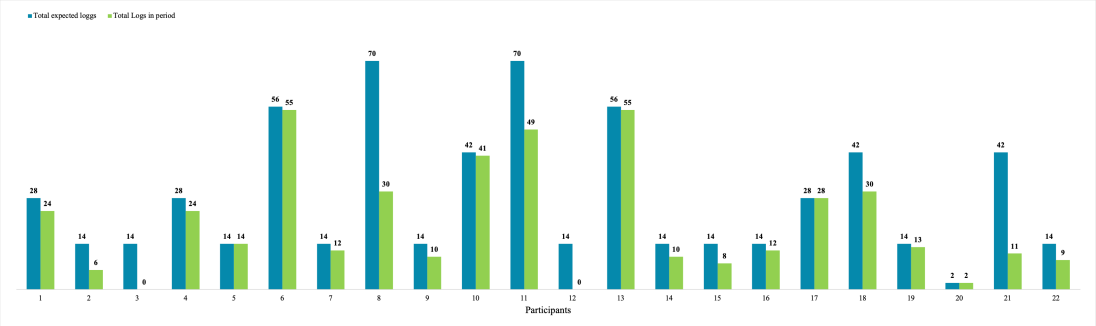

Figure 7.7: Expected number of pills in period per user vs the number of pills taken

Then, we have **Figure 7.8**, the adherence rate in relation to the number of medications. We noticed that the adherence rate was acceptable, and the number of medications taken per day did not affect this, considering multiple medications and the complex regimen plays a big role in adherence rate. For example, user 9 had three medications and user 3 had one medication, yet their adherence rate was zero (0%) and 0.79 (79%), respectively. Another example was where user 6 had four medications and user 8 had one medication and both adherence rates were one (100%).

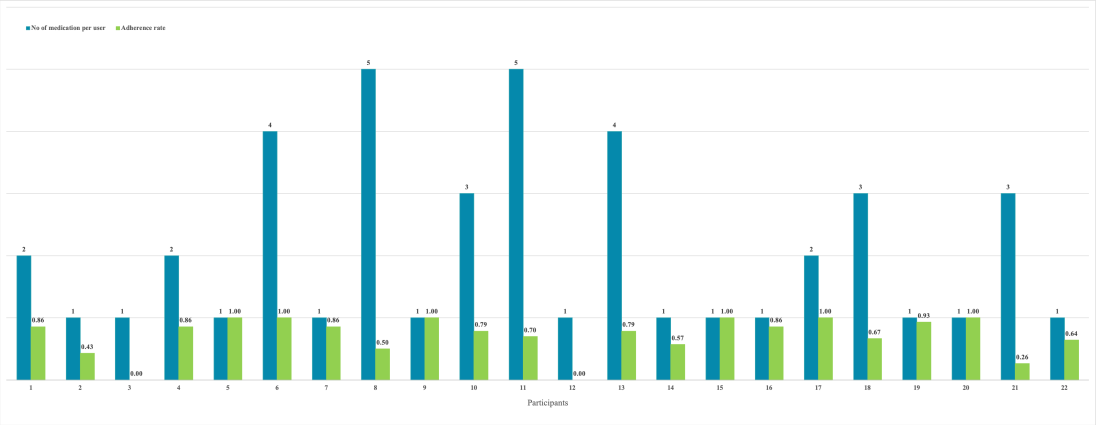

Figure 7.8: Adherence rate in relation to the number of medications

Figure 7.9 presents the adherence rate for participants in relation to their age group. The rate is calculated using the Proportion of Days Covered (PDC), a newer method of calculating adherence rates according to the Pharmacy Quality Alliance (PQA) recommendations (Nau, 2006). The resulting PDC ranges from 0 to 1, where a value of 1 corresponds to 100% adherence. This metrics defines adherence as >0.8 or 80% of days covered. As shown in the figure we have participants in age group 65+ with adherence rate 0.79, 0.57 and 1.00. Moreover, we can see participants in the age group 25-44 with adherence rate 0.43, 0.79, 0.86 and 1.00. We noticed that the adherence in age groups 44-64 and 65+ was relatively high. That means the age group did not affect the adherence but other variables like the number of medications or the scheduled medication time may be a reason behind low adherences such as 0.43.

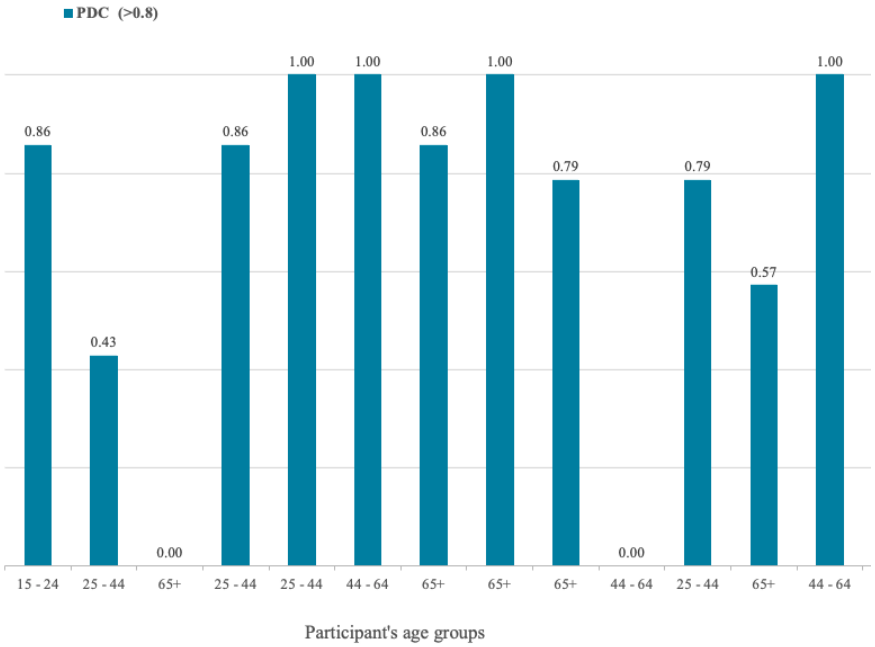

Figure 7.9: PDC rate among participants, (>0.8) as an optimal rate for chronic conditions

Figure 7.10 presents a comparison between the number of pills taken in the first and second weeks of the pilot study. From the figure, we can see that participants used MAMA during both weeks. There was no apparent drop in usage. As shown,

participant 1 logged 14 pills taken during the first week and ten pills taken during the second week. Moreover, the third participant had 12 pills in the first week and 12 pills in the second week. Also, we have participant 7, with 15 pills taken during the first week and 20 pills during the second week, and that confirms the acceptance of using the app to remind them of their medication intake. The same with participant 10, with 19 pills during the first week and 30 pills taken during the second week. We can see that it is a positive sign of user acceptance of technology in the health context.

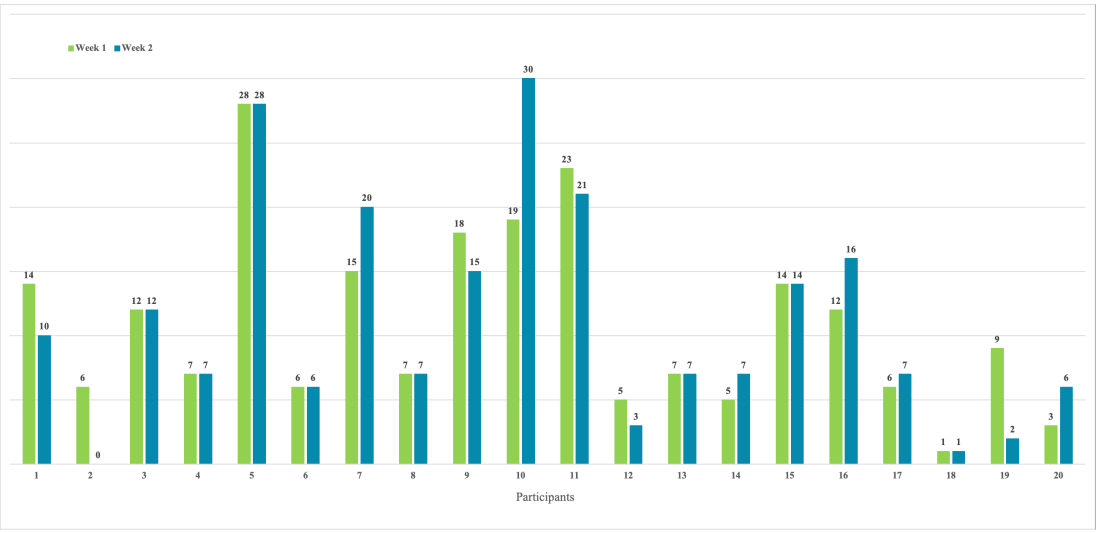

Figure 7.10: A comparison between the number of pills taken in the first and second week of the pilot study

7.4 MAMA Feedback Questionnaire Results

The questionnaire was valid and reliable with a reliability coefficient of (α=0.75) for Q7 and Q10 (see **Table 7.1**), which is considered acceptable, and (α= 0.9) for Q8, Q11 and Q13, and this result is considered excellent. The relative importance index analysis ranked the features according to their relative importance. **Table 7.3** shows the ranking results for each feature according to the RII analysis.

The *first question* was about the participants' age group as listed in **Table 7.2**. The

Table 7.3: The ranking results for each feature

Question	Feature	Relative Index	Overall ranking	Importance level
Q7	Scan & auto-load of meds	0.477	4	M (0.4 ≤ RI ≤ 0.6)
Q8	Multiple reminders	0.791	3	H-M (0.6 ≤ RI ≤ 0.8)
Q10	Stop medication	0.469	5	M (0.4 ≤ RI ≤ 0.6)

second question asked the users about their experience with using reminder apps: "Did you have previous experience with medication reminder apps?" - 90.91% (N=20) of the participants answered "No" and only 9.09% (N=2) responded with "Yes". The *third question* asked about the type of phones they were using during the pilot: 10 were using iOS and 12 were using Android. The *fourth question* asked about the number of medications the user added to the app. The number of medications ranged from 1 - 5 medications per user. More than half of the participants, 54.55% (N=12), added one medication; 18.18% (N=4) added two medications; 13.64% (N=3) added three medications; 9.09% (N=2) added four medications; and 4.55% (N=1) added five medications (see **Figure 7.11**).

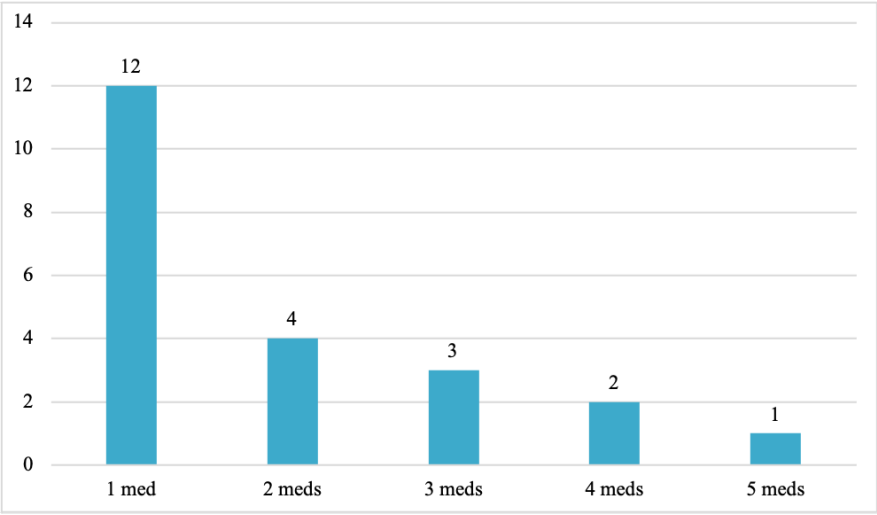

Figure 7.11: Number of medications added to MAMA accounts

Then, the *fifth question* asked: "Did MAMA help you take your medication on time?" More than half of the participants, 68.18% (N=15), answered "Yes", and 13.64%

(N=3) answered with "Somehow helped" and 18.18% (N=4) answered "No".

The *sixth question* asked "What features did you like the most?" This question was designed to allow more than one answer. The participants' answers to the sixth question were promising, as presented in **Table 7.4**. It is clear that the top ranked features were multiple reminders, medication report, daily generic reminder and scanning Rxs for auto-load of medication.

Table 7.4: MAMA features according to participants preferences

MAMA features	Participants choice	Percentages
Multiple reminders	13	59.09%
Stopped medication	3	13.64%
Scan prescription	7	31.82%
Medication report	9	40.91%
Contact GP	4	18.18%
Contact researcher	5	22.73%
Daily generic reminder	9	40.91%

The next questions, seven and eight, were a 5-star Likert scale with "Extremely useful" for the highest scale and "Not at all useful" as the lowest scale, in addition to the option of "not applicable" or "feature not used". The *seventh question* asked the participants to rate the scan Rx and auto-load of the medication feature: "How would you rate the Scan Rx and Auto-load of medication? (if you shared Rx with the DET)." More than half of the participants, 54.55% (N=12), did not use this feature to auto-load medication, one participant selected "Not at all useful" and one participant selected "Moderately useful", 13.64% (N=3) participants chose "Very useful" and 22.73% (N=5) participants selected "Extremely useful".

In the *eighth question*, they were asked to rate the multiple reminders. Of the participants, 50% (N=11) selected "Good", 31.82% (N=7) of participants rated this feature as "Excellent", 9.09% (N=2) selected "Fair" and 9.09% (N=2) participants chose "Inadequate" (see **Figure 7.12**).

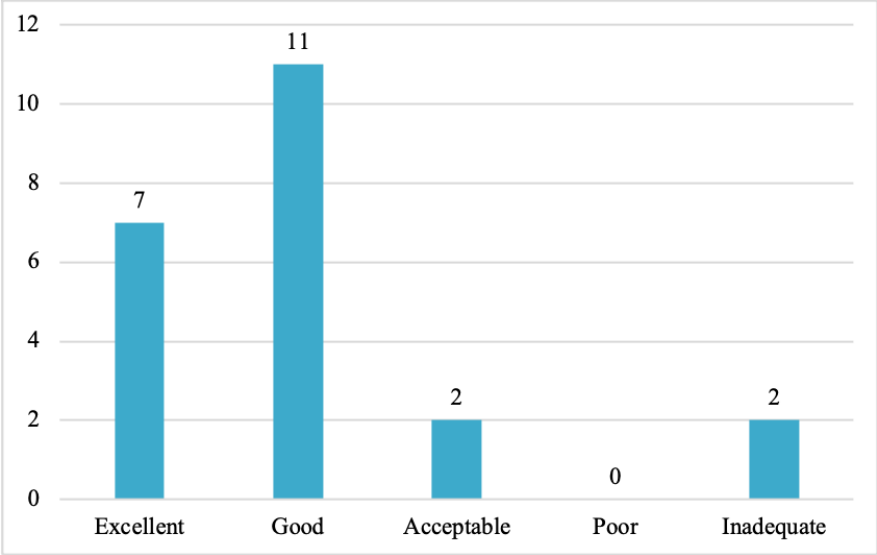

Figure 7.12: Multi-channel reminders rating

The *ninth question* asked which of the four reminder channels were more useful than the others from each perspective and they were given the option to choose more than one answer: The app "push notification" was highly preferred and selected by 62.07% (N=18) of the users. The second selected feature was "email reminder" with 27.59% (N=8), then the last two least selected were 6.90% (N=2) for "Phone call reminder" and 3.45% (N=1) for "Caregiver SMS" (see **Figure 7.13**).

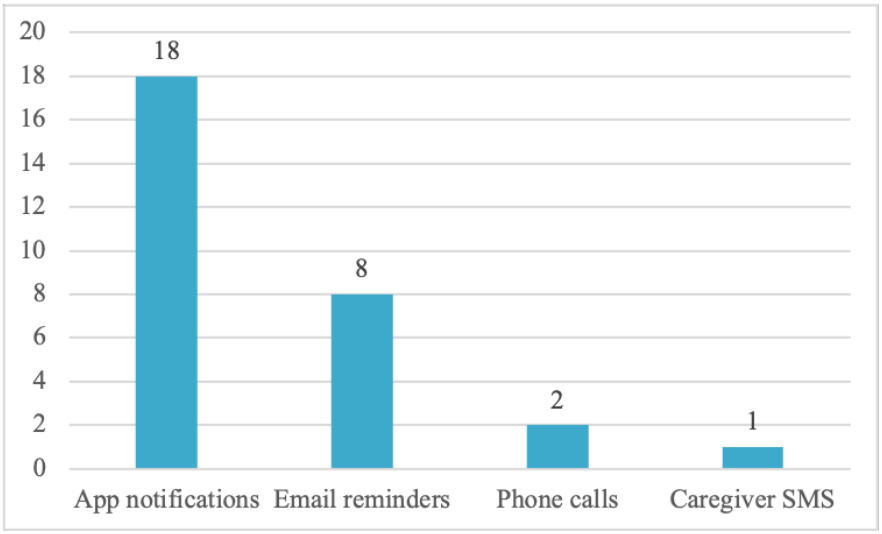

Figure 7.13: Reminders ranking

The *tenth question* was "How would you rate the Stop medication feature?" This feature was not used by 59.09% (N=13), and that's more than half of the participants. However, of the other nine participants, 22.73% (N=5) selected "Good" and 18.18% (N=4) selected the "Excellent" response.

The next two questions, eleven and twelve, asked the participants if they would recommend MAMA to their friends and if they would like GPs to recommend it to their patients. Both questions were followed by an open-ended question to allow elaborating on the choice given. The participants actively responded to *question eleven* "Would you recommend MAMA to your friends?" with 77.27% saying "Definitely", which represents 17 out of 22 participants, and 9.09% (N=2) responded with "Probably" and the same number responded with "Possibly". However, one participant chose the option of "Probably Not" recommending the feature to a friend, justifying the choice by having a personal daily routine that had been followed for years (see **Figure 7.14**).

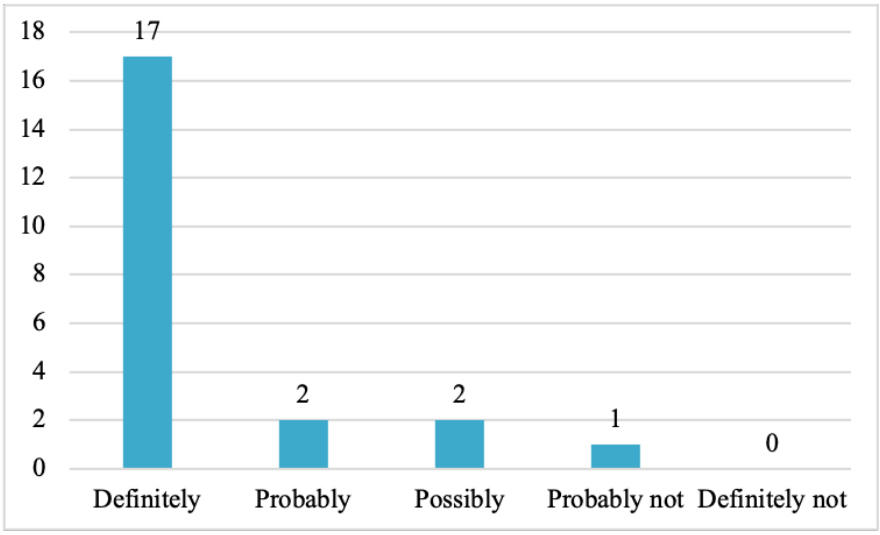

Figure 7.14: Participants responses when asked about recommending MAMA to a friend

For *question twelve* "Would you like the GP to recommend MAMA to patients?" 72.73% (N=16) of participants chose "Definitely", 13.64% (N=3) participants selected "Probably" and 9.09% (N=2) selected "Possibly", with the same participant as for the

previous question choosing "Probably not" with a similar justification of not benefiting from the app due to the routine followed (see **Figure 7.15**).

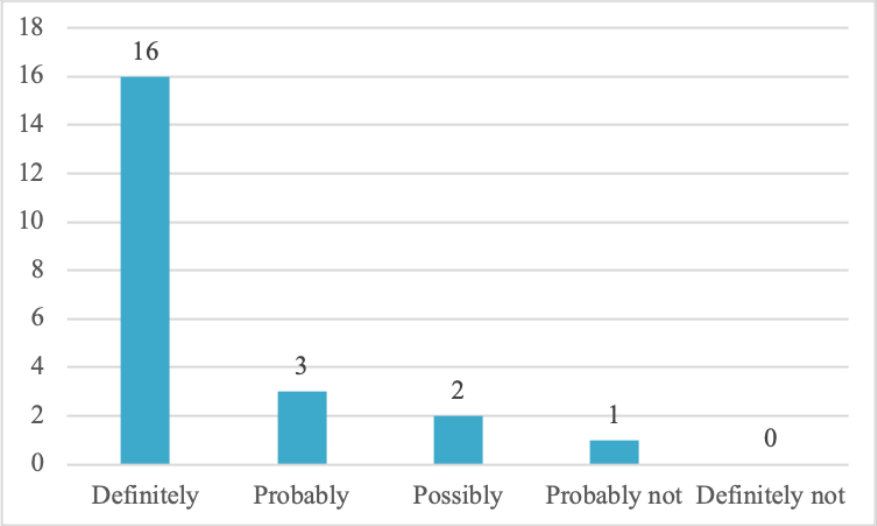

Figure 7.15: Participants responses when asked if they would like the GP to recommend MAMA to patients

Our participants had the chance to further comment and explain their views after giving their answers to the last two questions which we present in **Table 7.5**, as quotes from participants.

Then, *question thirteen*, the last question, was an open-ended question about the features they would like to add or replace to satisfy their needs: "To make MAMA satisfy your needs, please let us know what features would you like to add or replace in the app?", Eight participants said they didn't have any suggestions and that the app is "Great", "Excellent work", and "No need to add or replace features" (see **Figure 7.16**, for the words used describing the app) Others had some suggestions such as to have the push notification sent before the medication scheduled time, to remind them of having a scheduled dose after a certain time (i.e. a pre-reminder about 15 minutes earlier).

Table 7.5: Quotes from participants

Reasons for recommending MAMA to friends	Reasons GP recommending MAMA to patients
"I benefited a lot from the app. From my view it can be very useful for patients with chronic diseases" (*Participant A*)	"MAMA is a very effective app especially for people with a super busy schedule to remember to take their important medications" (*Participant B*)
"I can see the need for this if one has multiple pills to take. Time reminders are important for pill effectiveness. As mine was monthly, I forget to take it the same time every month" (*Participant B*)	"I will mention it to my GP because as I said it did not work for me (with established habit) but it may work for some other patients" (*Participant G*)
"It helps patient to be always in contact with GP as well as it always keeps both sides updated without the need for going to see the doctor which will be helpful for example during covid times" (*Participant C*)	"The medication report is a very nice feature. This can be a useful reference for both doctors and patients. This app can be helpful especially for doctors who need to work out whether the prescribed medicine is effective or not. The medication report is good evidence to refer to when making the judgement on the effectiveness of the prescribed medicines" (*Participant I*)
"Was able to use it with minimum efforts" (*Participant D*)	"A great tool in the hand of the GP to know how his patient is coping with the treatment" (*Participant H*)
"Old people like myself do need this kind of medication reminder, and this app helps" (*Participant E*)	"Ease of use across all age groups" (*Participant J*)
"It reminded me to take my medicine especially when I'm very busy at work" (*Participant F*)	"It is a great app that keeps remind you about taking medicine by email notification" (*Participant K*)

Figure 7.16: Words used in describing MAMA

In addition, one of the participants suggested the integration with other smart devices like Amazon Alexa, and they liked that they were able to receive the reminder on their Apple watches if it was connected to their iPhones. Other suggestions and feedback are summarised in **Table 7.6**.

Table 7.6: Features recommended by participants

No	Suggested Features
1	Capture the time the medication was taken if taken at a later time (ex: time >30 min late)
2	Audible alarm as a reminder
3	Refill reminder according to med logs
4	Add the options of taken or snooze on the push notification
5	To be able to use the NZEPS barcode to enter the medication details
6	Add filter to medication report (by status or date range)
7	Access the app through medical ID to view medication list for emergency reasons
8	Integrate with Siri or Alexa
9	App link is added to email reminder for ease of access

7.5 Discussion

The participants shared positive feedback about MAMA in general. Overall, they found it easy to use and thought it was useful in reminding them to take their medication on time. The data collected through the app indicated that participants used the system for most of the piloting period consistently. The same was concluded from the feedback showing that MAMA was well accepted by users. Participants started at different times over the two weeks, and some of the participants were already on a long-term medication plan, while others were at the end of their treatment period when the risk of non-adherence and discontinuation increases (Olfson, Marcus, Tedeschi & Wan, 2006).

There are two ways to measure MA: direct and indirect. The direct method is by measuring the concentration of the drug level in the blood (Brien et al., 1992). The indirect method is to use the patient refill record, which is the most appropriate method in the case of reporting patient adherence to a particular drug or health plan which does not account for taking the medication on time. The direct way does not fit with the purpose of our study. Also, with the indirect way, there is no refill period to base the calculations on. However, according to the American Pharmacists Association (APhA), most adherence is measured via claims data, and adherence can be wrongly represented using these calculations. Additionally, these methods do not take into account administration techniques or timing of dosing. For this reason, the best way to assess adherence is to get the medication intake reporting directly from the patient (Ministry of Health – Manatū Hauora, 2021). Hence, we have used the self-reporting way through medication intake reporting via MAMA and the questionnaire after the pilot period to report medication intake adherence.

There is no optimal level of adherence, as non-adherence differs widely, and in various studies it has been recorded as low as 10% and as high as 92% (Jimmy & Jose, 2011). According to an extensive review of the literature, the average adherence

to medication is 50% in developed countries (Jimmy & Jose, 2011). Furthermore, WHO revealed that patients' MA is generally considered acceptable if their adherence percentage is greater than 80% for the days covered (Brown & Bussell, 2011), and that was the metric percentage used to evaluate the results from the logged medication in this research.

While the main intention of this pilot was to evaluate the feasibility and acceptance of MAMA, it had an acceptable level of efficacy in improving users' medication intakes, with an average of 79% (SD= 0.21) adherence across all participants, ranging from as low as 26% and as high as 100%. These findings support the feasibility and potential utility of the app.

MAMA provides a novel approach to improving medication management and reminding of medication intake through multi-channel notifications, in particular for patients who need to take medication on time. The app targeted failure points in MA, including patient factors such as forgetfulness of pill taking and multi-medication management.

To better tailor the app to each age group, the results were examined across gender, age groups, previous experience, and the number of medications loaded into the app. From the medication intake logs, we closely examined a number of factors. These factors have been previously associated with adherence, such as age, use of technology, and the inability to manage multiple medications, as well as factors not investigated further, such as time of scheduled medication, user gender, and type of medication. In addition, the users' feedback on the developed new features and their recommendations were analysed and compared between age groups, number of medications, gender and adherence rate.

Evaluating adherence in relation to the participant's age was found to be relatively high >80% in participants in age groups three and four (i.e., 44-64 and 65+), and this was consistent with the findings from the feedback questionnaire when asked if MAMA

helped them take their medication on time. From that we conclude that the age variable did not have a statistically significant relationship with medication intake (p= 0.189). This corresponds with the study expectations, and with Krueger et al.'s (2015) research findings from their systematic literature review comparing older age groups' MA to that of younger aged people with newly-diagnosed conditions. Moreover, it corroborates the findings from a previous app-reminder study that investigated whether these apps work for different age ranges, and which concluded that age does not affect the usability and efficacy of the medication reminder apps (Fallah & Yasini, 2017). In saying that, the few participants from the same age group who had low adherence of < 50%, reported having issues with the technology. And several participants commented on receiving the reminder as a push notification, that they were not able to see it sitting under their notifications, which they did not check frequently.

During the pilot study period, we tried to provide one-on-one support when possible, specifically for downloading the app, modifying the medication details and setting notifications, to decrease the frustration that negatively influences acceptance. We found that the technical issues did affect the users' motivation in using the app and these findings align with the UTAUT2 extension mechanism discussing the relation between age and solving technical problems when they occur (Sudburya et al., 2013).

In addition, medication intake was compared between genders. Males were found to be more adherent to their medication compared with females, although they had a higher number of medications to take. This could be due to their health conditions as some diseases require more than 80% adherence to medication to achieve an effective treatment. However, our results contradict findings from another study conducted by Raum et al. (2012) that reported men's non-adherence as 37% while women's non-adherence was 19%. Yet, it corroborates with the research revealed by Torbjørnsen et al. (2018), showing that men benefited more than women in using the Type 2 diabetes app to improve their adherence.

Furthermore, comparing the number of medications per user, the adherence rate dropped to below 50% for some users taking more than three medications. This finding corresponds to the results from a study conducted by Benner et al. (2009), where the adherence rate dropped to 30% in patients taking two medications. That justifies the increased adherence to 100% in participants with once-daily dosing. This may be preferable for medications with multiple doses per day because minimising the frequency of dosing has been shown to improve adherence (Schroeder, Fahey & Ebrahim, 2004). Moreover, requiring multiple doses at different times of the day is expected to affect adherence levels because complex treatment regimens are associated with decreased adherence (Becker, 2015). This aligns with our findings of users with either morning or evening scheduled times, who had adherence ranging between 43% and 86%, whereas participants with a morning and evening dosage treatment plan had adherence ranging between 26% and 100%, although studies suggest that a 10% decrease in adherence will occur with each additional daily dose (Brown & Bussell, 2011).

Looking at the adherence rates, we believe the possibility of measuring participants' MA using the Morisky (1986) scale before the pilot, would have provided us with more insight into the participants' adherence before using the MAMA. Thus, this could be compared with results after using the app. The questionnaire was anonymised, so it was difficult to know the level of improvement for each participant after using MAMA. In saying this, however, the data logs collected through the app confirmed the feedback in general, when asked if the app helped them take their medication on time.

The app provides many features as detailed in **section 5.4** and summarised in **Table 6.1** such as *multi-channel notifications*, *medication acknowledgement*, *stop reminders for discontinued medication*, *medication reporting* and *auto-load of medication* to ease the process of adding medication manually by users. This feature minimises data-entry error especially with elderly participants, and also helps multi-medication

users. However, only six participants tested this feature, and they were the ones with more than three medications and multiple dosages a day. The participants scanned their medication details' sticker on the pillbox, in some cases (e.g., when a prescription was not available) and others sent their prescriptions to be loaded into their accounts through the MAMA Webform by the Rx DET.

The *multi-channel reminders* were triggered based on a workflow and pushed at the medication's scheduled time. This feature addressed patient factors such as forgetfulness and double dosing (as part of polypharmacy). The users responded to the reminders most of the time and generally favourably. We believe the multi-types of reminders also served to keep people reminded regardless of their varied daily plans and lifestyles. We found that the availability of the MAMA Webform played an important role in the process of adding to users' medication, because of its simplicity and ease of use. Although testing and evaluating the Webform by a healthcare provider was not part of this study, having the medication loaded for the participants was appreciated by the users, who benefited from it, and by users who read about it in the documentation of the MAMA. This is commensurate with a study conducted by Scott and McClure (2010), showing the importance of engaging healthcare providers to gain valuable insights into their patients' medication intakes. Moreover, the idea of a platform that can have the GP access their medication intake to help improve the medication plan was welcomed.

A previous study discussed the concern of notification fatigue, which can occur when notifications are repeated, and considered that auto-messages can become a noise for the recipient (Corden et al., 2016). Several participants appreciated the multi-channel reminders and suggested having one of the reminder types scheduled for 15 minutes before the medication's actual dosage time. Some participants did not like the use of tray notifications and pop-ups as a means of providing the first channel of reminders, although this was acceptable by the FG participants (presented in **Chapter 5**) and useful to others in this user testing. Two participants who suggested to have the call reminder

first, are the ones who took their medication when they received the email reminder, which was auto-scheduled (based on the workflow) 30 minutes after the medication time. To address this, one possible solution that we can suggest for future research is to give users more control over how they receive the multi-channel reminders, which would likely improve the system. For example, patients could choose to receive their first reminder via an automated phone call (scheduled 15 minutes before medication time), then a second reminder via tray notifications, then a third reminder as an email or text message. Three participants reported not receiving the push notification on their iOS phones; two of them were related to not enabling the notification or the notifications were on silent mode, and one participant had an old version of iOS and had to update it to be able to install the app. As mentioned earlier, these issues were related to technology.

Some participants reported adding their medication for two repeats per day, then by the second week this was changed to two doses per day and they were not able to delete one of the doses. This was intended to prevent patients from changing their dose without consulting the health provider, to not affect the treatment due to any random change (Bennadi, 2014). However, this restricted the users who had their plan to decrease the dose at a certain point in the treatment plan. This case was expected and addressed before the user testing, by adding a toggle button implemented to turn off/on the dosing schedule, which would also disable the notifications for that particular time.

Furthermore, for the individuals who reported during the pilot setting that they entered medication incorrectly, we were able to correct it through the database access. Another possible adjustment could be to give the option of editing the non-prescribed medication. Another reason for low adherence from a number of participants was the inclusion criteria, such as individuals interested in testing the MAMA although they had their traditional routine and no challenges with medication intake. This can be explained as the attitude towards the use of mobile technology in the health context, which was

not included in the original UTAUT model. Thus, this leads us to user acceptance of mobile technology in healthcare theoretical models UTAUT2 (Sudburya et al., 2013).

Concluding from the feedback questionnaire results, the acceptability of the app was not affected by users from the older age group and with more than one medication added into the app, although the majority of participants did not have prior experience with medication reminder apps. Moreover, users with medication reminder experience rated the functions as "Excellent", especially the multi-channel reminders and the stopping the medication option. Most of the participants responded positively to recommending MAMA to their friends and/or to have the GP recommend it to patients. Thus, MAMA is perceived as valuable to be recommended by GPs.

In spite of a few technical problems, the system functioned well. MAMA was easy for participants to use and they found it helpful. As shown in **Table 7.2** the relative index analysis numerical scores enabled us to compare the relative importance of the features as perceived by participants. The RII revealed that the multi-reminders feature is highly ranked thus it shows the participants agreed that the multi-reminders feature should be sustained in the app. The findings from this study support the further development and evaluation of MAMA in a randomised controlled pilot as well as in future research.

7.6 Summary of Chapter 7

This pilot study demonstrated the feasibility and acceptability of MAMA by individuals who were willing to improve their medication intake. We can confirm that medication reminder apps can improve medication intake when used purposefully. Our findings show promise for future implementation but should be considered with reservations. More than half of the participants participated in the pilot voluntarily and did not choose to receive a gift voucher. However, patients recruited for this pilot were those who would have likely been highly adherent regardless of the use of MAMA or due to their

commitment to use the app for the purpose of this study. Also, it was a single-arm pilot and no claims can be made about MAMA efficacy over a longer pilot period. Moreover, to our knowledge, none of the age groups' participants had a disability (e.g., recognised visual impairments or manual dexterity), which is known to be a barrier to technology acceptance (Venkatesh, Morris, Davis & Davis, 2003). Thus, no feedback was reported from this category.

Finally, reports show that MAMA was successful in improving medication intake. Therefore, as part of our future work we will be looking at involving the healthcare provider to pilot the Webform access with patients and to use the medication report to experience the whole proposed workflow. In our opinion, the findings will be broadly represented when conducted through clinical practice, or across some clinics either here in NZ or abroad. Thus, the focus needs to be on whether users as patients will continue to use MAMA over longer periods and derive clinical benefits, which we listed in **Chapter 8** as one of the points for future research.

Our next chapter will conclude this study and propose the future work. This will cover the sixth phase in the DSRM - Communication - as shown in **Figure 7.17**. **Chapter 8**, will reflect on the previous chapters and present the challenges and limitations we experienced throughout the study. We also propose what could be applied to overcome those challenges in the future work to improve the outcomes, and how it could be implemented in clinical settings.

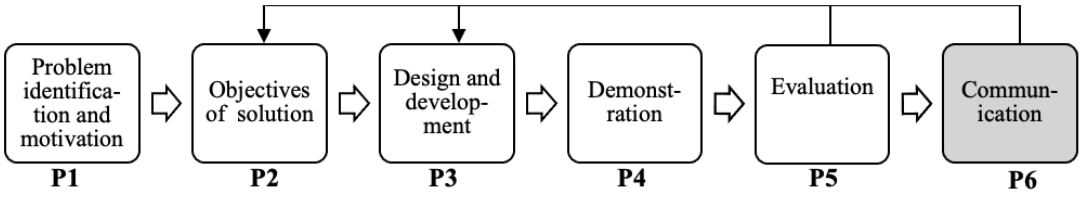

Figure 7.17: The sixth phase in the DSRM – Communication

Chapter 8

Conclusion and Future Work

"The goals of solving a real-world problem to achieve practical relevance, and developing a theoretical contribution to achieve scientific rigour can be combined." - Robert Gregory

This research aimed to investigate the use of digital technology in addressing MA by involving multidisciplinary experts and end users to understand their perspectives. The main research question of this study was: *How can digital technology improve users' medication intake?* Based on the quantitative and qualitative methods followed in exploring MA and the use of mobile technology to improve medication intake, we can conclude that MA mobile apps can improve medication intake when they are easy to use and perceived useful. Our results from the pilot study with end users in NZ indicate that end users can potentially accept and adapt these apps to remind them of their medication intake.

This chapter concludes this thesis by summarising the activities conducted in each phase of the DSRM, the achievements of the research objectives leading to answering the main research question and, ultimately, the sub-questions and contributions to the body of knowledge. We share our experience from conducting the research activities,

describing the challenges and limitations faced throughout the study and how we overcame them using alternatives. The rest of the chapter is structured as follows: In **section 8.1**, we present the introduction. In **section 8.2**, we summarise each chapter. **Section 8.3** presents the challenges we experienced and limitations we faced in conducting the activities throughout the phases of the study. Lastly, **section 8.4** presents the future work and suggested directions.

8.1 Introduction

MA can directly affect patient outcomes more than the specific treatment itself (Kim, Combs, Downs & Tillman, 2018). Yet, patients often forget to take their medication as prescribed, so they lean towards using different types of reminders (Alam et al., 2019). With the growth in mobile phone ownership, reminder apps are promising tools for delivering mHealth interventions but can be challenging for patients with different lifestyles or complex treatment regimens, resulting in forgetting to take medication on time (Santo et al., 2017; Tabi et al., 2019). According to Stawarz et al.'s (2014) review of mHealth apps' functionality, most apps are developed to provide only one type of reminder, usually in the form of push notifications. In a review by the Business of Apps (2019), reminders in the notification centre can easily be missed by individuals with busy schedules, which makes them not as helpful as they are supposed to be.

8.2 Chapters Summary

In this study, we employed a rigorous research process and methods to investigate mHealth apps and how they could be improved to suit users' needs for better MA. We adapted multiple models to guide our work, investigating our topic from multidisciplinary experts and end-users' points of view. We conducted our investigation from

two angles: theoretical and practical. Our study results were revalidated through our theoretical findings, other theoretical models such as UTAUT2, and other MA research.

We performed in-depth and insightful interactions with the data gathered from our participants. As a result of that process, we designed and developed MAMA to better serve patients who need to adhere to their treatment plans. MAMA was co-designed and evaluated through an iterative process and then piloted with end users who faced challenges remembering their medication or were keen to pilot a novel features app other than manual schedules and alarms to improve MA.

The design of the MAMA to collect users' personal details was carefully considered in terms of privacy and data security principles regarding how health information should be collected and stored. We followed the data privacy regulations of healthcare information, such as the Health Information Standards Organisation (HISO), Privacy Act 1993, Health Act 1956, and the Health Information Privacy Code 1994 (Ministry of Health – Manatū Hauora, 2021).

Our main three stages - RE, iterative co-design via FG, and piloting - shown in **Figure 8.1**, required separate ethics applications based on the risk level of the data collected. The approvals were obtained from AUTEC prior to beginning the recruitment process at any stage.

Through the conducted work, we met our objectives listed in **section 1.6** and achieved our study aim. Hence, we were able to answer our research question: *How can digital technology improve users' medication intake?* Each chapter produced outcomes that contributed to the body of knowledge and publications in the form of a conference abstract, conference paper, or a seminar presentation. Below, we review each of the chapters in this work, summarising the activities that led us to how digital technology is used to address MA, thus improving users' medication intake.

In **Chapter 1**, we introduced the background on the use of technology in approaching MA. Next, we explained the issues of poor MA and demonstrated its significance

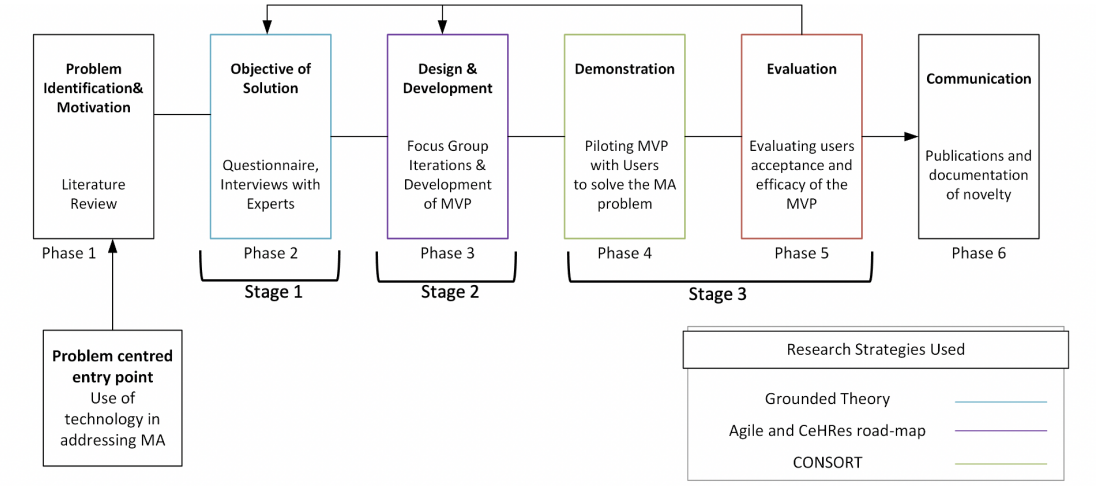

Figure 8.1: Study design phases adapting Peffers' (2007) model

and impact on the real world. This relevance motivated the research's technology-driven MA solutions, driving our contribution to the current body of knowledge. We also identified the scope of this study to address patient-related factors, such as forgetfulness and management of complex regimen. We drew our aim of the study to investigate MA approaches by involving multidisciplinary experts and end users to understand their perceptions of mobile app technology adoption to improve MA. To achieve the research aim, we formed our RQ to be: *How can digital technology improve users' medication intake?* Answering this question required articulating a set of objectives that helped us break down our study into several activities. The **outcomes** from this chapter were: (1) the significance of MA and its impact on the real world; (2) research scope and objective; and (3) the thesis structure and the chapters' orientation.

In **Chapter 2**, we presented the literature review on MA and how the use of technology addressed its issues and challenges, specifically the use of mHealth apps. We searched academic journals, commercial, and online news, articles, and magazines from the past ten years, then we filtered these according to the scope of our study.

We performed a comprehensive analysis of the literature, encompassing a critical

comparison of current medication management apps and an in-depth discussion of their limitations. We illustrated the issues and challenges of medication non-adherence. We presented the academic studies conducted on MA management. Then, we explored the technologies used in managing MA.

In addition, we explained the importance of managing MA via mHealth and the existing work achieved in this field. We re-evaluated the top five MA apps identified in previous research. We summarised the current state of digital health services in NZ and our preliminary findings and limitations from the literature. Lastly, we identified the gaps and refined our RQs. By the end of this chapter, we gained a clear understanding and a comprehensive view of what was missing and what needed to be studied further in improving MA apps to meet users' needs and to be easily accepted and adapted in their day-to-day life. This understanding and process allowed us to expound further on our contributions to the current body of knowledge. The **outcomes** produced from this chapter were: (1) a comprehensive literature review on MA; (2) the limitations of previous studies; and (3) cultivated research gaps and refined RQs.

In **Chapter 3**, we introduced the pragmatist worldview that underpinned this research. We presented the DSR methodology approach followed in conducting the research activities throughout the six phases introduced by Peffers (2007) as shown in **Figure 8.2**. We then explained how each phase contributed to achieving the objectives and answering our main RQ. We introduced and detailed our mixed-methods approach in collecting and analysing the data, where we followed a **complex sequential exploratory** design. Thus, we used multiple and mixed methods to collect data at different phases of the study. This chapter was the backbone and the blueprint of the whole study, as it guided us through the investigation of MA and the use of a technology-driven solution to improve it. At this stage, we were able to identify which phase required ethics approval and whether multiple applications were needed. In structuring the sections of this chapter, we followed Creswell's (2007) advice:

To make the information clear to the reader, the structure of a mixed-method study should mirror the design used.

This chapter contributed to the body of knowledge by filling the gap in the literature (presented in **Table 2.5**). In terms of theory consideration, we had the UTAUT2 model underpinning our study, which we used to compare our trial results against at the end of the study (pre-design and post-trial), in addition to our MA model grounded on participants' perceptions. Two main **outcomes** were produced from this chapter: (1) a research methodology as a blueprint to guide our research throughout the study and (2) the data collection and data analysis methods.

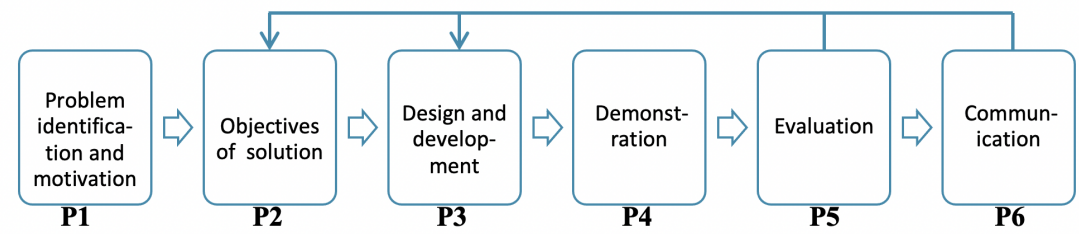

Figure 8.2: DSR model

In **Chapter 4**, we explored how MA is approached in NZ and investigated views on approaching MA using mHealth apps from a multidisciplinary expert perspective. This phase of the DSR methodology followed a sequential explanatory mixed-method consisting of two phases: *quantitative* then *qualitative*. Mixing and integrating the data was performed at two different points. In the *first phase* (quantitative), we gathered the requirements for MA app features through a questionnaire completed by 253 participants. The top recommended features were educational content, reminders, notifications, chat/communication, patient feedback, and calendar. The results from this phase needed clarification and explanation to gain a deep understanding of what was suggested by participants. We designed phase two (qualitative) questions based on the results from phase one and purposefully invited participants to further elaborate

on their answers. In this phase, we gathered further explanations from experts during the in-depth semi-structured interviews. The 22 participants interviewed in this study were concerned about poor MA, which, according to them, prevents patients from fully benefiting from their prescribed medications. The healthcare professionals expressed concerns about the consequences of not taking medication as prescribed and the resulting risk of failing to achieve the expected improvements in health outcomes within a specific period.

The pharmacists stressed the importance of having patients uplift prescriptions on time and preventing wastage of medication through medication literacy. The technology designers and researchers were interested in utilising technology to solve some problems related to time constraints, human errors, and accessibility.

From the interviewees, many ideas were postulated to mitigate the problems caused by poor MA. Some key insights included: (1) the *patients' ability* to engage in their courses of treatment; (2) *collaboration* among members of healthcare teams; (3) *medication use*; and (4) *acceptance and simplicity of technology* usage. The strength of this phase was our comprehensive sampling of participants, which included healthcare professionals in direct contact with patients and health technology designers experienced in developing technological tools for patients. The interviews were analysed to define the underlying themes and categories. Our *second mixing and integration* of data occurred while discussing the outcomes of this activity and building our MA conceptual model. Such mixing of the quantitative and qualitative aspects results in a higher quality of conclusions (Schoonenboom & Johnson, 2017). The categories were translated into features to implement in the MA app wireframe. We considered checking for the reliability and validity of the proposed wireframe by evaluating it through a subset of the participants from the two phases. We had to validate the results and make sure the wireframe reflected the participants' input. The **outcomes** from this chapter were: (1) a technology-driven MA conceptual model; (2) a mobile app wireframe, given

the name MAMA. This phase answered RQ1 and RQ2 and **contributed** to the body of knowledge in two ways: first by filling the gap identified in the literature (presented in **Table 2.5**), secondly by developing a theoretical model of patients' MA dynamics, which future research can use as a guide. The work conducted in this chapter resulted in a conference publication (Chanane et al., 2019).

In **Chapter 5**, we co-designed MAMA with end users through FGs in an iterative process. Each iteration feedback improved MAMA to serve the users' needs. As mentioned in Chapter 3, this study follows a complex mixed-method approach, in which we are able to utilise different data collection methods at different phases to serve the purpose of our research. Therefore, we utilised CeHRes road maps for the eHealth design and development process (van Gemert-Pijnen et al., 2011). We presented a working prototype of MAMA to end users who either had experience with medication reminder apps or were taking medication and were keen to participate in one of the three FG sessions. The feedback elicited informed our final MAMA MVP design, which resulted in the outcome of this chapter. The participants suggested several ideas to resolve the challenges of medication reminder apps' usage and discontinuity. We analysed the data collected from each FG using event frequencies. Furthermore, we examined the feedback from each iteration, and the amendments were applied to the prototype accordingly. Moreover, the feedback from the three iterations was categorised based on their relativity. We grouped similar categories into general themes, which helped us translate those themes into functions to implement in MAMA. The implemented features were: (1) *multi-channel reminders*; (2) *medication intake acknowledgement and reporting*; and (3) *smart loading of medication into the app*, as novel features. We achieved the **objectives** of demonstrating and evaluating the prototype through FGs. The **outcomes** from this chapter were: (1) results of three iterations of the FGs; (2) discovery of features to achieve sustained usage of MAMA; (3) MAMA MVP built through an iterative design and implementation process; and (4) an updated version

of MAMA incorporating the co-design results. This phase **contributed** to the body of knowledge by identifying novel approaches to improve MA. The work conducted in this chapter resulted in a conference publication (Chanane et al., 2020).

In **Chapter 6**, we presented the work conducted to develop MAMA by implementing the requirements gathered from multiple phases of RE, including iterative FG sessions. We developed MAMA via several iterations, and here we demonstrated the entire system development, including the incorporation of feedback from the FG iterations. Our objective was achieved by customising our solution, due to the limitation of modifying the existing apps. MAMA is different from the available apps not only in functionality but also in its unique features, as presented in **Table 5.10**, which were grounded in user's needs. While developing MAMA, we ensured that it provides value to users and is technically sound.

We ensured that these two equally essential elements must be valid when building MAMA to be successful. As a result, we achieved the **objectives** of developing a medication management MVP. The **outcomes** of this chapter were: (1) translation of requirements into a working app; (2) three iterations of user feedback, development and testing; and (3) the effective tools and functions used to produce the final app. In addition, this phase **contributed** to the body of knowledge by providing the key steps, tools used in the development and presentation of what worked best and the reminders workflow postulated from the theoretical phase.

Chapter 7 presents the piloting of MAMA with end users for two weeks to evaluate its feasibility, user acceptance and efficacy. We designed MAMA with the primary goals in mind of addressing (1) *the failure of taking the scheduled medication on time*; (2) *ease of use and age-related data entry errors*; and (3) *management of multi-medication use leading to pill burden*. We used a qualitative exploratory questionnaire to evaluate the feasibility and user acceptance of MAMA. We recruited participants to pilot MAMA with their medications. We collected data in two ways: (1) via MAMA, and (2) through

the evaluation questionnaire during the pilot. Before we started the analysis, we had in-depth and insightful interactions with the data for a meaningful interpretation. We analysed the users' daily usage of the app and calculated and illustrated their adherence rates.

In addition, we interpreted their acceptance of technology based on their feedback and suggestions for improvement. We were able to conclude its significance to theory and practice and to identify our future research accordingly. Our findings show promise for future implementations. More than half of the participants voluntarily participated in the pilot and did not choose to receive a gift voucher. We achieved the **objectives** of evaluating the feasibility, user acceptance, and efficacy of the app through a pilot study with medication users. The **outcomes** from this chapter were: (1) feasibility and acceptability evaluation of MAMA from end-users' perspective; and (2) early adopters' feedback and recommendations for future development and enhancements. This phase answered RQ3 and **contributed** to the body of knowledge by providing a practical and theoretical angle, conveying a comprehensive view of end-users on MA apps and their foreseen future needs. This chapter also filled gaps in the literature (presented in **Table 2.5**): first, the trial was not idealised, thus, the possibility of biased results was minimal. Secondly, we involved the end-users in designing MAMA through co-design focus group sessions to address their current and expected future needs. We also created a novel way of reporting adherence unlike most studies by providing a survey at the end of the trial. We accumulated our user's adherence report from the data collected through the medication intake acknowledgement and the survey to achieve an in-depth analysis of their adherence. The work conducted in this chapter resulted in an article (Chanane & Mirza, 2021).

In **Chapter 8**, we demonstrated the achievements of this study. Our research contributes to the current body of knowledge and will inform future researchers in the field, who can use our work and findings as a starting point for their future research.

Sharing our experience can guide other researchers on what worked well, clarify the challenges and how we overcame them, and identify limitations that could set goals for future work.

This chapter concludes this thesis by summarising the achievements of the research objectives leading to answering the main research question and, ultimately, the sub-questions and contributions to the body of knowledge. We present the challenges experienced and limitations faced throughout the study, how we tried to overcome them using alternatives, and our suggestions for further research to benefit future studies. We achieved the **objectives** of documenting the novelty of our research and communicating the research output through publications.

8.3 Research Challenges and Limitations

The overall challenge we faced in conducting this research was the research write-up, making sure we have documented all the activities and presented them in sequence to make them clear and simple to our readers. Other challenges related to data collection and activities across the research phases are identified below:

1. Reaching experts in the field - health experts who are involved with health innovation and eHealth - to complete the survey: Therefore, we requested assistance from the HiNZ marketing team by having our research at its early stages posted in their newsletter. We achieved a very good number of participants who were at the forefront of this research in NZ. Next, we approached leaders in the health industry and healthcare experts through LinkedIn by targeting those who had experience with MA programmes in NZ, which was not simple, as some of them considered LinkedIn as a social media tool and not for research recruitment. From this, we gained a sufficient number of participants to interview. Their feedback and interest in informing our research on how they approached patients with MA

issues was invaluable. We believe their input during the interviews was sufficient to conclude that they appreciate a solution that could help patients take prescribed medication on time and keep healthcare providers informed.

2. The technical aspects, which involved the development of MAMA system: Dealing with multiple technologies within the same project was also a challenge. Ideally similar projects would involve a multidisciplinary team. However, for a PhD study it was an extraordinary level of work involved which was challenging to scope within the given time frame for a PhD study.
3. Selecting the app development tool: We first started with Ionic 2 and Cordova at the prototype stage, but there was a lack of support for these tools, and we preferred to pursue one that would cater to users of both iOS and Android. We searched for other tools and obtained the advice from experts in app development, eventually choosing React Native. Choosing the database to store the data was another hurdle to cross. Google Firebase Database was chosen due to its flexibility, user friendliness, and ability to update data in realtime.
4. The timing of the pilot study: as it was during COVID-19, a difficult year for everyone, and we believe this affected our ability to reach people to participate. We had some potential participants who were not in the country, or who were not able to take part in the study due to personal circumstances. We also had individuals who replied to the invitation two months after we concluded the pilot study, and some participants' situations did not allow them to commit to the pilot, which was beyond our control.
5. Including all the medication attributes to accommodate all types of medication was complex. So, to overcome this we had as our start point the attributes included in our NZ prescription, then we added the attributes raised and discussed in the focus groups.
6. The reminders order in the multi-channel notifications workflow was a point of

discussion; i.e., which notification to start with. We went with the default app push notification first, then the email reminder which could be a reminder that can be received through any other device other than their phone. Then, we had the auto-voice call reminder, and the last channel was the caregiver's SMS.

7. The reminder for long term medication was not included so we had to adjust when adding medications. The trial was for two weeks only, so even if the participants had long-term medication added, we had to schedule it only for those two weeks.

The study limitations were as follows:

1. Piloting MAMA and MAMA Webform with patients through a GP clinic or a Pharmacy.
2. Involving the participant's healthcare provider or pharmacists within the trial.
3. Integrating MAMA with the NZ health system or pharmacy.
4. Connecting MAMA Webform with the medication database.
5. Providing face-to-face support to participants who had challenges with using the technology.

8.4 Future Work

This section provides suggestions for future research and directions according to the pilot study participants' feedback and our conclusions from interacting with the participants through focus groups and the trial; discussions with experts in the field of health informatics; and from the experiences and lessons learnt throughout this PhD study. Here, we list points that we believe to be significant for future research:

1. Potential improvements in app development techniques to achieve better performance and simpler data retrieval systems: Consideration is needed for integration

with NZ big systems that can be accessed by multiple stakeholders and support the wider community.

2. Involving a third-party to integrate MAMA with the health system, pharmacy system, ACC, and dental clinics as a plug-in.
3. Piloting MAMA through a pharmacy with patients enrolled into the NZ adherence programme.
4. Extending MAMA to address other adherences affecting the individual's health and well-being in general, not only MA. We have researched The National Institute for Health Innovation's research on eHealth and mHealth, and we believe there is a good opportunity to advance our research by seeking specialist advice to bring our research ideas to life in a collaborative project.
5. Continuation of design iterations to implement the proposed features suggested by the actual users of the app to help benefit from its use: This will help its sustainability and increase its acceptance among different age groups, especially as mobile apps are now widely used in social media, reaching 3.60 million NZ users in January 2020; however, they are used less in the health context.
6. Adoption of a new generation of technology, possibly Alexa or Siri, could be considered.
7. Integrating MAMA with the SmartPill, this could record directly into the MAMA system.
8. Integrating MAMA with Apple medical ID to view medication lists in for emergencies.
9. Integrating MAMA system with hospital admissions, whereby if patients have checked out and have not taken their medication within 24 hours, it will flag the hospital admission system about the possibility of the patient returning.
10. Extending MAMA to include automated repeat prescriptions according to patients' adherence report, which will help in reducing medication wastage.

11. Extending MAMA to insert a flag in the patient record in the GP system if adherence rate is low or in the case of the patient discontinuing the prescribed medication.
12. Extending MAMA to use the NZEPS barcode to enter medication details from the original script.
13. Extending MAMA to include a filter for the medication acknowledgement report by status or date and add a link to MAMA in the email reminder for ease of access.
14. Extending MAMA to capture the time of the late medication intake to include in the medication report.
15. Generalising MAMA to allow integration and implementation within an international framework and settings.
16. Extending MAMA to cover veterinary for better animal healthcare management.

8.5 Summary of Chapter 8

In this study, we demonstrated the beauty of combining Design Science Research methodology with the Grounded Theory model and employing mixed methods. We connected the goal of solving a real-world problem to achieve practical relevance by developing a theoretical contribution to achieve scientific rigour and contribute to the body of knowledge. Mixed methods research brings together qualitative and quantitative methods and presents multiple ways of integrating them. We also aimed to ensure that the study's findings were grounded in participants' experiences, which gives a voice to the study's participants. We tried to contextualise patient experiences to improve our studies and enrich our understanding of the problem and the questions raised, thereby adding value and contributing to advancing our research topic. Our selection of mixed-methods research allows an understanding of MA challenges and their complex aspects,

which can not be achieved using either one approach alone. Our better understanding was obtained by triangulating one set of results with another to enhance the validity of our conclusions.

Referring back to the NZ digital health strategic framework in **section 2.11**, we were able to adopt a person-centred approach, with the end users primarily driving the design, development, and implementation of MAMA as the digital resource.

From the five main goals of the digital objectives, we showed that the outcomes of our study aligned with three of those goals: (1) *people are in control of their health information*; (2) *digital services enable health providers to deliver better services*; and (3) *data insights provide evidence to make and support informed decisions*.

In conclusion, we recommend adopting MAMA, a simple mobile app that can be used as a stand-alone app or as a plug-in, where other health systems or other apps can benefit from its features, such as the NZ Zoom Pharmacy app. Implementing an MA app with its sustainability in mind is achieved by utilising an infrastructure that is secure, stable, and agile so that it can be deployed quickly with minimal interruption to patients, caregivers, and healthcare professionals.

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Appendix A

Glossary

Activity Activity refers to what we have conducted to achieve our project aim.

Artefact An artificial refers to a product that help describe the function, architecture, and the design of the application.

Co-design Co-design which can also be called a participatory design, and it refers to the act of creating our prototype with end-users specifically within the design development process to ensure the results meet their needs and are usable.

Digital health ecosystem The term 'digital health ecosystem' refers to the complex network of interactions between the individuals, organisations, technologies, information and resources that make up the health sector. The ecosystem concept is the basis for understanding how we can best intervene and guide action in the health system as defined by the New Zealand Ministry of Health.

Experts Experts refer to the multidisciplinary individuals from Clinicians, GPs, Pharmacists and Researchers who participated in our research study.

Iteration An iteration refers to the repetition of a process in order to generate our MVP. Each repetition of the process is a single iteration, and the outcome of each iteration is the starting point of the next iteration.

Instrument An instrument refers to the tool used to collect, measure, and analyse data

related to our research activities.

Mixed-method A mixed methods refers to the "mixing" of both quantitative and qualitative research methods as a procedure for collecting and analysing data in a single study to understand a research problem.

MVP A minimum viable product is a version of a mobile application product which we developed with just enough features to be usable by early users who can then provide feedback for future product development. We tried to avoid lengthy and unnecessary work.

Multi-channel A multi-channel refers to several channels to communicate the same message, which in our context is the multiple ways of reminding end-users to take their medication on time.

Process A process refers to a series of actions which are carried out in order to achieve our research objectives.

Participant A participant is referred to the individuals who were involved or participated in an activity or event at any stage of our study.

Prototype A prototype is an early sample of a product built to test a concept or process. It is generally used to evaluate a new design to enhance precision by developers and users. Prototyping serves to provide specifications for a real, working system rather than a theoretical one.

Smart loading Smart loading refers to adding medication to the users MAMA app account with minimum effort. Where the medication is added by the researcher for the study purpose.

Stopped medication Stopped medication refers to the discontinuation of a medication treatment for a patient by either the clinician or the patient them self. However, when initiated by the clinician, it is known as deprescribing.

Sketch A sketch refers to a simple drawing which can be a preliminary, giving the essential features without the details.

Trial A trial refers to testing our prototype over a limited period of time, to discover how effective or suitable it is for end-users.

User Manual A user manual refers to the document we created which contains all essential information for the user to make full use of the MAMA app. This manual includes a description of the MAMA functions and capabilities and step-by-step procedures for MAMA access and use.

Worldview A worldview is defined as basic set of beliefs that guide our actions.

Appendix B

Abbreviations

ACC Accident Compensation Corporation

AUTEC Auckland University of Technology Ethics Committee

AUT Auckland University of Technology

APhA American Pharmacists Association

APP Application

CONSORT Consolidated Standards of Reporting Trials

CeHRes Centre for Health Research

DET Data Entry Tea

DSRM Design Science Research Model

DHE Digital Health Ecosystem

eHealth Electronic Health

EA Ethics Application

EMERGE European Society for Patient Adherence, Compliance and Persistence

FCM Firebase Cloud Messaging

FG Focus Group

GP General Practitioner

HISO Health Information Standards Organisation

HiNZ Health Informatics New Zealand

IT Information Technology

IS Information System

MA Medication Adherence

MARS Medication Application Rating Scale

MVP Minimum Viable Product

mHealth Mobile Health

MAMA Medication Adherence Management Application

MMSE Mixed-Methods Sequential Explanatory

NHI National Health Index number

NZHIT New Zealand Health Information Technology

NZePS New Zealand ePrescription Service

OSN Online Social Communication

PQA Pharmacy Quality Alliance

PDC Proportion of Days Covered

RE Requirements Elicitation

RQ Research Question

Rx Prescription

RII Relative Importance Index

TAM Technology Acceptance Model

UI User Interface

UTAUT Unified Theory for Acceptance of Technology

UX User experience

Appendix C

Ethics Approvals

- Stage 1: Application 17/372 A technology driven approach for improving patients medication adherence: A pilot study
- Stage 2: Application 19/343 A focus-group co-design and evaluation of an mHealth medication adherence application
- Stage 3: Application 19/343 Smart reminders to improve medication intake

AUTEC Secretariat

Auckland University of Technology
D-88, WU406 Level 4 WU Building City Campus
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

13 November 2017

Farhaan Mirza
Faculty of Design and Creative Technologies

Dear Farhaan

Re Ethics Application: **17/372 A technology driven approach for improving patients medication adherence: A pilot study**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved in stages for three years until 13 November 2020. This approval is for the first stage of the study only and full information about the other stages needs to be submitted to and approved by AUTEC before participants are recruited or data collected for the other stages.

Standard Conditions of Approval

1. A progress report is due annually on the anniversary of the approval date, using form EA2, which is available online through http://www.aut.ac.nz/researchethics.
2. A final report is due at the expiration of the approval period, or, upon completion of project, using form EA3, which is available online through http://www.aut.ac.nz/researchethics.
3. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form: http://www.aut.ac.nz/researchethics.
4. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
5. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.

Please quote the application number and title on all future correspondence related to this project.

AUTEC grants ethical approval only. If you require management approval for access for your research from another institution or organisation then you are responsible for obtaining it. You are reminded that it is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

For any enquiries, please contact ethics@aut.ac.nz

Yours sincerely,

Kate O'Connor
Executive Manager
Auckland University of Technology Ethics Committee

Cc: , nawal.chanane@aut.ac.nz; Asif Naeem

Auckland University of Technology Ethics Committee (AUTEC)

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13 September 2019

Farhaan Mirza
Faculty of Design and Creative Technologies

Dear Farhaan

Re Ethics Application: **19/343 A focus-group co-design and evaluation of an mHealth medication adherence application**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 13 September 2022.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted. When the research is undertaken outside New Zealand, you need to meet all ethical, legal, and locality obligations or requirements for those jurisdictions.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

Yours sincerely,

Kate O'Connor
Executive Manager
Auckland University of Technology Ethics Committee

Cc: nawal.chanane@aut.ac.nz; Asif Naeem

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23 April 2020

Farhaan Mirza
Faculty of Design and Creative Technologies

Dear Farhaan

Re Ethics Application: **19/343 Smart reminders to improve medication intake**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

The third stage of your ethics application has been approved for three years until 23 April 2023.

Non-Standard Conditions of Approval

1. Please ensure that the data will be kept securely on a data storage device on AUT premises for 10 years; and an update of the Information Sheet to reflect this

Non-standard conditions must be completed before commencing your study. Non-standard conditions do not need to be submitted to or reviewed by AUTEC before commencing your study.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: nawal.chanane@aut.ac.nz; Asif Naeem

Appendix D

Tools for EA stages

D.1 Tools for EA Stage 1: Questionnaire and Interview

a) Email invitation - Questionnaire

b) Participant information sheet and consent form

c) Questionnaire questions

d) Email invitation - Interview

e) Participant information sheet

f) Consent form

g) Interview questions

Invitation to participate in a Survey

Dear *[Potential Participant],*

My Name is Nawal Chanane, a PhD student at Auckland University of Technology (AUT), School of Engineering, Computer and Mathematical Sciences. I would like to invite you to participate in a Medication Adherence Research Study Survey.

This research seeks to contribute to improving medication adherence by providing solutions to engage patients to optimize medication self-management and avoid what leads to poor clinical outcomes, low quality of life and increased health care costs.

We appreciate your assistance in this process and request that you access the survey link below at your earliest convenience, no later than the 1st of December 2017.

If you have any questions regarding the survey process or experience any technical difficulties, please contact me at nawal.chanane@aut.ac.nz

Follow this link to the Survey:

Take the Survey

Or copy and paste the URL below into your internet browser:
https://aut.au1.qualtrics.com/jfe/form/SV_20iTOY0AOcemMvz?Q_DL=1TgUWsr0Gr4WADj_20iTOY0AOcemMvz_MLRP_0VA3HXstRs7Woq9&Q_CHL=email

Prize Draw
By taking part in this survey you could win a $50 Prezzy Card. Please enter your email address at the end of the survey.

Thank you for your participation

Regards,

Nawal Chanane

A Technology-Driven Approach for Improving Medication Adherence: A Pilot Study

Start of Block: PART 1

Thank you for taking the time to fill out the survey for my project: **A Technology-Driven Approach for Improving Medication Adherence: A Pilot Study**

My name is Nawal Chanane and I am a PhD student in the School of Engineering, Computer and Mathematical Sciences at Auckland University of Technology. I am conducting this study as part of my PhD research.

The purpose of this research:

Although taking medication may be seen as a task that can be easily added to a daily routine, for many patients it is a constant reminder of their illness. Additionally, some patients find it difficult to follow the instructions as prescribed by their healthcare providers. Patients who do not take their medication as prescribed are likely to face poor clinical outcomes, low quality of life and increased healthcare costs. Therefore, supporting New Zealanders with long-term disease to self-manage their medication to be taken on-time is the focus of my research. The study will explore your input, of which features can be included in a mobile application to improve patients' medication management. The findings from my research will be included in my PhD, research publication in peer-reviewed Health Informatics journals and conference papers and presentations.

How was I identified and why am I being invited to participate in this research?

I have identified your details from health point New Zealand website or LinkedIn. And you have been selected to participate because you work in a health organization or work in an organization that develops ICT products or services for a health organization.

How do I agree to participate in this research?

By selecting "Yes" in the online survey, when you are asked if you would like to proceed. Your participation in this survey is voluntary and you may withdraw at any time before you hit the "submit" button.

What will happen in this research?

This phase involves you responding to online questions related to your thoughts about medication management for long-term disease, which consists of 7 questions and will take approximately 5-7 minutes to complete.

What are the discomforts and risks, and how will they be alleviated?

I do not anticipate you will experience any discomfort or risk. During the survey, you do not have to answer the question you feel uncomfortable about.

What are the benefits?

Firstly, you will be contributing to increase our knowledge of how to improve medication management using mobile app.
Secondly, my research also seeks to inform individuals, health providers and pharmacists how to tackle the adherence dilemma. This information will be useful to design tailored apps. Finally, this research will be included in my PhD, research publication in peer-reviewed Health Informatics journals and conference papers and presentations.

How will my privacy be protected?

No identifiable information will be collected and the responses to the survey will be totally anonymous. Data will be maintained on a secure online server and confidentiality will be maintained at all times.

What are the costs of participating in this research?

Approximately 5-7 minutes of your time if you choose to complete the online survey.

What opportunity do I have to consider this invitation?

Please read the information sheet and if you have any questions please contact me through my email: nawal.chanane@aut.ac.nz. You can start the survey any time and to be completed no later than **28th of February 2018.**

Will I receive feedback on the results of this research?

If you would like to receive a summary of the findings, please tick the appropriate box before submitting the survey.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor,

Farhaan Mirza, farhaan.mirza@aut.ac.nz, (09) 921 9999 ext 5868.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, ethics@aut.ac.nz , 921 9999 ext 6038.

Whom do I contact for further information about this research?
Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Nawal Chanane, nawal.chanane@aut.ac.nz

Project Supervisor Contact Details:

Farhaan Mirza, farhaan.mirza@aut.ac.nz, (09) 921 9999 ext 5868.
Muhammed Asif Naeem, mnaeem@aut.ac.nz, (09) 921 9999 ext 5083.

I have read and understood the information provided by the researcher in regards to this project and consent to the collection of my responses.

By taking part in this survey you could win a $50 Prezzy Card. Please enter your email address at the end of the survey. Your email address will not be linked to your responses, which will remain anonymous.

- ○ Yes, I would like to start now (1)
- ○ No, I prefer accessing survey later (2)

Q1: Before starting the survey, please choose your role:

- ○ Health Provider (1)
- ○ Pharmacist (2)
- ○ Health Planner (3)
- ○ Health Technology Developer (4)
- ○ Other (7) _____

Q2: Which region do you work in?

▼ Northland (1) ... Southland (16)

Q3: Do you think patients need to be reminded for taking their medication?

- ○ Yes (1)
- ○ Maybe (2)
- ○ No (3)

Q4: How many times a day the patient should be reminded?

- ○ Once - End of the day (1)
- ○ Twice - midday and evening (2)
- ○ A reminder should be based on medication prescription (4)

Q5: Do you think the daily activities or diet will affect medication adherence?

- ○ Yes (1)
- ○ Maybe (2)
- ○ No (3)

Q6: Do you think two-way communication between the patient and health provider will improve medication adherence?

- ○ Yes (1)
- ○ Maybe (2)
- ○ No (3)

End of Block: PART 1

Start of Block: Block 1

Q7: If a mobile application is designed to improve medication adherence. What would be the best feature to be added other than a reminder?

_____

_____

_____

_____

_____

End of Block: Block 1

Invitation to participate in an Interview

Dear *[Participant Full Name],*

My Name is Nawal Chanane, a PhD student at Auckland University of Technology (AUT), School of Engineering, Computer and Mathematical Sciences. I would like to invite you to participate in a Medication Adherence Research Study.

This research seeks to contribute in improving medication adherence by providing solutions to engage patients to optimize medication self-management and avoid what leads to poor clinical outcomes, low quality of life and increased health care costs.

It would be highly appreciated if you take few minutes to read through the information sheet and consent form. You will be contacted by a phone call after two weeks from receiving this email to set the date, time and meeting location. The interview will be for 30 minutes approximately, and your participation is voluntary and you may agree or disagree at any time before the interview. During the interview, you do not have to answer a question if you feel uncomfortable about it. You may stop and leave the interview at any time.

During the period of this research, your consent form, contact details, discussions, and data will be kept confidential. All data will be stored securely and disposed of through the university document destruction service.
If you have questions regarding the interview, please feel free to contact nawal.chanane@aut.ac.nz.
Thank you.

Regards,

Nawal Chanane

Participant Information Sheet

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

For Interview

Date Information Sheet Produced:

26/ 01/2018

Project Title

A Technology Driven Approach for Improving Medication Adherence: A Pilot Study

Researcher Introduction

My name is Nawal Chanane and I am a PhD student in the School of Engineering, Computer and Mathematical Sciences at Auckland University of Technology. I am conducting this study as part of my PhD research. I would like to invite you to participate. This information sheet will help you decide to take part.

What is the purpose of this research?

Although taking medication maybe seen as a task that can be easily added to a daily routine, for many patients it is a constant reminder of their illness. Additionally, some patients find it difficult to follow the instructions as prescribed by their healthcare providers. Patients who do not take their medication as prescribed are likely to face poor clinical outcomes, low quality of life and increased healthcare costs. Therefore, supporting New Zealanders with long-term disease to self-manage their medication to be taken on-time is the focus of my research. The study will explore your input, of which features can be included in a mobile application to improve patients' medication management. The findings from my research will be included in my PhD, research publication in peer-reviewed Health Informatics journals and conference papers and presentations.

How was I identified and why am I being invited to participate in this research?

I have identified your details from health point New Zealand website or LinkedIn. And you have been selected to participate because you work in a health organization or work in an organization that develops ICT products or services for health organization.

How do I agree to participate in this research?

You will be contacted by a phone call after two weeks from emailing you the information sheet and consent. Your participation in the interview is voluntary and you may agree or disagree at any time before the interview. You will be offered the choice about withdrawing any data that is identifiable as belonging to you prior to the commencement of analysis. The transcripts of the interview recording will be sent to you for verification and confirmation.

What will happen in this research?

This phase involves an interview for 45 minutes at your preferred location and time. And it will cover the questions you will be provided prior to the interview.

What are the discomforts and risks?

I do not anticipate you will experience any discomfort or risk.

How will these discomforts and risks be alleviated?

You will be given the questions before the interview. During the interview, you do not have to answer a question if you feel uncomfortable about it. You may stop and leave the interview at any time.

What are the benefits?

Firstly, you will be contributing to increase our knowledge of how to improve medication management using mobile app.

Secondly, my research also seeks to inform individuals, health providers and pharmacists how to tackle the adherence dilemma. This information will be useful to design tailored apps. Finally, this research will be

included in my PhD, research publication in peer-reviewed Health Informatics journals and conference papers and presentations.

How will my privacy be protected?

During the period of this research, your consent form, contact details, discussions and data will be kept confidential. All data will be stored securely and disposed of through the AUT document destruction service.

What are the costs of participating in this research?

Participation will take approximately 45 minutes of your time. There are no direct financial costs for participating.

What opportunity do I have to consider this invitation?

Please take two weeks to read the information sheet, consent form and the interview questions sent to you by email and to consider participating. If you have any questions please contact me through email: nawal.chanane@aut.ac.nz or phone (09) 921 9999 ext 8360.

After this time, I will contact you by phone to ascertain whether or not you wish to participate in the interview.

Will I receive feedback on the results of this research?

If you would like to receive a summary of the findings, please tick the designated circle and write your contact details on the consent form.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor,

Farhaan Mirza, farhaan.mirza@aut.ac.nz, (09) 921 9999 ext 5868.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Nawal Chanane, nawal.chanane@aut.ac.nz, (09) 921 9999 ext 8360.

Project Supervisor Contact Details:

Farhaan Mirza, farhaan.mirza@aut.ac.nz, (09) 921 9999 ext 5868.
Muhammed Asif Naeem, mnaeem@aut.ac.nz, (09) 921 9999 ext 5083.

Approved by the Auckland University of Technology Ethics Committee on 1*3 November 2017*, AUTEC Reference number *17/372*.

Consent Form

Project title: **A Technology Driven Approaches for Improving Medication Adherence: A Pilot Study**

Project Supervisor: ***Dr. Farhaan Mirza***

Researcher: ***Nawal Chanane***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 26 - 01 - 2018.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that notes will be taken during the interviews and that they will also be audio-taped and transcribed.
- ○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- ○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- ○ I agree to take part in this research.
- ○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature: .....

Participant's name: .....

Participant's Contact Details (if appropriate):

.....

.....

.....

.....

Date:

Approved by the Auckland University of Technology Ethics Committee on 13 November 2017 AUTEC Reference number 17/372

Note: The Participant should retain a copy of this form.

Indicative Questions for the Interview

School of Engineering, Computer and Mathematical Sciences
Auckland University of Technology
Private Bag 92006
Auckland 1142

Medication Adherence Research Study

Please take few minutes to read through these questions. Your thoughts will help us identify which functionalities to include in a mobile app that can help improve medication adherence for patients with long-term disease in New Zealand. Our research team welcomes your feedback. Your responses will be kept confidential. Thank you for your participation.

Section A: Participant Feedback

1. Welcome / Introduction
   Taking medication maybe seen as a task that can be easily added to a daily routine, for many patients it is a constant reminder of their illness. Additionally, some patients find it difficult to follow the instructions as prescribed by their healthcare providers. Patients who do not take their medication as prescribed are likely to face poor clinical outcomes, low quality of life and increased healthcare costs. Therefore, supporting New Zealanders with long-term disease to self-manage their medication to be taken on-time is the focus of my research. The study will explore your input, of which features can be included in a mobile application to improve patients' Medication Adherence (MA).

2. How can you describe MA?
   a. Your perspective?
   b. Patient prospective?

3. What do you think about the way MA is promoted today?

4. Have you been involved in any MA initiatives?

5. What do you think about technology assisted MA?
   a. Reminders for taking medication.
   b. Smart pills dispensers
   c. Support person
   d. Text messages
   e. Real-time electronic monitoring
   f. Wearable sensors
   g. Prescription claims databases
   h. Automated pill cap with remote monitoring sensor
   i. Multimedia adherence enhancement program

6. What benefits could we achieve by introducing solutions for MA?
   a. To patients

b. To provider
c. Pharmacist
d. To the health industry

7. What challenges do we anticipate?
    a. Own perspective.
    b. Organizational perspective.
    c. Privacy and security implications.

8. What implementation implications do you envisage?
    a. Technological
    b. Policy
    c. Cost
    d. Training
    e. Staff and human resources

9. Would we require wider support to make similar solutions successful
    a. Family
    b. Nurses
    c. Support groups (ex: diabetes association)
    d. Pharmacist
    e. Insurance Companies

Section B: Prototype Feedback

The prototype will be on a Tablet. Or we go through it online in the case of a skype interview. Or email the link feedback.

D.2 Tools for EA Stage 2: Focus Groups

a) Email invitation

b) Participant information sheet

c) Consent form

d) MAMA evaluation form

e) Provision of a protocol for recording consent

Invitation to participate in a Focus Group

Dear *[Participant Full Name],*

My Name is Nawal Chanane, a PhD student at Auckland University of Technology (AUT), School of Engineering, Computer and Mathematical Sciences. I would like to invite you to participate in a Medication Adherence Research Study.

This research seeks to contribute in improving medication adherence by providing solutions to engage patients to optimize medication self-management and avoid what leads to poor clinical outcomes, low quality of life and increased health care costs.

It would be highly appreciated if you take few minutes to read through the information sheet, evaluation and consent form. You will be receiving an email for the session date, time and meeting location, one week prior to session. The focus group session will be for 60 minutes approximately, and your participation is voluntary and you may agree or disagree at any time before the session. During the session you may stop and leave at any time.

During the period of this research, your consent form, contact details, discussions and data will be kept confidential. All data will be stored securely and disposed of through the university document destruction service.
If you have questions regarding the interview, please feel free to contact nawal.chanane@aut.ac.nz

Attendance appreciation gift

You will be given a Thank you card for participating and a gift card.

Thank you for your participation.

Participant Information Sheet

For Focus Group

Date Information Sheet Produced:

30/ 09/2019

Project Title

A Focus-Group Co-design and Evaluation of an mHealth Medication Adherence Application

An Invitation

My name is Nawal Chanane and I am a PhD student in the School of Engineering, Computer and Mathematical Sciences at Auckland University of Technology. I am conducting this study as part of my PhD research. I would like to invite you to participate. This information sheet will help you decide to take part.

What is the purpose of this research?

Mobile phone technology is increasingly being used as part of 'mhealth' approaches towards providing low cost and sustainable health care to patients with chronic illness (Menon, Selvakumar, Kattimani, & Andrade, 2018). MHealth apps targeting medication adherence (MA) are considered useful tools to help patients take medications as prescribed. As a result of our MA management requirements elicitation, we have developed a MA Minimum Viable Product (MVP) of a mobile application (app), that is simple to use and serves the patients and clinicians in keeping record of medication status and the med intake progress. In this research, health service users will be consulted in a co-design focus group session, to enhance the likelihood of the success of the app (Gracey et al., 2018). This process will include users who bring a deep understanding of their context, their needs and the opportunities that can then be explored. Also to foster the creativity and further develop ideas on the design and features with the developers (Treasure-Jones & Joynes, 2017). The findings from my research will improve the design of MVP.

The findings of this research may be used for academic publications and presentations.

How was I identified and why am I being invited to participate in this research?

You have been selected to participate in this study as a consumer of medication management or medication reminder apps, according to the email we received from you as a potential participant. And /or you were involved in the first phase of the project and you agreed to be contacted for the second phase (the app co-design and evaluation).

How do I agree to participate in this research?

If you agree to participate you will contact us through the email included in the advertisement. You will be contacted for confirmation by a phone call after two weeks from emailing you the information sheet and consent form.

Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

This phase involves a co-design focus group for 1 hour at AUT meeting room (details of the location will be sent one week prior to the meeting date). The session will follow the principals of co-design; inclusive, respectful, participative, iterative and outcome focused.

Firstly, the session will cover a presentation of the purpose of the research. Then, participants will be required to download the app on their own phone, and access the app for evaluation. In groups of two, participants will be given A3 paper to sketch / list suggested changes. Finally, an evaluation form will be presented. The main points to be evaluated and discussed are: 1) the user interface (UI) and 2) usability testing, to identify problems faced by users while using the functions of the MVP. The session plan will be emailed 3 days prior to the focus-group session.

What are the discomforts and risks?

I do not anticipate you will experience any discomfort or risk.

How will these discomforts and risks be alleviated?

During the session, you may stop and leave the session at any time.

AUT Health Counselling and Wellbeing is able to offer three free sessions of confidential counselling support for adult participants in an AUT research project. These sessions are only available for issues that have arisen directly as a result of participation in the research, and are not for other general counselling needs. To access these services, you will need to:

- drop into our centres at WB219 or AS104 or phone 921 9992 City Campus or 921 9998 North Shore campus to make an appointment. Appointments for South Campus can be made by calling 921 9992
- let the receptionist know that you are a research participant, and provide the title of my research and my name and contact details as given in this Information Sheet

You can find out more information about AUT counsellors and counselling on http://www.aut.ac.nz/being-a-student/current-postgraduates/your-health-and-wellbeing/counselling.

What are the benefits?

You will be contributing to the design of medication management MVP of a mobile app. That will be implemented and tested by users who are in need to manage their medication adherence and may help provide a solution to MA and ultimately better health.

Moreover, this research will be included in my PhD, research publication in peer-reviewed Health Informatics journals and conference papers and presentations.

How will my privacy be protected?

During the period of this research, your consent form, contact details, discussions and data will be kept confidential. All data will be stored securely and disposed of through the AUT document destruction service.

What are the costs of participating in this research?

Participation will take 1 hour of your time. There are no direct financial costs for participating.

What opportunity do I have to consider this invitation?

Please take two weeks to read the information sheet and consent form sent to you by email and to consider participating. If you have any questions please contact me through email: nawal.chanane@aut.ac.nz or phone (09) 921 9999 ext 8360.

Will I receive feedback on the results of this research?

If you would like to receive a summary of the findings, please tick the designated circle and write your contact details on the consent form.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Farhaan Mirza, farhaan.mirza@aut.ac.nz, (09) 921 9999 ext 5868.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Nawal Chanane, nawal.chanane@aut.ac.nz, (09) 921 9999 ext 8360.

Project Supervisor Contact Details:

Farhaan Mirza, farhaan.mirza@aut.ac.nz, (09) 921 9999 ext 5868.
Muhammed Asif Naeem, mnaeem@aut.ac.nz, (09) 921 9999 ext 5083.

Approved by the Auckland University of Technology Ethics Committee on 13 September 2019, AUTEC Reference number 19/343.

Consent Form

Project title: **A Focus-Group Co-design and Evaluation of an mHealth Medication Adherence Application**

Project Supervisor: ***Dr. Farhaan Mirza***

Researcher: ***Nawal Chanane***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 30 09 2019
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that identity of my fellow participants and our discussions in the focus group is confidential to the group and I agree to keep this information confidential.
- ○ I understand that notes will be taken during the focus group and that it will also be audio-taped and transcribed.
- ○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- ○ I understand that if I withdraw from the study then, while it may not be possible to destroy all records of the focus group discussion of which I was part, I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- ○ I agree to take part in this research.
- ○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature: .....

Participant's name: .....

Participant's Contact Details (if appropriate):

.....

.....

.....

.....

Date:

Approved by the Auckland University of Technology Ethics Committee on 13 September 2019, AUTEC Reference number 19/343.

Medication Adherence App Prototype Evaluation

Please take few minutes to read through the evaluation sections. If you have any questions please clarify before the evaluation starts. Your feedback will improve our minimum viable product (MVP) which is proposed to improve medication adherence for patients with the need for managing their medication intake throughout the course. Our research team welcomes your evaluation and remarks. Thank you for your participation.

Section A: Top features that should be available in an Medication Adherence App

Question	***Response***
What kind of feature should be available?	
What kind of things would you want/need in it?	
What kind of things do you think other users might need / want in it?	
What would motivate you to spend time on it?	

Section B: User Interface Testing

Criteria	√/ X	Remarks
Interface changes with change in screen direction		
Labels and buttons text are clear and concise		
Minimalist design- excess feature removed		
Minimized user actions		
Prompt display of errors and warning messages		
You can recognize between inactive buttons from active buttons		
Colours used provide god contrast and good readability		
Speaks the user language		
Tool tips on login page		
Text and spelling /grammar		
Number of buttons/ links is reasonable		
Further Comments and suggestions		

Section C: Usability Testing

Criteria	√/ X	Remarks
User interface elements provide visual feedback when pressed within 3 seconds max.		
Easy Navigation across different screens		
When clicking on notification it opens the app		
Functionality of the exit options at any point of running the application		
Enabling responsive menu button		
Further Comments and suggestions		

Section D: Functionality Testing

Criteria	√/ X	Remarks
Login page responsiveness		
Functioning of redirect options		
Scroll bar properly working		
Compatibility on different devices, screen size, resolution and OS.		
Further Comments and suggestions		

Section E: Security and Data Privacy

Criteria	√/ X	Remarks
The availability of authentication such as username/password		
The availability of the consent form and participant information sheet in the App		
The availability of the Withdrawal from the study in the App.		
Further Comments and suggestions		

Section E: General Feedback

Question	Response
What are your initial reactions to the prototype?	
Would you use this app? Prompt: why/why not?	
What do you like most/least about the app?	
What changes would you make to the app?	
What is the most important thing researchers should consider when developing medication adherence mobile applications?	

A Focus-Group Co-design and Evaluation of an mHealth Medication Adherence Application

Provision of a Protocol for Recording Consent

Project supervisor: Dr. Farhaan Mirza
Researcher: Nawal Chanane

To collect the participants consent for the focus group recording, the below will be followed:

Before the interview

- Send the consent form to participants and ask them to sign and email it back to nawal.chanane@aut.ac.nz before the focus-group.

During the interview:

- I will check with the participant before I start recording the focus group session, if they agree on audio recording for the session by signing the consent form and emailing it back to nawal.chanane@aut.ac.nz, and
- Go through the points they agreed on:
  - I have read and understood the information provided about this research project in the Information Sheet dated 30 - 09- 2019.
  - I have had an opportunity to ask questions and to have them answered.
  - I understand that notes will be taken during the interview and that they will also be audio / video recorded and transcribed.
  - I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
  - I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
  - I agree to take part in this research.
  - I wish to receive a summary of the research findings (please tick one): Yes○ No○

Approved by the Auckland University of Technology Ethics Committee on 13 September 2019, AUTEC Reference number 19/343.

D.3 Tools for EA Stage 3: MAMA Piloting

a) Email invitation

b) Consent form

c) Participant information sheet

d) In-app evaluation form

Invitation to participate in an Pilot Study

Dear *[Participant Full Name],*

My Name is Nawal Chanane, a PhD student at Auckland University of Technology (AUT), School of Engineering, Computer and Mathematical Sciences. I would like to invite you to participate in a Medication Adherence Pilot Study to use a medication reminder app for 1-2 weeks.

This pilot study trials an mHealth prototype as a smart reminder to improve medication intake using multi-channel notification.

It would be highly appreciated if you take few minutes to read through the information sheet and consent form. You will be emailed the link to download the app after two weeks from receiving this email and emailing back the signed consent form. You will be able to add your medication and start using the app when you download the app. Your participation is voluntary and you may drop from the study at any time. During the study, you do not have to continue using the app if you feel uncomfortable about it. You may delete the app any time.

During the period of this research, your consent form, contact details, discussions and data will be kept confidential. All data will be stored securely and disposed of through the university document destruction service after research.
If you have questions regarding the interview, please feel free to contact nawal.chanane@aut.ac.nz

You will be given a gift card.

Thank you for your participation.

Regards,

Nawal

Participant Information Sheet

For Pilot Study

Date Information Sheet Produced:

05/ 03/2019

Project Title

A Technology Driven Approaches for Improving Medication Adherence: A Pilot Study

An Invitation

My name is Nawal Chanane and I am a PhD student in the School of Engineering, Computer and Mathematical Sciences at Auckland University of Technology. I am conducting this study as part of my PhD research. I would like to invite you to participate. This information sheet will help you decide to take part.

What is the purpose of this research?

Mobile phone technology is increasingly being used as part of 'mhealth' approaches towards providing low cost and sustainable health care to patients with chronic illness (Menon, Selvakumar, Kattimani, & Andrade, 2018). mHealth apps targeting medication adherence (MA) are considered useful tools to help patients take medications as prescribed. As a result of our MA management requirements elicitation, we have developed a MA Minimum Viable Product (MVP) of a mobile application (app), that is simple to use and serves the users in keeping record of medication status and the med intake progress. In this research, participants will be invited to download the proposed MAMA app, to trial it for one to two weeks. Then, provide feedback on the efficacy of the app. The findings from my research will allow me to improve and upgrade the app according to the users' feedback.

How was I identified and why am I being invited to participate in this research?

You have been selected to participate in this study as a previous participant who selected to be contacted for the trial. You are taking medication and find difficulty in taking it on time.

How do I agree to participate in this research?

If you agree to participate you will email us the signed consent form. Then, the researcher will send you the app link to download. You will be contacted through email one week from downloading the app if no medication was logged at all.

Your participation in this research is voluntary (it is your choice) and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time through the app. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

This phase involves trailing MAMA app (medication adherence app) for 1-2 weeks. There are 4 steps required:

1- **Installing the app:** After you agree to participate and send through the consent form, you will be emailed the MAMA app link to download on your mobile phone.

2- **Creating account and adding meds:** After installing the app, you will need to create / signup an account (try to enter all the contact information to be able to trial all multi-channel notifications. Then, add your medication using the add medication button. The medication will be added with a default time for the reminders. However, you will be able to adjust the reminder time according to your prefered time. If you need help with loading your medication into the app, you can scan your medication details (using the scan button in the app), and we will load them for you through our webform.

3- **Using the app:** You will receive notifications to remind you take your added medication according to the times selected. When you click on the notification, you will be directed to the app to log the medication status by selecting one of the three options of (taken, will not take or snooze). If you forget to log your medication

before the next scheduled time, the multi notification will be triggered. Then, you will expect another type of reminder coming through as an email or SMS or a voice call unless the medication is logged.

4- **Evaluating the app:** At the end of the trial period, you will be able to click on "Rate this app" button in the app MENU. Which will direct you to an external anonymous survey link to evaluate the app features.

At this stage MAMA app is accessible for trailing purposes only. Therefore, after the trial period is over, the app will be discontinued, your account will be disabled and you no longer receive notification. If you feel like the app was of help in improving your medication intake, and you would like to use it in the future please indicate that in the evaluation form.

What are the discomforts and risks?

I do not anticipate you will experience any discomfort or risk.

What are the benefits?

You will be contributing to the updates of a medication adherence mobile app, which will help users to improve their medication intake on time.

Moreover, this research will be included in my PhD, research publication in peer-reviewed Health Informatics journals and conference papers and presentations.

How will my privacy be protected?

During the period of this research, your consent form, contact details, and provided data will be kept confidential. All data will be stored securely and disposed of through the AUT document destruction service.

What are the costs of participating in this research?

Participation will be less than 5 minutes for installing the app. After that less than 1 minutes per day using the app for 1-2 weeks and there are no direct financial costs for participating.

What opportunity do I have to consider this invitation?

Please take two weeks to read the information sheet and consent form sent to you by email and to consider participating. If you have any questions please contact me through email: nawal.chanane@aut.ac.nz or phone (09) 921 9999 ext 8360.

Will I receive feedback on the results of this research?

If you would like to receive a summary of the findings, please indicate that in the consent form.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Farhaan Mirza, farhaan.mirza@aut.ac.nz, (09) 921 9999 ext 5868.

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz* , 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Nawal Chanane, nawal.chanane@aut.ac.nz, (09) 921 9999 ext 8360.

Project Supervisor Contact Details:

Farhaan Mirza, farhaan.mirza@aut.ac.nz, (09) 921 9999 ext 5868.
Muhammed Asif Naeem, mnaeem@aut.ac.nz, (09) 921 9999 ext 5083.

Approved by the Auckland University of Technology Ethics Committee on *23/04/2020*, **AUTEC Reference number** *19/343*

Consent Form

Project title: **A Technology Driven Approaches for Improving Medication Adherence: A Pilot Study**

Project Supervisor: ***Dr. Farhaan Mirza***

Researcher: ***Nawal Chanane***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 05 03 2020
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- ○ I understand that if I withdraw from the study then, while it may not be possible to destroy all records of the medication intake status in the app that I logged, I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- ○ I agree to take part in this research.
- ○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature: .....

Participant's name: .....

Participant's Contact Details (if appropriate):

.....

.....

.....

.....

Date:

Approved by the Auckland University of Technology Ethics Committee on *23/04/2020* ***AUTEC Reference number*** 19/343

Note: The Participant should retain a copy of this form.

MAMA App Feedback

Start of Block: MAMA App Rating and Feedback

Smart Reminders to Improve Medication Intake

Thank you for being part of **MAMA app** trial. We do our best to update the app with the latest feedback to create a better user experience. Few questions for you to help improve this app to be ready for deployment.

Q1 To help us tailor **MAMA** app to all age groups, please specify your age:

- ○ 15–24 (1)
- ○ 25–44 (2)
- ○ 45–64 (3)
- ○ 65+ (4)

Q2 Did you have previous experience with medication reminder apps?

- ○ Yes (1)
- ○ No (2)

Q3 What type of mobile were you using for the trial?

- ○ IOS (i.e. iPhone) (1)
- ○ Android (i.e. Samsung, Huawei...etc) (2)

Q4 What is the number of medications added to the app?

▼ 1 (1) ... 5 (5)

Q5 Did **MAMA** app help you take your medication on time?

- ○ Yes (1)
- ○ Somehow (2)
- ○ No (3)

Q6 What features you liked the most? (you may choose more than one)

- [ ] Multiple reminders (1)
- [ ] Stopped medication (2)
- [ ] Scan prescription and auto-load of medication (3)
- [ ] Medication report (4)
- [ ] Contact GP (5)
- [ ] Contact researcher (6)
- [ ] Daily generic reminder (7)

Q7 How would you rate the Scan prescription and Auto-load of medication? (if you shared prescription with researcher)

- ○ Feature not used (1)
- ○ Not at all useful (2)
- ○ Slightly useful (3)
- ○ Moderately useful (4)
- ○ Very useful (5)
- ○ Extremely useful (6)

Q8 How would you rate the Multiple reminders?

- ○ Bad (1)
- ○ Poor (2)
- ○ Fair (3)
- ○ Good (4)
- ○ Excellent (5)

Q9 Which reminders were more useful to you? (you may choose more than one)

- ☐ App notification (1)
- ☐ Email reminder (2)
- ☐ Phone call reminder (3)
- ☐ Caregiver SMS (4)

Q10 How would you rate the Stop medication feature?

- ○ Feature not used (1)
- ○ Bad (2)
- ○ Poor (3)
- ○ Fair (4)
- ○ Good (5)
- ○ Excellent (6)

Q11 Would you recommend **MAMA** app to your friends?

- ○ Definitely not (1)
- ○ Probably not (2)
- ○ Possibly (3)
- ○ Probably (4)
- ○ Definitely (5)

Q12 What is the reason for your choice?

_____

_____

_____

_____

_____

X→

Q13 Would you like the GP to recommend **MAMA** app to patients?

- ○ Definitely not (1)
- ○ Probably not (2)
- ○ Possibly (3)
- ○ Probably (4)
- ○ Definitely (5)

Q14 What is the reason for your choice?

_____

_____

_____

_____

_____

Q15 To make **MAMA** app satisfy your needs, please let us know what features would you like to add or replace in the app.

_____

_____

_____

_____

_____

End of Block: MAMA App Rating and Feedback

D.4 Further Resources

a) Focus Group 1 feedback summary

b) Focus Group 2 feedback summary

c) Focus Group 3 feedback summary

d) MAMA testing feedback on multiple devices

e) MAMA explained

f) MAMA WebForm explained

g) MAMA mini videos

h) MAMA app storyboard

i) MAMA piloting participants list

j) MAMA feedback data

k) Student Showcase

Summary of Changes from Focus Group (1)
Changes to screens
Why when i click on the app to open, always shows the login page then it opens, it's supposed to not show the login page if i"m already logged in. (very slow to load the home page)
Name of page "Menu" -> "Settings"
Name of page "MAMA" -> "Home"
move logo (profile pic) to settings page and replace it with "Add med" (or a pic for +)
Add "GP contact / email" to (screen: create account)
Add "Contact GP" to (screen: settings)
Add " prescriber name" to (screen: add medication)
Add "Side effects" and " Do not have with:" but not must to fill (to Screen: add medication)
Change " Route" to " Method" in (Screen: add medication)
Display "Prescriber name" beside medication info (Screen: Profile)
Change the color of the submit button (I will provide you with the color number)
Add "Allergies" for the user to fill in (Screen: Profile)
remove the lines separation, just leave the one under "Medication:" (Screen: profile)
keep the data in the input box of add medication incase accidently pressed on back button
app orientation changes when the phone changes
New Screens/ features
As soon as the user add the meds the default time will be: Morning: 9:00am, Midday: 12:00PM, Afternoon:03:00PM, Evening: 06:00PM. Then the user can change it if needed: When user will click on medication name it will take him to Med Settings. User can click on the "Morning" and it will open the screen Choose Time, Same for Midday, Afternoon and evening (add a toggle on/off beside each time)
Add another ringtone to notification (select just one ring tone that is different than the phone one)
Summary page for the med taken/not taken/ snooze (Screen: settings)
Multi-channel notification. If no med taken for the day send email to user
Scan prescription and send to GP (for now send to my email)

Summary of Changes from Focus Group (2)
Changes to screens
Caregiver number in signup screen
on "Med Settings" page - medication name should appear
GP Email is mandatory field- would not complete registration until I had entered it.
New Screens/ features and other ideas
if all meds taken the date showing in HOME screen will be cirlcled **Green O,** if all not taken cirlce is **Red O**, if 1 or more not taken then cirlce is **Orange O**
In MENU add toggle on/off for multi-channel notification
A place for feedback/ comments on how the medication is / is not working
Quick, reliable way to ask the doctor question.
A key use driver will be the follow up on the infrastructure side. If I use this and the doctor does not get or act on my information , why bother?
A voice saying "Hi, you didn't take your meds today" ??

Summary of Changes from Focus Group (3)
Changes to screens
Add to Signup Screen " Next of Kin number" (optional)
Add to MENU "Medications History", it will display a screen will all (meds names/status/start and end date)
"Prescriber name" in Add medication screen should be (Optional)
In HOME screen, Display "Dose" under the medication info
New Screens/ features and other ideas
Add "Call Emergency" button in MENU, when click itcalls 911
Add in MENU "Medical Bracelet" toggle on/off to indicate if user wears medical bracelet.
maybe a joint partner in the app, so they can act as a human reminder
Patient should be able to see the list their alergies
It would be great if the patient can record notes, including doses taken on the day.
If the app provides details of trends, it will be very valuable.
May be add button for family member support, just like the emergency support in GP.

No	Device model	OS	Issues occured while testing
1	iPhone 7	IOS 14.0.1	No push notifications received
2	iPhone 8	IOS 13.3.1	Push notifications didn't pop up until app was open. Then, solved but no email received for meds not logged in the following days
3	iPhone 8plus	IOS 14.0.1	
4	iPhone 12	IOS 14.2.1	
1	Samsung Galaxy S9+	Android 10	1- Camera didn't open after granting permission. 2- Push notifications appeared only if med manually added
2	Samsung Galaxy S8	Android 9	Push notifications appeared only if med manually added
3	Huawei Y9	Android 9	1- Camera doesn't open after granting permission. 2- Push notifications appeared only if med manually added
4	Samsung Galaxy S9	Android 10	push notifications received only when app open but email reminder received and call received fine
5	Redmi note 9S	Android 10	1- Camera doesn't open after granting permission.

MEDICATION ADHERENCE MANAGMENT APPLICATION (MAMA)

The Smart Multi-Channel Reminder App Explained

Abstract

Mobile health (mHealth) apps targeting medication adherence (MA) are considered useful tools to help patients take medications as prescribed. This document is designed for the participants invited for the two weeks app trial. This guide explains the use of the app, how to install, how to use each of the main screens and how to provide feedback to the research team on the efficacy of the app.

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nawal.chanane@aut.ac.nz

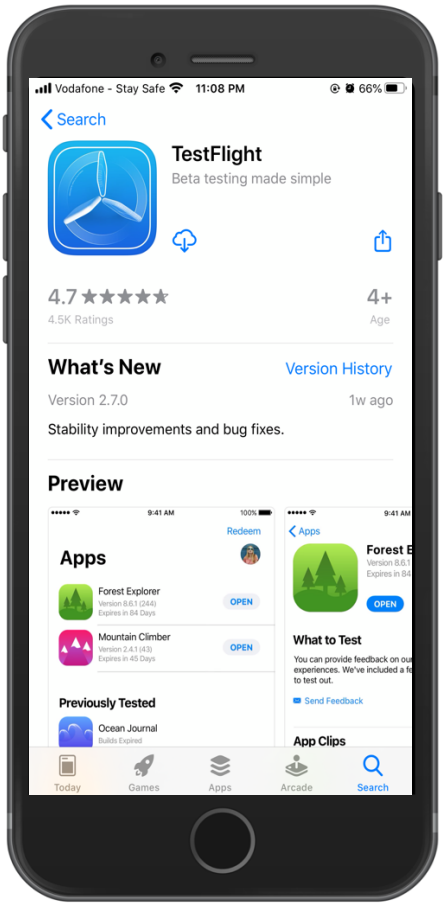
Medication Adherence Management Application (MAMA):

The Smart Multi-Channel Reminder App Explained

MAMA is a simple to use app that serves the users in keeping record of medication status and the medication intake progress.

Installing MAMA App

On Android device, click on the link you will receive in the invitation email to download the app.
On IOS device you will receive an email invitation from Apple TestFlight, follow the three steps listed in the invitation or go through the below steps if you are using the public link to install the app.

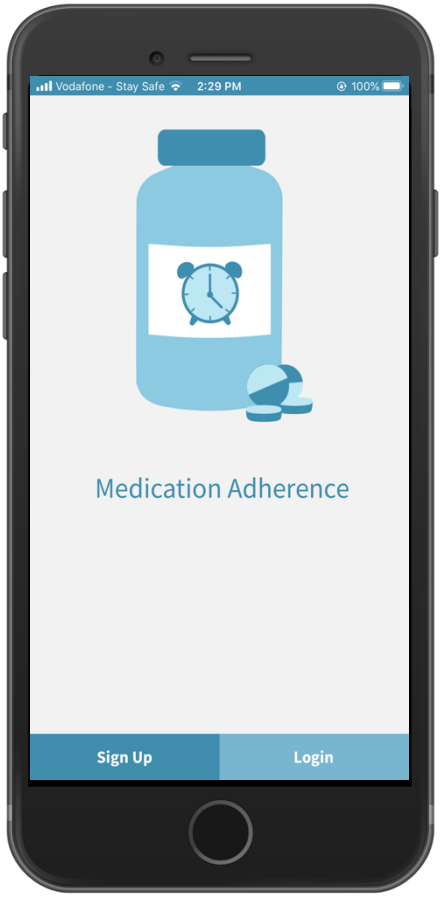


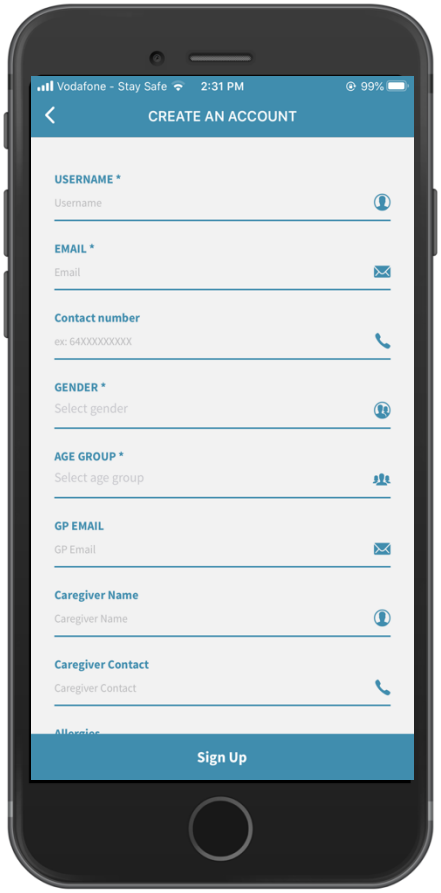
Installing TestFlight

1. Install TestFlight on the iOS device that you'll use for testing.
2. Open your invitation email or tap on the public link sent to you, on your iOS device.
3. In TestFlight tap Install or Update for the app.
4. When the app is installed/updated, tap open.

Login or Signup for new user

- If you have an existing account, tap login and enter your email address and password.
- If you are a new user, tap on sign up and create your account.
- It is not required to enter your credentials each time using the app, unless you logout.
- When creating your account, you can use any preferred username and it does not have to be your NHI ID.





Create an Account

1. Enter a username, you can use any preferred username and it does not have to be your NHI ID.

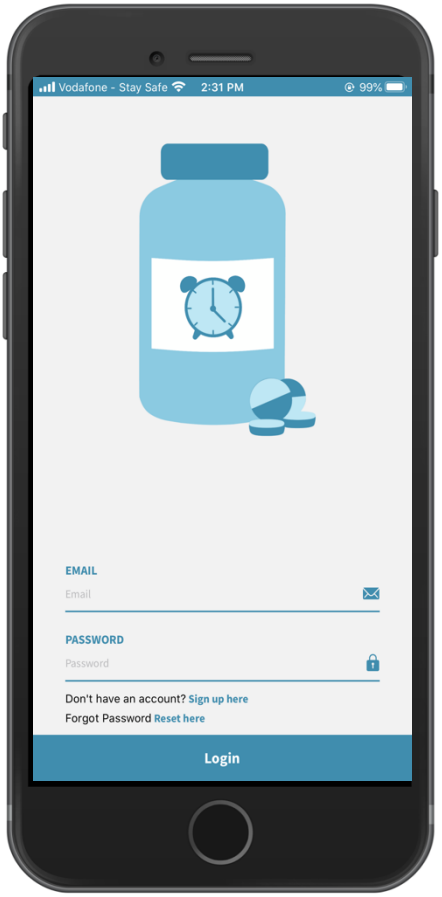
2. Enter an active email address, that you use/check most frequently, to be able to receive the email reminder.

3. Add your cell phone number, to activate receiving the auto-call reminder

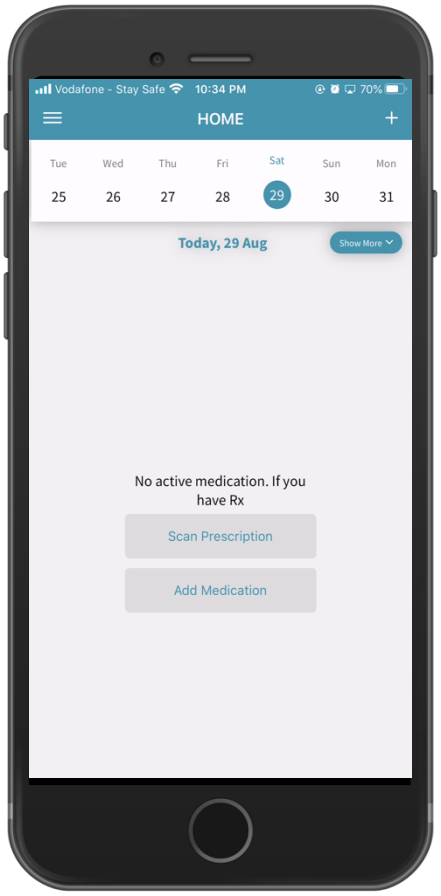
4. Add the caregiver cell phone number, to activate the caregiver SMS notification (only if the caregiver was involved in the treatment).

The entered information will be loaded into the database to activate the notifications/reminders and more. You can choose which information you would like to enter if the field is not required (identified with *)

Login / Reset password



1. Enter your email and password to login.
2. If you forgot your password, click on "Reset here" to reset password.
3. The reset password link will be sent to the email you have provided when creating the account.
4. Tap Login.



Home screen

1. From the Home screen you can scroll between the calendar days.

2. To go to the Menu Tap on the three lines  .

3. You have two options of adding your medication, either:

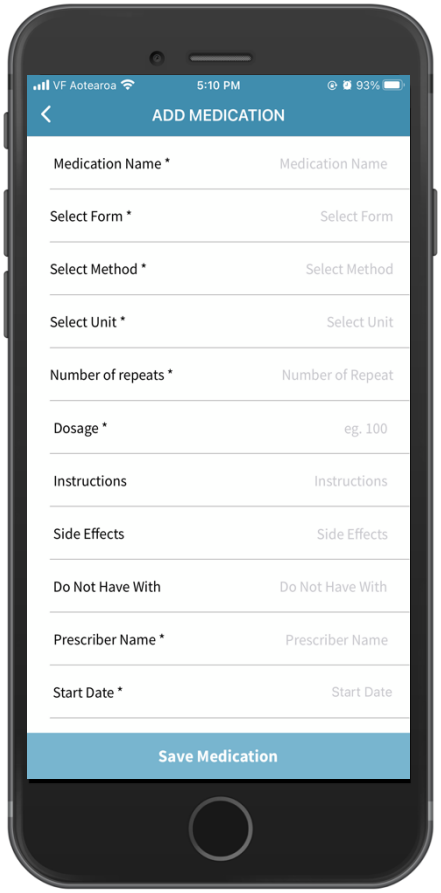
   a) Self-add medication by tapping on the plus  or on the icon .

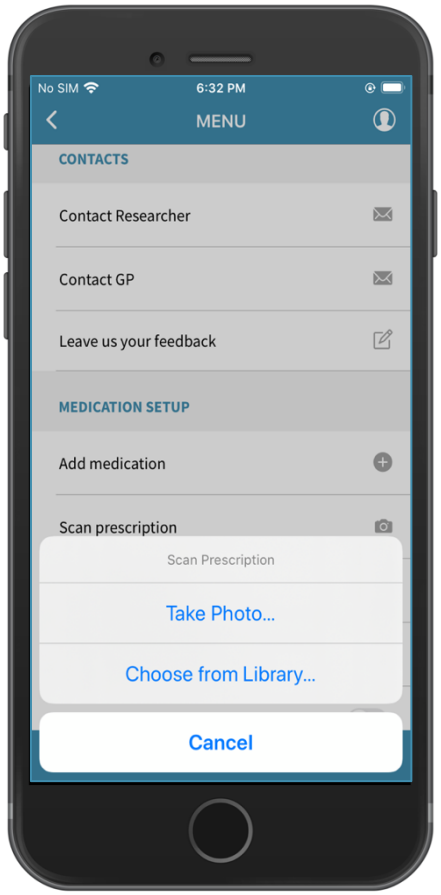
   b) scan and send your prescription to the research to load your medications for you, tap on .

Add Medication

1. Enter your medication details according to your prescription.
2. Tap Save Medication.
3. Tap on medication name to setup medication reminders.

Note: If you prefer to have your medication loaded for you, use the scan prescription to send your prescription/medication details to the researcher to load it for you. You will receive an SMS when your medication(s) are added.





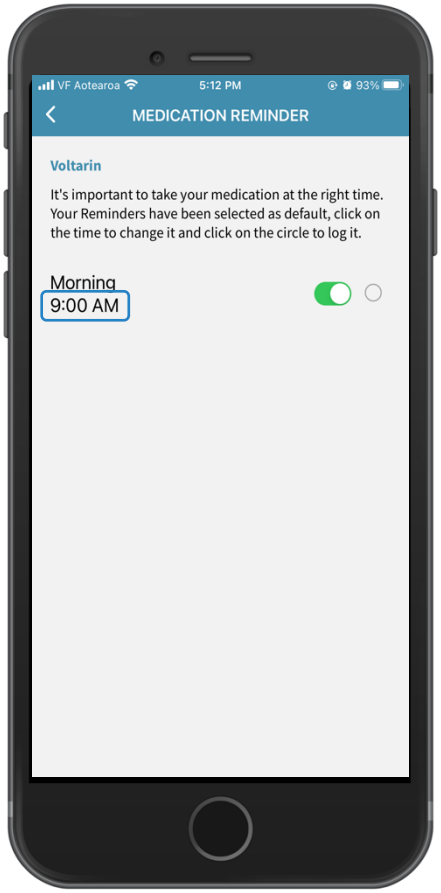
Scan Prescription and Send for auto-load of medication into your account

1. Tap **Scan prescription** from the Home screen or Menu.
2. Tap **Take Photo** or **Choose from library**.
3. Take prescription photo, then tap **Use Photo.**
4. A popup box will appear "Are you sure you want to send email of your prescription", **if yes**, tap **Proceed**, otherwise tap **Cancel**.
5. If you choose to proceed with sending prescription, a popup box will appear "Your prescription is sent to the researcher to have your medication loaded into your MAMA account".
6. Tap **OK**.

Note: After sending the prescription, please allow 30 minutes to have you medication loaded into your account.

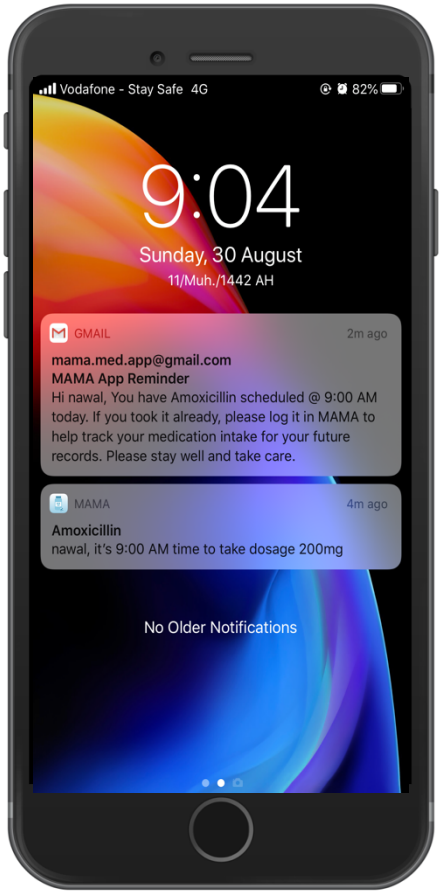
Setup Reminders

Tap the Medication name from the Home screen and you will be directed to the medication reminder. The number of reminders (repeat medication) will be loaded according to your prescription. You will be able to edit the time according to the time of your first dose.



Note: The default time will be 9:00am, 12:00pm, 3:00pm and 6:00pm. If you change the toggle to off, then you will not be receiving any reminder for that scheduled time. It is not recommended to change the number of medication repeat before consulting with your GP/prescriber.

1. To change the time, tap on the default time and scroll to preferred time.
2. Tap Done.



The multi-channel notifications

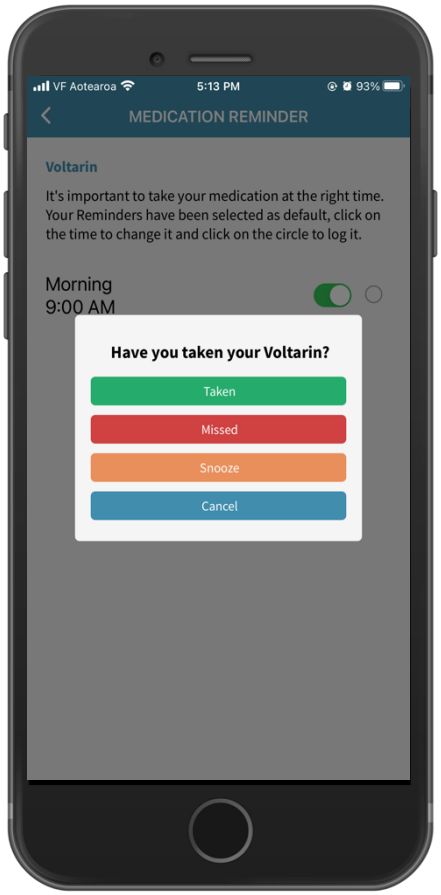
There 3 types of notifications the user will receive if the scheduled medication is not logged into the app and the 4th notification is sent to the caregiver if the contact number is provided by the user when creating the account.

Here are the scenarios of receiving the reminders and logging your medication intake:

- If you take your medication before the scheduled time and log it in the app as taken or missed, then, you will not receive notification for that logged time.
- The first notification you will receive is the app notification and by tapping on it, you will be directed to the log medication popup screen.
- If you missed logging your medication when receiving the app notification, you will be sent an email reminder 15 minutes after the scheduled time.

- If you missed logging medication after receiving the email reminder within the first 30 minutes from the scheduled time, you will receive an auto-call reminder.
- If you missed logging medication after receiving the auto-call and did not log the med as Taken, or Missed anytime during the day, then an SMS will be sent to your caregiver to check if you need any help(to check on you??).

Note: All notifications will be received through your Apple Watch if you mirror your iPhone alerts from the Watch app.



Log your medication intake

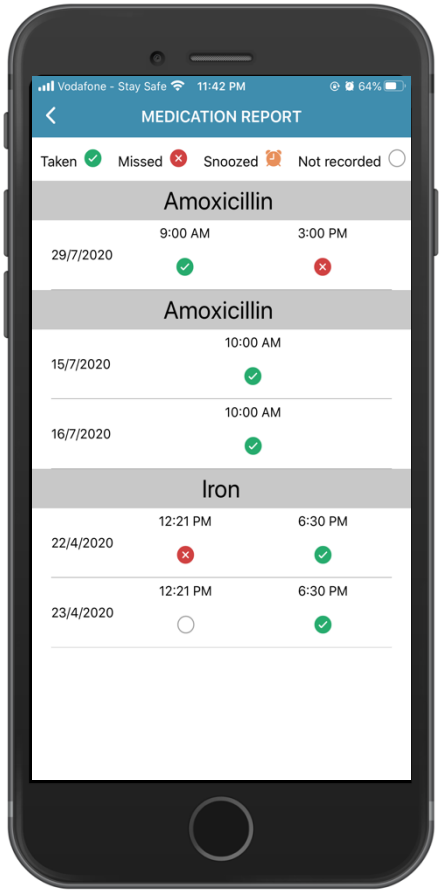
1. Tap on MAMA notification from your phone screen (if device locked)or from notification centre.
2. Choose one of the four options displayed in the popup box. If you tap Snooze you will receive a notification after 15 minutes (default snooze time).
3. Tap Cancel if you wish to change the time.
4. If you choose Taken or Missed, no reminders will be sent for this scheduled dose.

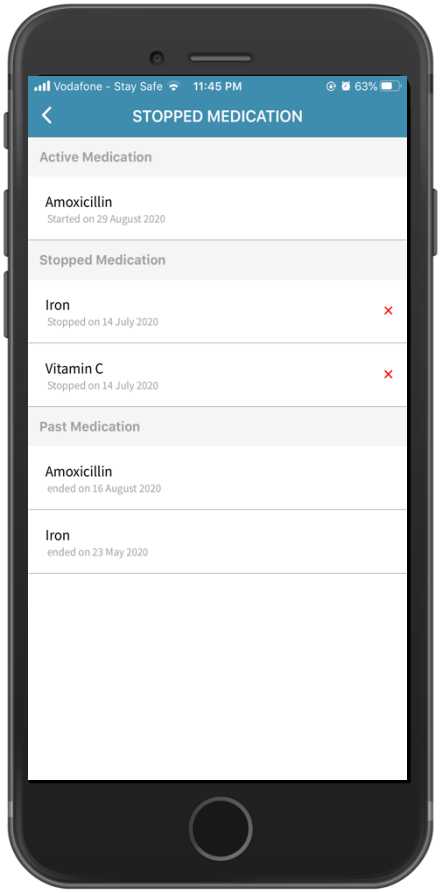
Check your medication intake report

You can check the status of your medication intake from Medication Report screen.

1. From the Menu, tap Medication Report.
2. On the top of the screen you can see the legend for each status.
3. Scroll up and down to check status of each medication dose for

Note: Having the report handy in your app will make is easy to follow your medication intake.





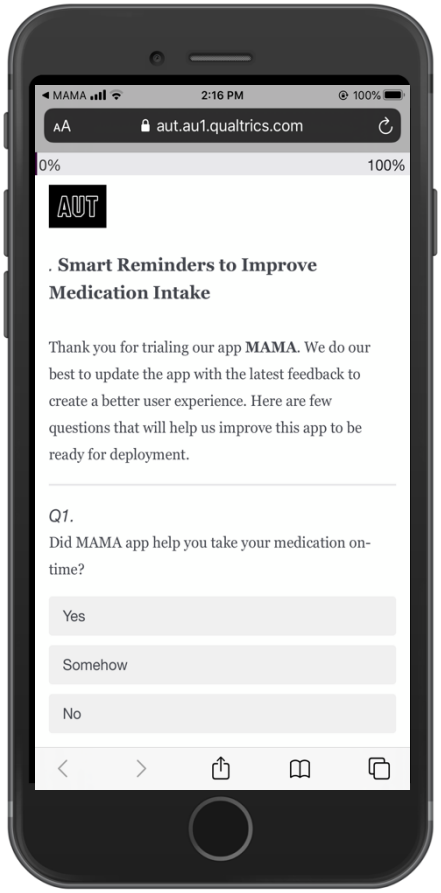
Know what medications you stopped taking/stop medication you discontinued

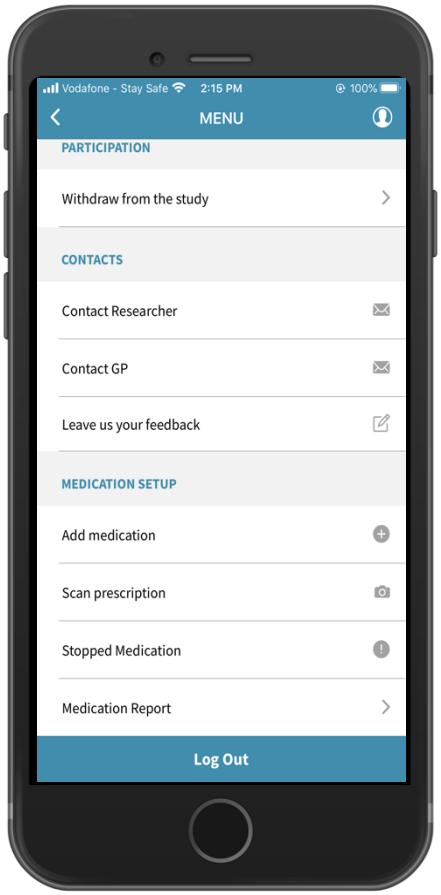
1. From the Menu, tap Stopped Medication.
2. You can see the Past medications, Stopped medications and Active medications (that you are still taking).
3. If you wish to discontinued an Active medication, tap on the medication name.
4. A popup box will appear "You want to stop this medication? If yes! This medication will no longer be available on medication list", if you wish to proceed **tap Stop**, **otherwise** tap **cancel**.

Share your feedback with the research team

1. From the Menu, tap Leave us your feedback.
2. You will be directed to an external feedback form.
3. Scroll down to answer all questions.
4. When done tap Submit.

Note: This form will collect users feedback anonymously for app improvement purposes and research output.





Menu and Logout

1. Tap the profile icon in the top right-hand corner to view your details and medication list.
2. Tap Withdraw from the study if you do not wish to continue.
3. Tap Contact Researcher if you wish to email about any question regarding the app use/functionality during the trial period.
4. Tap Contact GP if you wish to email your GP. (This app is for research purposes only at this stage and not integrated with your GP system).
5. Tap logout if you wish to exit the app.

Note: You do not need to logout each time from the app. If you logout, you will need to login again with your credentials to access your account.

MEDICATION ADHERENCE MANAGMENT APPLICATION (MAMA)

MAMA Webform Explained

Abstract

According to research, an easy to use app with minimum purposeful functionalities, responsive and useful to the patient is more likely to be used. One of the most distinctions between the available medication reminders app and MAMA is the auto-load of medication through a webform which could be integrated with the health system. This document introduces the MAMA Webform used to load medication into users accounts according to their prescription. In a real case scenario this could be done by the pharmacist when dispensing the medication to the patients or the health provider when prescribing the medications.

Research Team

nawal.chanane@aut.ac.nz

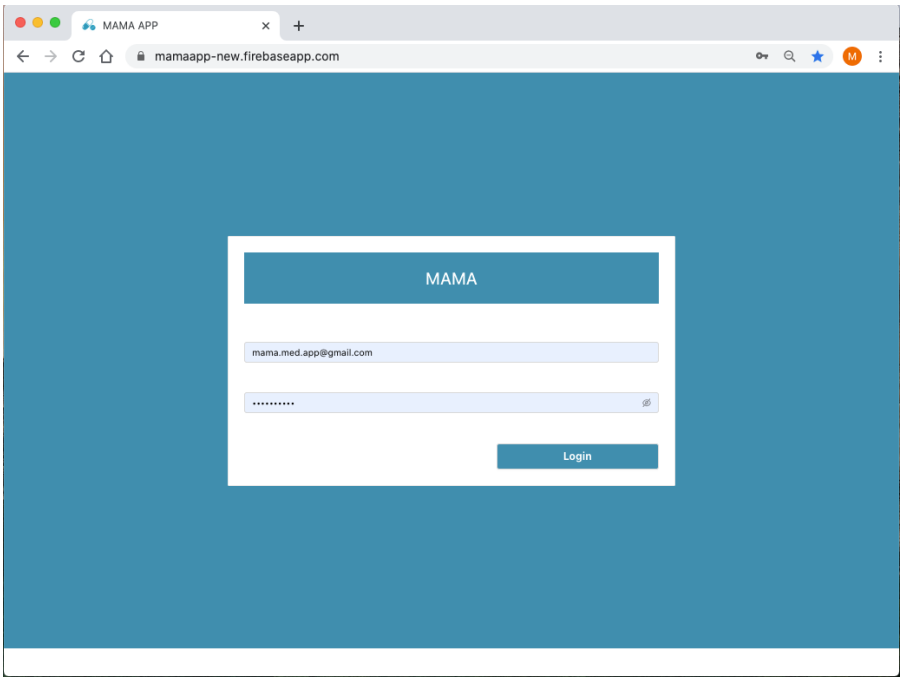
Medication Adherence Management Application (MAMA): Webform Explained

MAMA APP

MAMA Webform is used to load medication into users accounts according to their prescription. The user will need to Scan and send prescription first through the app. This Webform is designed for the purpose of the trial only to replace a similar scenario using the Health Provider system when prescribing medication. However, we anticipate loading medication into the users MAMA accounts is preferably done by the pharmacist at the point of dispensing medication to the user.

Web Form access

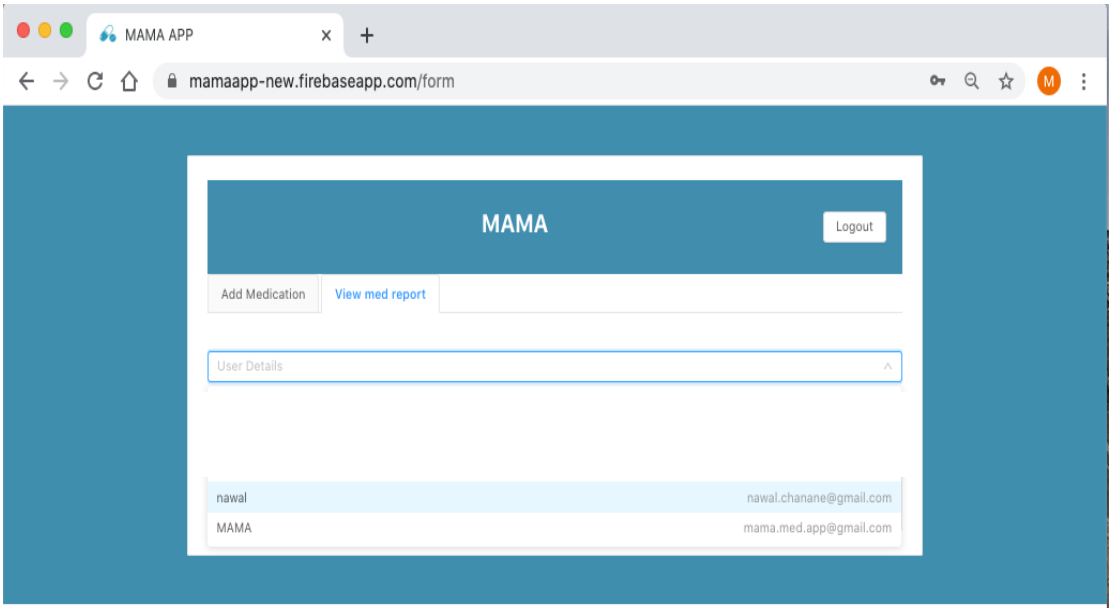
This webform is connected to the Google cloud firebase database. The Firebase Realtime Database is a cloud-hosted database that lets you store and sync data between users in real-time. This will allow the instant loading of medication into the users app when the prescription is added.

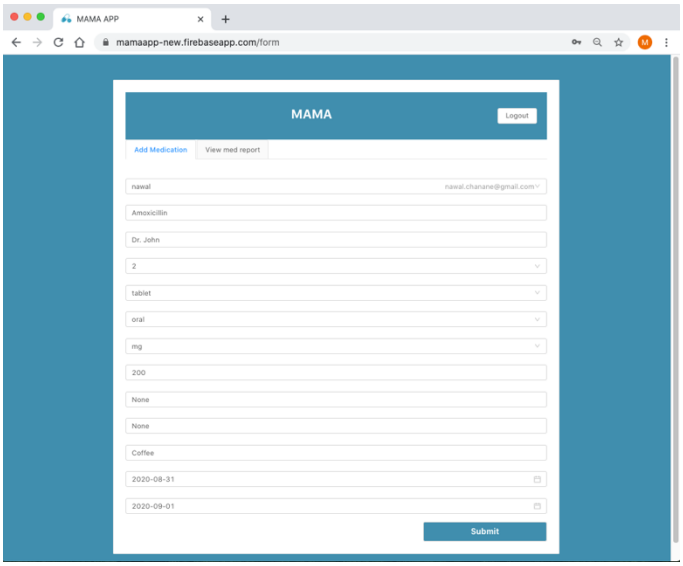


Add medication tab

When the users create a MAMA account, their data will be saved in the database. This will allow the search for their username through the Web form to be able to add their medication. To load medication on users' account through the webform, the below steps are followed:

- After logging into the Webform.
- Click on the drop down menu for the usernames.
- Look for the username matching the full name in the prescription received through mama.med.app@gmail.com.
- Click on the username.





Add medication

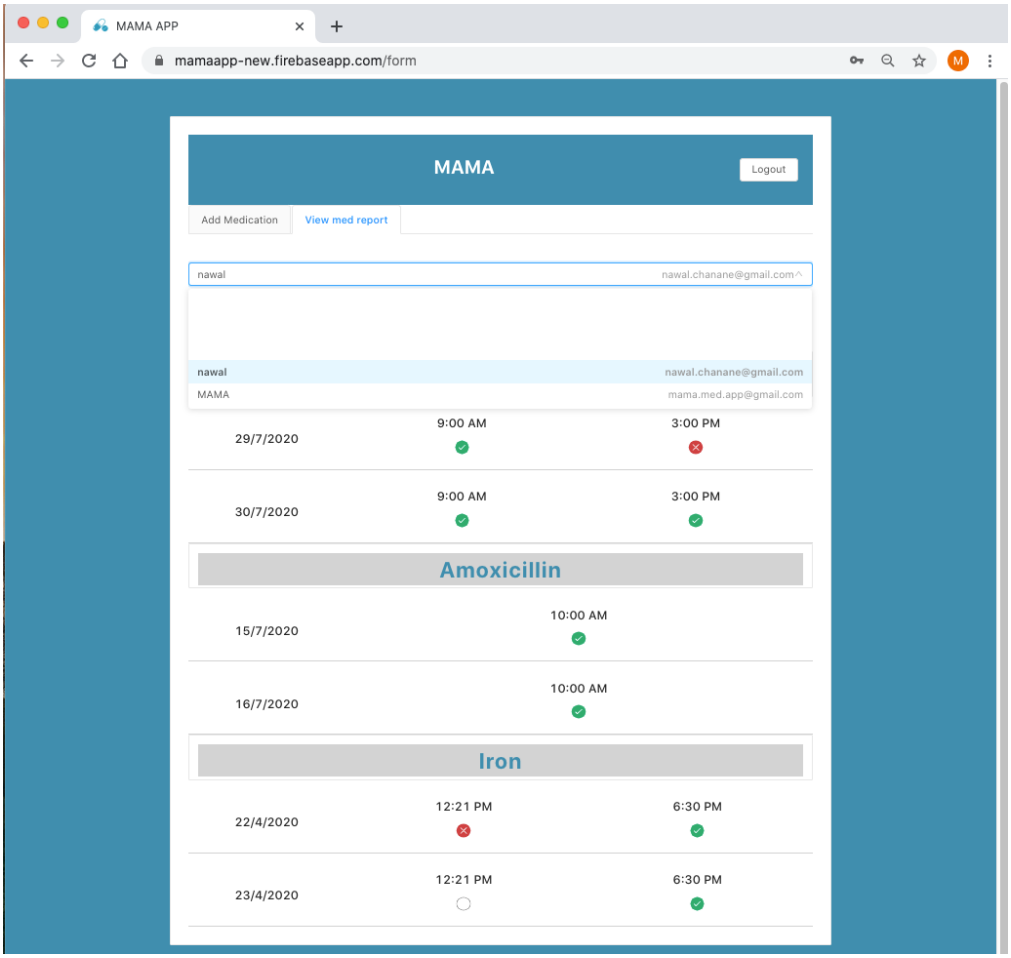
- Add the details of medication in the form according to the prescription.
- Click submit.
- An SMS will be sent to user confirming the loading of medication on MAMA count.

Check medication report tab

When the users create a MAMA account, their data will be saved in the database. This will allow the search for their username through the Web form to be able to add their medication. To view the medication intake report for a specific user through the webform, the below steps are followed:

- After logging into the Webform.
- Click on the drop down menu for the usernames.
- Look for the username matching the full name in the prescription received through mama.med.app@gmail.com.

Click on the username.



MAMA Mini Videos

No	MAMA functions
1	Download App - from invite link
2	Create account
3	Login- with correct password
4	Login- with wrong password
5	Reset password
6	Reset password- create new password
7	Add medication- through the app
8	Scan prescription
9	Researcher receive prescription
10	Add medication from Webform
11	User Change medication reminder
12	Push Notification received - log Snooze
13	Push Notification received - no action
14	Email reminder received - no action
15	Call reminder received – reply but no action
16	Caregiver SMS notification
17	Log medication – missed
18	Log medication – taken
19	View medication report
20	Stop one medication – Medication no longer in the Home
21	Contact researcher
22	Contact GP
23	GP view report -Webform
24	Leave us your feedback
25	Logout from account
26	Account Disabled when Login to account with wrong password multiple times
27	Withdraw from the study
28	Login after withdrawing
29	Daily generic reminder

Scan Me to load videos on your device

Sarah's Journey

MAMA Scenario

Sarah Smith

Age: 45

Marital status: Single

Occupation: Product Director

Location: Auckland

Bio

Sarah is a Product Director and a business owner. She works more than 16 hours a day and she doesn't have time to take care of her health at all. Although she's still young, she has multiple health conditions which require her to take multiple pills at a different time during the day. With her daily full schedule, she always misses her pills and never gets it right. From her last visit to her GP, he advised her to take care of her health if she really loves her job and wants to keep doing it until her retirement. Her health will deteriorate fast if she keeps missing her dose every day.

> *"If you want to make it!! You need to take it!!"*

1- GP Visit

Sarah visits Dr. John every 6 months when her health condition got worse.

2- Pharmacy visit

The pharmacist dispenses the medication for Sarah and proposes MAMA (medication reminder app)

3- Start using MAMA

Patient downloads the app and creates an account

4- Adding medication

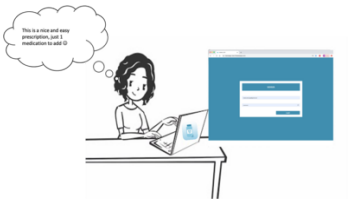
Sarah logs in and adds her prescribed and over counter medication:

- Tiotropium inhaler (18 micrograms) 1 puff once a day
- Carbocisteine 750 mg twice a day
- Aspirin 75 mg once a day
- Zopiclone 7.5 mg at night
- Amoxicillin (short course) 200 mg once a day for 7 days.

5- Scanning Rx

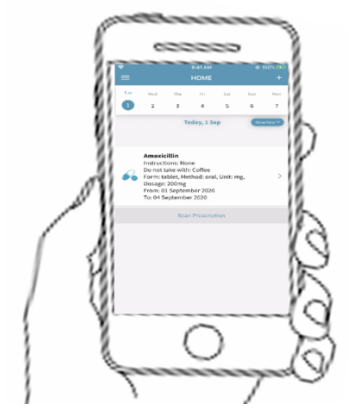
Sarah didn't manage to add manually all her medication, so she scans her prescription and sent it to the DET to help her with that.

6- DET adds Rx to Sarah's account



DET receives Sarah's prescription through email and uses the Webform to load medication into Sarah's account

7- Auto-load medication



Sarah receives an SMS that her medication is loaded into her MAMA account and she can change the reminders according to her first intake.

8- Using MAMA to log medication intake

Sara starts taking her medication when she receives a push notification. With her busy schedule, she doesn't notice that her medication time reached. Sarah working at her desk with her email open, she receives an email reminder to take her medication and she sees it. However, sometimes she's busy on the go and she doesn't check her email but luckily the Automated call comes in handy in this case and she hears her devices ringing to remind her to take her pill.

9- GP follow-up visit

After 6 months Sarah visits Dr. John for follow-up. Dr. John notices that Sarah improved in taking her medication, which is a good sign. During reconciliation Dr. John also notices that Sarah is still on the following medicines:
•Tiotropium inhaler (18 micrograms) 1 puff once a day
•Carbocisteine 750 mg twice a day
•Aspirin 75 mg once a day
•Zopiclone 7.5 mg at night
•Amoxicillin (short course) 200 mg once a day for 7 days.
Dr. John was able to go through the medication report and make few adjustments to her treatment plan.

MAMA not only saved Sarah's treatment plan and her health but also gave a good report on the past six months for Dr. John to look at and make adjustments to the treatment plan.

"Drugs don't work in patients who don't take them." - Everett Coop

No	Participants	Participant Code	Gender	Recruitment date	Eligible (Y/N)	Invitation Sent (Y/N)	Participant Consent form (Y/N)	Consent date	Phone type	Voucher (Y/N)	App Link & guide sent(Y/N)	Need for Follow-up (Y/N)	Dowload app (Y/N)	Account created (Y/N)	Updated version (11) sent (Y/N)	# of Medication added	App use starting date	Expected finish date	Evaluation email sent (Y/N)	App Evaluated	Participation Status (continued or withdrawn)	Notes
1	FG participant	A	F	28-Oct	Y	Y	Y	9-Nov	Android	Y	Y	N	Y	Y	Y	1	24-Nov	8-Dec	Y	Y	Continued	
2	Participant	B	F	28-Oct	Y	Y	Y	27-Oct	Android	Y	Y	Y	Y	Y	Y	1	1-Dec	15-Dec	Y	Y	Continued	emailed them again Reason for follow up was the delay in downloading the app. Participant using Android not IOS, so the Android version sent to her.
3	Participant	C	F	28-Oct	Y	Y	Y	30-Oct	Android	N	Y	N	Y	Y	Y	1	24-Nov	8-Dec	Y	Y	Continued	app crashed after adding med from webform
4	Participant	D	F	28-Oct	Y	Y	Y	4-Nov	IOS	N	Y	N	Y	Y	Y	1	16-Nov	30-Nov	Y	Y	Continued	emailed them again. User added med with old date 2017. User was contact to ask if any assistance needed in loading the med.
5	FG participant	G	M	28-Oct	Y	Y	Y	10-Nov	IOS	N	Y	Y	Y	Y	Y	5	19-Nov	3-Dec	Y	Y	Continued	Reason for follow up was the delay in downloading the app. issue reported, draining of battery when changing med time. didn't receive notification (change settings)
6	FG participant	H	F	28-Oct	Y	Y	Y	4-Nov	IOS	Y	Y	Y	Y	Y	Y	2	18-Nov	2-Dec	Y	Y	Continued	Reason for follow up was the delay in downloading the app. issues reported not receiving notification but received email reminder
7	FG participant	I	F	29-Oct	Y	Y	Y	29-Oct	Android	N	Y	N	Y	Y	Y	1	19-Nov	3-Dec	Y	Y	Continued	
8	external	J	F	2-Nov	Y	Y	Y	5-Nov	IOS	N	Y	N	Y	Y	Y	1	15-Nov	29-Nov	Y	Y	Continued	report not displaying all med log
9	external	K	F	2-Nov	Y	Y	Y	16-Nov	Android	N	Y	Y	Y	Y	Y	1	29-Nov	13-Dec	Y	Y	Continued	emailed them again. Sent follow up email, user didn't set the reminder for 1 or 2 weeks. med was set for 2 days only.
10	external	M	F	3-Nov	Y	Y	Y	5-Nov	IOS	Y	Y	Y	Y	Y	Y	3	26-Nov	10-Dec	Y	Y	Continued	User thought she had Android but it's iPhone, so she was sent the iPhone version
11	external	N	F	5-Nov	Y	Y	Y	16-Nov	Android	N	Y	Y	Y	Y	Y	1	25-Nov	9-Dec	Y	Y	Continued	
12	external	O	F	5-Nov	Y	Y	Y	9-Nov	IOS	N	Y	Y	Y	Y	Y	1	22-Nov	6-Dec	Y	Y	Continued	Reason for follow up was the delay in downloading the app (waiting to receive new phone)
13	external	S	F	5-Nov	Y	Y	Y	9-Nov	Android	N	Y	N	Y	Y	Y	3	23-Nov	7-Dec	Y	Y	Completed	emailed them again
14	external	T	M	5-Nov	Y	Y	Y	11-Nov	Android	Y	Y	Y	Y	Y	Y	1	27-Nov	12-Dec	Y	Y	Continued	
15	external	V	F	5-Nov	Y	Y	Y	6-Nov	IOS	Y	Y	N	Y	Y	Y	3	26-Nov	11-Dec	Y	Y	Continued	user sent other email address to send the app invite through
16	external	W	M	5-Nov	Y	Y	Y	9-Nov	IOS	N	Y	N	Y	Y	Y	1	15-Nov	29-Nov	Y	Y	Continued	
17	external	X	F	6-Nov	Y	Y	Y	11-Nov	Android	Y	Y	Y	Y	Y	Y	1	26-Nov	10-Dec	Y	Y	Continued	emailed them again. Forgot about it
18	external	Y	M	9-Nov	Y	Y	Y	11-Nov	Android	N	Y	N	Y	Y	Y	5	27-Nov	11-Dec	Y	Y	Continued	
19	external	AC	M	29-Nov	Y	Y	Y	29-Nov	IOS	Y	Y	N	Y	Y	Y	2	29-Nov	14-Dec	Y	Y	Continued	
20	external	AD	F	29-Nov	Y	Y	Y	30-Nov	IOS	Y	Y	N	Y	Y	Y	4	1-Dec	15-Dec	Y	Y	Continued	emailed them again
21	external	AE	F	29-Nov	Y	Y	Y	30-Nov	IOS	Y	Y	N	Y	Y	Y	4	1-Dec	15-Dec	Y	Y	Continued	
22	external	AF	F	30-Nov	Y	Y	Y	1-Dec	Android	Y	Y	N	Y	Y	Y	1	4-Dec	19-Dec	Y	Y	Continued	emailed them again

Age group	App experience	Mobile type	# of medications	App helped	Features you liked	Scan Rx & Auto-load rate	Multiple reminders rate	Useful reminders	Stop meds rate	Recommend app	Reason	GP to recommend	Reason	Features recommended
25–44	No	IOS (i.e. iPhone)	1	Somehow	Daily generic reminder	Feature not used	Fair	App notification	Good	Definitely	Ease of use	Definitely	Ease of use across all age groups.	Existing features are good, no change required. Maybe when the medication is taken at a later time (e.g. greater than 30min) capture the time at which the medicine was taken?
65+	No	Android (i.e. Samsung, Huawei...etc)	1	Somehow	Multiple reminders,Scan prescription and auto-load of medication,Medication report	Extremely useful	Good	Email reminder,Phone call reminder	Good	Definitely	This is a very useful app. From my experience, it would be extra useful for those who have many medications to take at different times. The auto-load prescribed medicine is very helpful. I think this will be greatly appreciated by elderly users who are not very confident with mobile technologies. It's easy to navigate and use. The app notifications only worked sometimes. However, this is a technical issue. The idea is more important, and I believe there are definitely needs around this area.	Definitely	The medication report is a very nice feature. This can be a useful reference for both doctors and patients. This app can be helpful especially for doctors who need to work out whether the prescribed medicine is effective or not. The medication report is a good evidence to refer to when making the judgement on effectiveness of the prescribed medicines.	It will be nicer if the app notification works reliably. As I mentioned above, this is a pure technical issue. The idea is great and I believe this app will be beneficial for many people who struggle to take their medicine on time.
65+	No	IOS (i.e. iPhone)	2	No	Medication report	Feature not used	Bad	App notification	Feature not used	Probably not	App crashed multiple times. Did not receive daily reminders - perhaps this was not set up properly in the first place.	Possibly	People have to be very proactive to use it, especially if they don't receive reminders	Good reminders
25–44	No	IOS (i.e. iPhone)	1	Yes	Multiple reminders,Medication report	Feature not used	Excellent	App notification	Feature not used	Definitely	It reminded me to take my medicine especially when I'm very busy at work.	Definitely	It helps the patient take his medicine on time and not miss doses	Everything is good.
65+	No	Android (i.e. Samsung, Huawei...etc)	1	Yes	Multiple reminders,Scan prescription and auto-load of medication	Very useful	Good	Email reminder	Feature not used	Definitely	Very easy to forget to take medication	Probably	It's a useful tool	An audible alarm as a reminder
45–64	Yes	Android (i.e. Samsung, Huawei...etc)	2	Yes	Multiple reminders,Contact GP,Daily generic reminder	Very useful	Excellent	App notification,Email reminder	Good	Probably	Because a lot of people forget there medication so this app will be helpful.	Definitely	Very useful	Nothing
15–24	No	Android (i.e. Samsung, Huawei...etc)	1	Yes	Multiple reminders,Contact GP,Daily generic reminder	Feature not used	Good	App notification	Feature not used	Definitely	Helpful reminder app to ensure I take my medication	Definitely	I feel like it would be a helpful tool to remind patients if they are forgetful. Especially ones that are crucial to their daily lives.	I would like the app to have notifications rather then sending it to my email. I could not get the app notifications working. However the idea and purpose of the app is very useful and the experience was intuitive.
25–44	No	IOS (i.e. iPhone)	3	Yes	Daily generic reminder	Feature not used	Good	App notification	Feature not used	Definitely	N/A	Definitely	it is a great app keeps remind you about taken medicine Email notification	Overall this app is good however, I haven't tried other features so can't have things to add or replace.
25–44	No	Android (i.e. Samsung, Huawei...etc)	1	Yes	Multiple reminders,Medication report	Feature not used	Good	App notification	Excellent	Definitely	I can see the need for this if one has multiple pills to take. Time reminders are important for pill effectiveness. As mine was monthly, i forget to take it the same time every month	Definitely	Life is so busy that having reminders is useful. Less stress on trying to remember everything yourself	I inserted the meds myself and realised that i didnt know if what mm etc. Meant. A reminder about the pills will be running out would be good so i can make appointment in advance. If blood test is needed then this can be sent
65+	Yes	IOS (i.e. iPhone)	2	Yes	Multiple reminders,Scan prescription and auto-load of medication,Medication report,Contact researcher,Daily generic reminder	Extremely useful	Excellent	App notification	Excellent	Definitely	very useful for busy and/or old people	Definitely	a great tool in the hand of the GP to know how his patient is coping with the treatment.	excellent work
65+	No	Android (i.e. Samsung, Huawei...etc)	3	Yes	Multiple reminders,Stopped medication,Scan prescription and auto-load of medication,Medication report,Contact GP	Moderately useful	Good	App notification,Email reminder	Good	Definitely	Its a great app. Helps me make sure medication is taken on time especially when you have a busy da y planned.	Probably	It would be great for my GP to help track if of the medication i've taken	I think the app is overall great to have. One thing i'd recommend to jmprove would be the taken button. When the notification appears on my phone there should be an option of either snooze or taken button to tap on rather than having to open the app and doing it on there
65+	No	IOS (i.e. iPhone)	3	Yes	Medication report	Feature not used	Good	App notification	Feature not used	Definitely	Good reminder	Definitely	So as not to miss medication	No need to add or replace features
65+	No	Android (i.e. Samsung, Huawei...etc)	5	Somehow	Daily generic reminder	Feature not used	Good	App notification	Feature not used	Definitely	Old people like myself do need this kind of medication reminder, and this app helps.	Definitely	This app does help.	The app notification feature did not work well on my phone. I hope it can be improved.
25–44	No	Android (i.e. Samsung, Huawei...etc)	2	Yes	Multiple reminders,Stopped medication,Scan prescription and auto-load of medication,Contact GP	Very useful	Good	App notification	Good	Definitely	It help patient to be always in contact with GP as well as it always keep both sudes updated without the need for going to see the doctor which will be hepful for example during covid times	Definitely	Same as mentioned above plus it will allow GP to pricess many inquiries online	None
45–64	No	IOS (i.e. iPhone)	1	Yes	Multiple reminders,Daily generic reminder	Feature not used	Good	App notification	Feature not used	Definitely	Would be good if you are taking multiple medications at different times of the day.	Definitely	Would be helpful to many people!	Nothing. It was great.
45–64	No	Android (i.e. Samsung, Huawei...etc)	1	No	Contact researcher	Feature not used	Bad	App notification	Feature not used	Possibly	It didn't work for me, I didn't get past loading the medication. here are some email comments to Nawal 1: "forgot to mention that I had to enter an end date and I don't have one, it is indefinite. Perhaps no end date should be an option or if it is, it could be more conspicuous." 2:"I have just downloaded the app and set it up. However when I go to log in to set up reminders I can't get in and the error message is" the app keeps stopping". I have a Samsung mobile.... android. Also there was some information I didn't know that I had to put in so I made it up. For example the unit of measure for a drop...I said mcg. And I said I don't know the side effects. I have been putting the drops in my eye for ages and don't have the info to hand." 3. "I got in once and tried to change the Medication time. It didn't work and kicked me out. Now when I try to open it I can't, same message: "MAMA keeps stopping" " Nawal offered to help but I didn't have the time to take her up on the offer.	Possibly	I didn't end up using the App - I couldn't get it set up in the time i had available adn I have another system that works, but I have had to answer questions as if I did - so I have made up the answers.	I suspect that the elderly who are not mobile app savvy like me (I use Apps but it can take me a while to work them out and I didn't have the time with this one), may have similar problems to those I noted above? Also I only had the one ongoing prescription item and I didn't have a prescription available to upload or anything. I use my phones reminder system on repeat to jog my memory where required.
65+	No	Android (i.e. Samsung, Huawei...etc)	1	No	Multiple reminders	Not at all useful	Good	App notification	Feature not used	Probably	This system does not work for me, but it may work very well to somebody else. It does not work for me because I have already developed a habit to take my medication the first thing in the morning, sometimes when I am in bed. It sits on my night table with the bottle of water. That is how my day begins.	Probably	I will mention it to my GP because as I said it did not work for me (with established habit) but it may work for some other patients.	N/A
25–44	No	Android (i.e. Samsung, Huawei...etc)	1	Yes	Daily generic reminder	Feature not used	Excellent	Email reminder	Feature not used	Definitely	Very effective medication reminder app	Definitely	MAMA is a very effective app especially for people with super busy schedule to remember to take their important medications.	If possible, an alarm system with snooze functions.
65+	No	IOS (i.e. iPhone)	1	No	Contact researcher	Feature not used	Fair	App notification	Feature not used	Possibly	Didnt realise I had to enter an original prescription - I started working off my last repeat and the process wasnt intuitive for my final repeat of a 3 month prescription	Probably not	As above - not user friendly at this stage	to be able to use the NZEPS barcode to enter details on an original script (provided the script was correct - often NZEPS scripts are incorrect? That system needs sorting before other systems can hang off them. My medications are complex with bi weekly, weekly and specific days of treatment as well as am and pm medications. I've devised a system that mostly works, its extra occasional medications where things become unstuck
25–44	No	IOS (i.e. iPhone)	4	Yes	Multiple reminders,Stopped medication,Scan prescription and auto-load of medication,Medication report,Contact researcher	Extremely useful	Excellent	App notification,Email reminder,Phone call reminder,Caregiver SMS	Excellent	Definitely	Was able to use it with minimum efforts	Definitely	To share my meds intake with my doctor and so he can follow and advise on any over-the-counter meds	Adding filters to the medication report (ie. by status, date range) Link/access the app through medical ID (viewing medications list for emergency reasons)
45–64	No	IOS (i.e. iPhone)	4	Yes	Multiple reminders,Scan prescription and auto-load of medication,Medication report,Contact researcher	Extremely useful	Excellent	App notification,Email reminder	Feature not used	Definitely	I benefited a lot form the app. From my view it can be very useful for patients with chronic diseases	Definitely	To benefit the patients as expected from the treatment plan For better follow up from the doctor end in case of possibility of medication change or replacement	Integrate with siri/alexa
45–64	No	Android (i.e. Samsung, Huawei...etc)	1	Yes	Daily generic reminder	Extremely useful	Excellent	Email reminder	Excellent	Definitely	I would recommend this app to people on regular medication because it will prompt them to take their medication as scheduled	Definitely	Efficiency	My suggestions below: The app link is added to the reminder email so that users can click on the link directly from the email. The days that medication was taken are color-coded on the calendar so that users can see at a glance the days their medication was taken. Overall good application that can be useful for people of all ages.

SMART REMINDERS TO IMPROVE MEDICATION INTAKE

NAWAL CHANANE + DR FARHAAN MIRZA AUCKLAND UNIVERSITY OF TECHNOLOGY

Mobile applications can be used to help patients struggling with medication adherence as it is usually an extra burden for those with multiple health conditions, or with complex regimens and multiple medications.

There are several reasons for non-adherence but forgetfulness is one of the most commonly reported barriers, counting for more than 30 percent even among motivated patients.[1] Therefore, we developed MAMA (Medication Adherence Management Application); a simple-to-use medication management mobile application. The goals of MAMA are to help keep records of medication list, medication intake logs and on-time medication remindres through a multi-channel notification workflow.[2] MAMA builds on the UTAUT 2 model for mobile IT in the healthcare context.[3]

The MAMA pilot study was designed with the primary goal to evaluate the intervention by assessing the:

- feasibility and acceptability through acquiring early adopters' feedback and recommendations for future development and enhancements.
- efficacy of MAMA in improving on-time medication intake.

The pilot study recruitment occurred from October 2020 to December 2020. Each participant was scheduled for two weeks period starting from the date of the first scheduled medication. Twenty-six individual enrolled on the pilot study. Of those 26 enrolments, only 22 created accounts; 17 females and five males. Out of these total enrolments, 22 participants completed the trial period and the feedback questionnaire.

The results from the pilot study validated the vision of this initiative. MAMA successfully helped participants to take their medication on-time. Our findings indicate that it had an acceptable level of efficacy in improving users' medication intake, with an average of 79 percent (SD= 0.21) adherence across all participants, ranging from as low as 26 percent and as high as 100 percent. Moreover, according to the outcome of a survey conducted, MAMA was rated favourably by the participants. Participants with medication reminders experience rated the functions as excellent. The majority of the participants responded positively to recommending MAMA to their friends and to have a GP recommend it to patients.

MAMA was found easy to use and useful in reminding users to take medication on-time. The data collected through the app indicated that participants used the app, for most of the trialling period consistently. Although the majority of participants did not have prior experience with medication reminder apps, it did not affect the acceptability by participants with multi-medications. This pilot study demonstrated the feasibility and potential utility of the app and revealed a promising future when implemented to address medication intake failure.

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