Using a Mobile Pill Reminder to Support Medication Compliance in South Africa

Cainos Mukandatsama

Supervisor: Prof JL Wesson

Department of Computing Sciences

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Declaration

I, Cainos Mukandatsama, hereby declare that the dissertation for the degree Magister Scientiae is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification to another University or for another qualification.

Cainos Mukandatsama

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Summary

This project investigated how to develop a mobile intervention to support medication compliance for patients with chronic and acute diseases. Chronic diseases cannot be cured but can be controlled, usually by taking medication every-day. Therefore, it is very crucial for a patient with a chronic disease to take their medication on time to prevent complications or negative impact on their health. Due to the widespread use of mobile phones, having an automated mobile mechanism to remind patients to take medication is regarded as an effective way of supporting medication compliance. The focus of the research was on investigating how mobile health applications can be used to support patients with chronic and acute diseases in South Africa.

Literature identified that medication compliance is low and that a need exists for an intervention to increase compliance. The main goal of this research was to produce a mobile health application to assist medication compliance and support patients with chronic and acute diseases in South Africa and investigate its perceived usefulness.

The project made use of two field studies to substantiate its results. The first field study involved patients with chronic diseases and the second one involved patients with acute diseases. The feedback from the first field study and from a literature review was used to redesign the mobile application. The project also investigated the attitude of patients taking medication over a short period of time as well as how such patients compared with those taking chronic medication. The project identified the benefits and disadvantages of using an m-health application to support medication compliance based on the participants' feedback and behaviour observed in using the application.

Keywords: Chronic disease management, medication compliance, self-care, self-regulating system, caregiver, m-health, m-health initiatives, context awareness, acute disease.

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Chapter 1 Introduction

1.1 Background

One of the main problems people are facing today is health and healthcare management. When a patient falls ill, the most important issue to deal with is finding ways to make the patient feel better and this usually happens by getting some medication. Chronic diseases are difficult to deal with since they persist for a long time, implying that the patient needs to seek medical attention for a long period. The World Health Organization (WHO) defines chronic conditions or disease as those conditions that require on-going medical management over a period of years (WHO, 2013). The problem of chronic disease management has been aggravated by the global population increase with the main consequence being an increase in the number of people having chronic diseases, disability and a high level of medication dependency (García-Sánchez, González, Mora, & Prieto, 2013). Chronic diseases take a huge toll on lives of an increasing number of people and are a major contributor to the rising costs in healthcare (Sunyaev & Chornyi, 2012).

Many elderly people suffer from chronic diseases. According to statistical analysis performed, it was found that 81.6% of elderly people have at least one chronic disease (National Centre for Health Statistics, 2012). In order to minimise the effects of these diseases, patients need to take pills on a daily basis (Australian Department of Health, 2010). Long-term conditions require daily attention because the goals and aims of chronic disease management are to reduce the disease burden of the condition (Williams, 2012). This problem results in a need to investigate and explore the most efficient ways of helping users with such conditions to take the right medicine at the right time. To improve chronic illness care and medication compliance, patients should be empowered and engaged in healthcare self-management (Chen, Yan, Shin, Kotz, & Berkel, 2012). This research investigated how this problem can be solved by making use of mobile technology.

To control chronic diseases, a patient needs to take pills every day and they need to be the correct pills and the right dosage at the scheduled time. Effects of not adhering to the schedule and deviating from the schedule have proven to have a negative impact on the patient's health and should be avoided as much as possible (Lorenz & Oppermann, 2009). This means that patients with chronic diseases require some form of a support mechanism in order to help them to stick to the medical schedules that they need to follow on a daily basis. Typically, such

patients (especially the elderly), have caregivers who are responsible for helping them in their daily activities including taking of pills, but the number of caregivers is significantly outweighed by the number of patients (Jing & Koronios, 2010). This implies that a self-regulating compliance mechanism would be useful in helping patients take their pills. It will also be responsible for helping them to identify the pills that they need to take as well as ensuring that the pills do not run out unexpectedly.

It is necessary to produce a solution that can be embedded within technology that a lot of people are currently using. This would reduce the complications of the users having to learn how to use new devices. At the moment, many people are using mobile phones. According to recent studies, more than five billion people are using mobile phones of which approximately 170 million of these are smart phones (Butler, McDaniel & Ongtang, 2010). Mobile technology has been piloted in a range of health-related areas, and has been used to improve the dissemination of public health information diagnosis and treatment, the distribution of health information to doctors and nurses, patient management, public health monitoring and the efficiency of administrative systems. Research suggests that mobile phones can play a significant role in health management (Kinkade & Verclas, 2008).

It is relevant to investigate the effect of using a mobile application to help users taking daily medication to be compliant to their medication schedule. Some work has been done in this field but unfortunately, the existing solutions have several limitations. Some of these applications can only run on expensive phones such as the Apple iPhones or the Windows Mobile phones, which cannot be afforded by many people in South Africa. Also, little work has been done in South Africa to investigate the impact that these possible solutions have on medication compliance (Kagee, 2014). Thus, it was deemed worthwhile to investigate if a mobile self-regulatory medication compliance application can support medication compliance for patients taking daily medication in South Africa.

1.2 Problem Statement

Patients suffering from diseases, which require taking daily medication, struggle to comply with their medication schedule, which has a negative impact on their health status (Sanner, Roland, & Braa, 2012).

There has been a general increase in the number of people suffering from diseases particularly, chronic diseases, which is a burden to the community (Elgazzar, Aboelfotoh, Martin &

Hassanein, 2012). Patients have problems in adhering to their medication schedule, i.e. taking the right type of pills in the correct amount as well as at the prescribed times especially if they are meant to take their medication frequently. The *My Pill Reminder* application was previously designed by the author to address this problem, but this research aims to extend this application to investigate the effect the application will have on the medication compliance of patients with diseases, which require taking daily medication in South Africa.

1.3 Aim of research

The main goal of this research is to develop a mobile health application that can be used to support medication compliance for patients taking medication on a daily basis in South Africa.

1.4 Research Questions

The main research question is as follows:

- How can the *My Pill Reminder* application be extended to effectively support and monitor medication compliance of patients taking medication on a daily basis?

This main research question can be sub-divided into the following sub-questions:

RQ.1. What are the current problems with medication compliance for patients suffering from chronic and acute diseases?

RQ.2. What are the shortcomings of existing m-health approaches that have been used in disease management for medication compliance?

RQ.3. What are the results of evaluating the first version of the *My Pill Reminder* application?

RQ.4. How should the existing version of the *My Pill Reminder* application be re-designed to further support medication compliance?

RQ.5. Can the proposed redesign of the application support patients in South Africa who take medication daily to comply with their medication schedules?

RQ.6. What are the contributions and suggestions for future work resulting from this research?

1.5 Research Objectives

The objectives of this research include the following:

RO.1. Identifying the current problems with medication compliance for patients suffering from chronic and acute diseases and how medication compliance is currently being enforced.

RO.2. Conducting a literature study to review m-health approaches that have been used in disease management for medication compliance.

RO.3. Conducting a pilot field study to evaluate the first version of the *My Pill Reminder* application to find usability issues and identify additional requirements.

RO.4. Re-designing and developing a modified version of the *My Pill Reminder* application based on the user feedback and additional requirements.

RO.5. Conducting a field study to investigate the effect of using the *My Pill Reminder* application on medication compliance for patients taking daily medication.

RO.6. Analysing the results of the research to identify the contributions and suggestions for future work resulting from the research.

1.6 Scope and Constraints

The scope of the research is to re-design an m-health application that is capable of supporting medication compliance. This application will then be used to determine the level of medication compliance support the application can offer to patients taking their medication on a daily basis. To determine the level of medication compliance support, field studies will be carried out with actual participants and the performance measured. This research will focus on medication compliance and not on patient monitoring. Studying the patients' behaviour and their overall health trends is regarded as out of the scope of this research.

1.7 Limitations and possible challenges

The users who are going to evaluate the artefact are people suffering from chronic and acute diseases that required taking medication consistently for at least a week. Ethical clearance will be secured before evaluations since the primary participants are going to be actual patients with diseases of interest. The participants will rely on the application to be reminded to take their medication, which makes it risky and hence the need to have ethical clearance. However, it is important to provide these users with a consent form in order to have evidence that they participated in the study voluntarily. Other potential challenges are as follows:

- **Participants**: Getting patients with chronic diseases who are willing to use the application to remind them to take medication is a possible challenge.

- **Ease of Use**: Smartphone applications can be confusing to those people who are not technologically experienced, especially the elderly;
- **Limited Data**: Obtaining a pills database and the patient's medical health records may be a challenge;
- **Privacy Concerns**: In the absence of clear guidelines, the transfer of medical information is likely to raise privacy concerns with patients (from the doctor and pharmacist to the patient and the caregivers);
- **Cost of Supporting Devices**: Smartphones are expensive and having sufficient phones for users to use may be a challenge; and
- **Data reliability:** Relying on the patients' honesty regarding the taking of pills

1.8 Research Methods

This section describes the methods that are going to be used to carry out the research. The section will outline the methodology to be used, the research strategies and the methods. The research design will provide the orientation of the research.

1.8.1 Research Methodology

The research is going to use Design Science Research (DSR) as the selected research methodology. DSR incorporates the design and development phases within the research process, which produces an artefact to be effectively used as a tool within the research (Ellis & Levy, 2010). DSR is problem focused and present the findings of the research and an artefact as the deliverables (March & Storey, 2008). In this research, DSR will enable the facility to determine the impact of using a *My Pill Reminder* on patients with chronic and acute diseases and produce a fully functional artefact. Since the goal of the research is to use an artefact to support disease management and measure the impact on the patients, DSR can be used to achieve this goal.

Positivism is a philosophy that holds that knowledge is objective and absolute and a single objective reality exists and the research is carried out to yield a clear representation of reality which is unbiased and absolute (De Villiers, 2005). Positivism has less emphasis on the design and development phases and relies mainly on quantitative data to reach conclusions (Levin 1988). In this research, qualitative data is as important as quantitative because it is essential to obtain the patients' perceptions and feelings especially in the field studies. Owing to the reasons

stated above, DSR was chosen over Positivism. DSR was preferred because it focuses on improving the effectiveness and efficiency of attaining goals or demonstrating the necessity of certain actions which add to the knowledge of goal attainment (Vaishnavi & Kuechler 2007), (De Villiers, 2005).

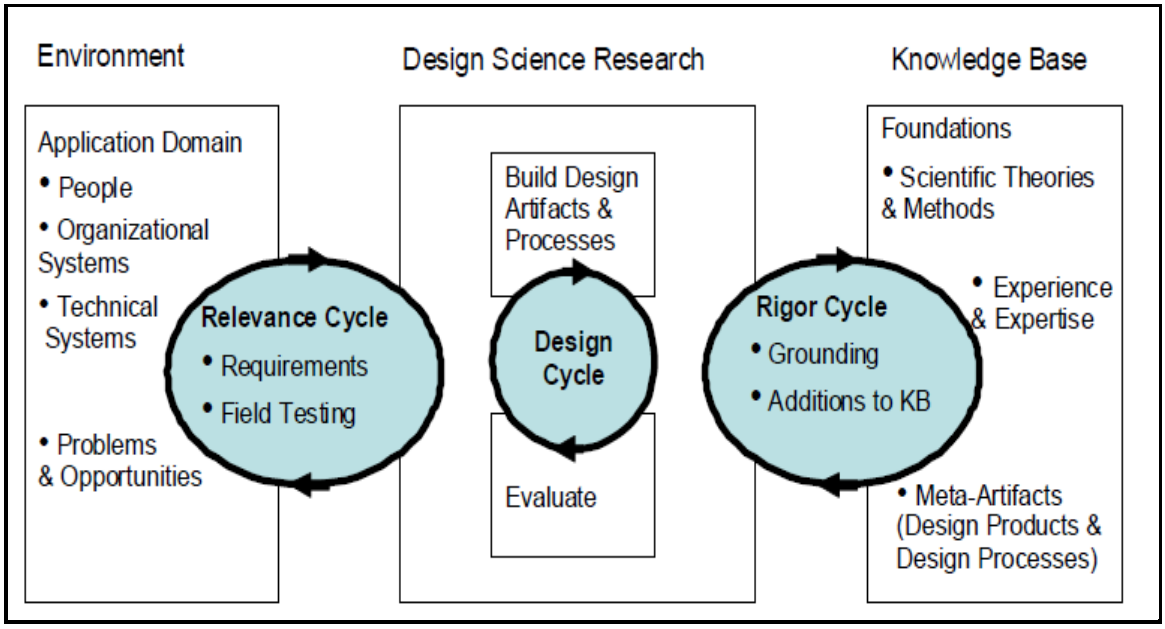

Figure 1.1: Design Science research cycles (Hevner, 2007)

Figure 1.1 shows the research cycles of DSR, which are going to be used for this research. The Relevance Cycle will input the requirements, which will be drawn from the field studies and will also be responsible for ensuring that these results are met. The Rigor Cycle will ensure that grounding theories and methods are provided from the foundation knowledge and add new knowledge generated by the research to the growing knowledge base (Hevner, 2007). The Design Cycle will enable the development and evaluation of the artefact to be carried out iteratively to allow improvement of the solution. The cycles and the guidelines listed in Appendix 1 represent the essential elements of DSR (Esearch, Hevner, March, Park, & Ram, 2004).

1.8.2 Research strategies

This section outlines the strategies that are going to be used within DSR to answer the research questions. These strategies were chosen to enable the research to be able to answer the research questions. These strategies includes: Literature study and Field studies.

1.8.2.1 Literature Study

A literature study will be used to provide literature on chronic disease management and m-health initiatives. This study will discuss the key concepts in chronic and acute diseases, how they are currently being managed and the problems associated with them. It will also look at the issues surrounding the emerging field of m-health and how it has been instrumental in using mobile phones to provide convenient solutions in the health domain. The literature study will also provide a detailed overview of the m-health initiatives that have been implemented in developing countries and highlight their strengths and shortcomings.

1.8.2.2 Field studies

Two field studies will be used for assessing the impact that the self-regulatory medication compliance mechanism has on the actual patients. This will involve having the patients using the mobile application over a period of time and assessing the impact it has on their medication compliance. The field studies will be used to gather requirements for the application and usability issues of the existing application. The first field study will be short (two-three days) and will get user feedback on the existing application. The subsequent field study will be longer (five days) and will also give an indication of the user acceptance of the application. Within the field studies, questionnaires will be used to get the feedback from the participants. Interviews will also be used after the field studies to get detailed feedback from the participants. Using post-test questionnaires and interviews will assist in obtaining detailed feedback from the participants which will possibly give a strong basis to make conclusions.

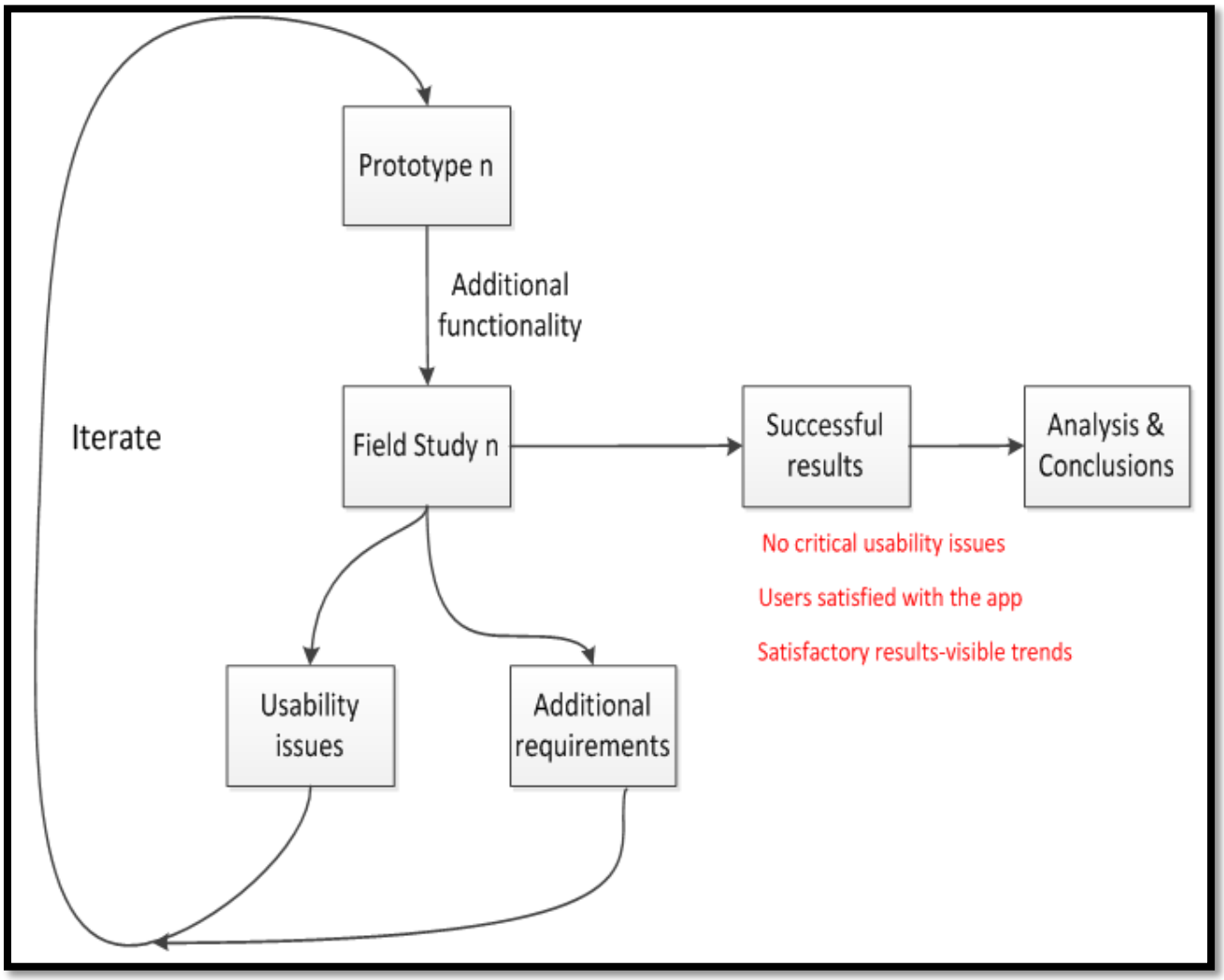

Figure 1.2: Outline of how the field studies will support iterative design

Figure 1.2 shows how the field studies are going to be used in the research. The field studies to be done and their corresponding reasons are as follows:

1. Initial study:
    - To evaluate the existing version of the application;
    - To gather requirements and usability issues;
    - For a short period (two to three days); and
    - The participants will be chronic disease patients.
2. Summative field study:
    - To evaluate the modified application;
    - With a back-end server;
    - Get additional requirements; and

- For a period of at least five days.

1.9 Chapter Outline

Table 1-1: Relationship between research questions, strategies and chapters

Research Question	**Chapter**	**Research strategy**	**Deliverable**
1. What are the current problems with medication compliance for patients suffering from chronic and acute diseases?	Chapter 2: Medication Compliance	Literature study	Outline of problems and challenges faced by patients in complying with their medication schedules.
2. What are the shortcomings of existing m-health approaches that have been used in disease management for medication compliance?	Chapter 3: M-health initiatives	Literature study	Strengths and weaknesses of existing approaches that have been used before. Outline of the m-health areas that are lacking sufficient research.
3 What are the results of evaluating the first version of the *My Pill Reminder* application?	Chapter 4: Pilot Field Study	Initial field study	A list of usability issues and additional requirements based on the user feedback.
4. How should the existing version of *My Pill Reminder* application be re-designed to further	Chapter 5: Re-designing and Implementation	Prototyping	An m-health application as a tool to be used for measuring the impact during the field studies.

support medication compliance?			
5. Can the proposed redesign of the application support patients in South Africa who take medication daily to comply with their medication schedules?	Chapter 6: Summative Field Study	Summative field study	Results of the user and field studies which can be used for determining the performance of the artefact.
6. What are the contributions and suggestions for future work resulting from this research?	Chapter 6: Conclusions	Critical analysis	Conclusions eliciting the achievements, limitations and contribution of the research.

Chapter 1 will present the introduction to the research. A brief background and the problems that exist within the domain will be presented. The problem statement presents the problem to be addressed by the study and the aim of the research provides the suggested solution to the problem. The main aim of this chapter is to provide the problem that needs to be solved and the manner in which the problem will be solved. The research design will also be discussed. The ethical clearance and limitations of the research will also be discussed.

Chapters 2 and 3 will focus on the literature study. Chapter 2 will provide literature on disease management and medication compliance. This chapter will discuss the key concepts in chronic and acute diseases, how they are currently being managed and the problems associated with them. The chapter will also look at medication compliance particularly for patients with long term conditions. Issues surrounding medication compliance will be reviewed and the reasons why it is important to follow medication schedules.

Chapter 3 will look at the issues surrounding the emerging field of m-health and how it has been instrumental in using mobile phones to provide convenient solutions in the health domain. The chapter will also present an overview of the m-health initiatives that have been implemented in developing countries and their strengths and shortcomings. In particular, focus will be placed on the issues surrounding work done so far in solving the issues surrounding medication compliance.

Chapter 4 will discuss the pilot field study to evaluate the first version of the application. The pilot field study will be conducted to meet the third research objective and the results of this study will be analysed. The goal of the chapter is to get user feedback and identify the usability issues with the first version of the application and identify additional requirements

Chapter 5 will discuss the re-design and implementation of the proposed m-health application, which will be used as a tool for the research. The *My Pill Reminder* application was previously developed by the author, but it needs to be modified to be able to be used as a tool to investigate if it can support medication compliance. Redesigning this application will be influenced by the results of the pilot field study. This chapter will outline the process of redesigning and implementing the m-health application.

An outline of the summative field study will be provided in Chapter 6. The artefact designed in Chapter 5 will be evaluated by selected patients with chronic and acute diseases. The chapter will discuss the design of the evaluation and will also present the results obtained during the field study. This will be followed by analysing the results and discussing them and making important observations. The chapter will also outline the users' perceptions towards the application and will provide information to enable a conclusion regarding the extent to which a *My Pill Reminder* can support medication compliance for patients in South Africa. Also, advantages and disadvantages of the proposed solution will be discussed in terms of the users' feedback.

Chapter 7 will provide the conclusions of the study and recommendations for future research that could be conducted. It will highlight the limitations and challenges faced during the research and possible solutions for future work.

Chapter 2 Medication Compliance

2.1 Introduction

Chapter 2 will provide literature on disease management and medication compliance. This chapter will discuss the key concepts in chronic and acute diseases, how they are currently being managed and the problems associated with them. The chapter will also look at medication compliance particularly for patients with long term conditions. Issues surrounding medication compliance will be reviewed and the reasons why medication is low. Chapter 2 also review the issues surrounding self-care.

2.2 Acute Diseases

An acute disease is a disease that lasts for a short time but usually begins very rapidly and has strong and visible symptoms (Wlodzimirow, 2013). Unlike chronic disease, most acute diseases can be cured by taking some medication for a short period of time. Generally, medication compliance is higher among patients suffering from acute diseases relative to patients suffering chronic diseases (Sabaté, 2003). Compliance is higher in acute diseases because the effect of not taking medication for acute diseases usually results in a very negative impact on the health status of the patient. Since acute diseases are for a short time, the period that a patient takes medication is also short.

2.3 Chronic Diseases

Chronic diseases are illnesses that are prolonged in duration, do not often resolve spontaneously and are rarely completely cured (Australian Department of Health, 2010). According to McKenna and Collins, a chronic disease can be regarded as an illness or sickness that persists for a long time, is rarely absolutely cured, does not go away on its own, and can result in disability of the patient later in life (2010). Chronic diseases can be referred to as any diseases that tend to persist for a long time. According to National Centre for Health Statistics (2012), any period which is greater than three months is regarded as a long time. Thus a chronic disease is one which persists for more than three months continuously. There are different types of chronic diseases and they have different intensities, which require different levels of attention. Unlike acute illnesses that may be controlled with short-term intervention, chronic diseases require long-term management and monitoring, changes in lifestyle, and compliance to medication schedules (Chen *et al*., 2012).

Chronic diseases are mainly caused by risk factors such as, high blood cholesterol, high blood pressure, obesity, physical inactivity, unhealthy diet, tobacco use and inappropriate use of alcohol (Steyn, Fourie & Temple, 2006). These factors result in various long-term disease processes which fall in the category of chronic conditions. People with chronic diseases require constant monitoring of their health. Not adhering to a medication schedule has a negative impact on the health of the patient. There is also a rise in the number of people suffering from chronic diseases and it is a burden to the community (Elgazzar *et al*., 2012). Efforts are being made to try and improve the management of chronic diseases at the same time minimizing the cost.

Some chronic diseases are critical, which means not taking the medication may impact severely on the patient's health status. On the other hand, some chronic diseases are not that serious and missing medication would not have the same impact as the serious ones. People suffering from chronic diseases need different levels of attention. Not all patients require accommodation and assistance offered by long term care facilities can be offloaded to their homes and their health conditions can be monitored there (Elgazzar *et al*., 2012). Studies done by the Health Research Institute, (2010), shows that patients are willing to adopt mobile health monitoring. The studies also found out that caregivers feel that mobile health monitoring would improve agile health monitoring and convenience. This means that it might be viable to have patients with chronic diseases having their health managed from home.

Figure 2.1: Circles of Influence in Self-Management of Chronic Disease *(UMCMCD, 2012)*

Figure 2.1 shows circles of influence in self-management of chronic disease. The circles shows that at the core there is self-management and the subsequent circles are the ones involving people who assist the patients and are usually referred to as caregivers (UMCMCD, 2012).

Governments of the majority of developing countries and international aid agencies have been making efforts to control the management of communicable diseases, chronic diseases and malnutrition (Sanner *et al*., 2012). However, according to World Health Organization (2012), less than 50% of patients suffering from chronic diseases in developing countries follow treatment schedules. This shows that there is a need to find ways of improving this situation in developing countries like South Africa.

Due to the reasons mentioned earlier, it is vital that patients with chronic diseases have some type of reminding mechanism to remind them to correctly take their medication as prescribed. Typically, they have caregivers whose major objective is to assist the patients in executing their daily activities as well as stick to their medical schedules. However, due to the large numbers of these patients', the number of caregivers is much smaller than required (Jing & Koronios, 2010). Due to the shortfall of caregivers, a more personalized reminding mechanism, which serves the same task as those provided by the caregivers might be useful. This mechanism will be in the form of a self-monitoring or self-regulating compliance system.

2.3.1 Causes of Chronic diseases

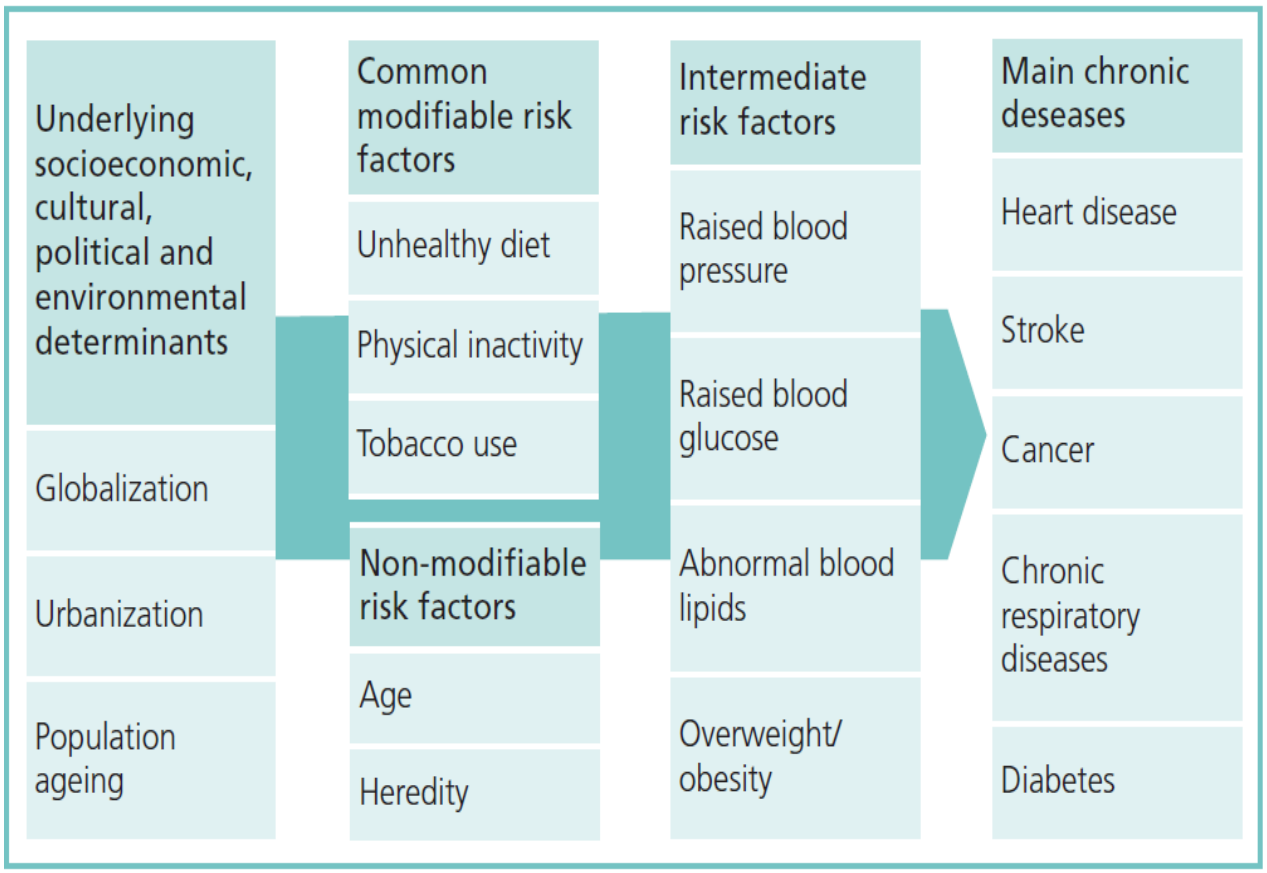

Figure 2.2: Top causes of chronic disease (WHO, 2013)

There are various factors which are responsible for the escalating rate of growth of chronic diseases in Africa (Prentice, 2006). Figure 2.2 outlines some of the factors which might lead to chronic diseases. Figure 2.2 also illustrates the underlying factors as well as the result of the factors over a period of time. Africa's chronic disease burden has been strongly attributed to the changing behavioural practices. The behavioural lifestyle change includes sedentary lifestyles and unhealthy diets, which are high in saturated fat, sugar and salt, which are linked to structural factors such as industrialization, urbanization and increasing food market globalization (Rabin, Boehmer & Brownson, 2007), (WHO, 2003).

Africa is also experiencing this transition and this account for the growing number of people with chronic diseases (Kagee, Le Roux & Dick, 2007). According to Globalization and Health, the major risk factors for chronic diseases are: physical inactivity, diets which are unhealthy and alcohol and tobacco use (de-Graft, 2010).

The risk factors only point out some practices which increase the likelihood of an individual suffering from a chronic disease and are not directly causative agents of chronic conditions.

There are other natural factors which can cause chronic diseases for example age or inheritance from parents (WHO, 2013). Some of the individuals living with these chronic diseases in African countries have poor knowledge of their conditions and how to manage them. People who cannot manage their health would need some assistance from health care providers or their families in order to manage their conditions. This creates a dependency between the patient and health care providers and caregivers. This in turn creates a burden on the health care providers since catering for all the people with chronic diseases is a challenge (de-Graft, 2005).

2.3.2 Elderly people and chronic diseases

It is very difficult to have a single cut-off value for age beyond which one is regarded as elderly. However, according to World Health Organisation, the arbitrary threshold age is regarded as sixty years (WHO, 2012). This implies that anyone who exceeds this age is regarded as elderly. As age increases, it is usually associated with reduction in the efficiency of the immune system, lessened and weakened hearing, diminished and decline in eyesight, reduced mental or cognitive ability, among others (Salthouse, Timothy, 2009). Owing to this elderly people face a lot of challenges in executing some tasks in their every-day activities. However one of the common conditions associated with this group is usually that of chronic diseases.

Chronic diseases are illnesses that are prolonged in duration, do not often resolve spontaneously, and are rarely cured completely (Australian Department of Health, 2010). Chronic diseases can be referred to as any diseases that tend to persist for a long time and according to National Centre for Health Statistics, any period which is greater than three months is regarded as a long time (National Centre for Health Statistics, 2012).Thus a chronic disease is one which persists for more than three months continuously. It is worth taking note of the fact that these diseases tend to be more defined as age increases. According to statistical analysis shown by Table 2-1, 81.6% of elderly people have at least one chronic disease. This data is an indication of the fact that chronic diseases are more prone to elderly people and this in turn implies that they would need to take many pills on a daily basis.

Table 2-1: Analysis of the National Health Survey for chronic diseases (National Centre for Health Statistics, 2012)

Proportion (%) of chronic conditions reported, by age group					
Number of chronic conditions	**0-14 years**	**15-24 years**	**25-44 years**	**45-64 years**	**65+ years**
None	86.9	80.8	74.0	47.0	18.4
One	12.3	17.0	21.0	32.0	32.0
Two	0.8	1.9	3.8	14.1	26.7
Three	-	0.3	1.1	5.1	15.3
Four	-	-	0.2	1.4	5.0
Five or more	-	-	-	0.5	2.6

2.3.3 Chronic Disease Management

There are many definitions of chronic disease management, but one of the more comprehensive of these was developed by the Disease Management Association of America (2010). Key elements of this definition include supporting the relationship and plan of care between the care provider and the patient, an emphasis on preventing worsening of disease using evidence-based practice guidelines and patient empowerment strategies, and on-going evaluation of outcomes with the goal of improving overall health (Disease Management Association of America, 2010). Figure 2.3 illustrates the major elements of chronic disease management. Figure 2.3 shows that patients can manage their chronic condition effectively if the community and the health care facility support them and can interact with them frequently. The goals of chronic disease prevention and management are to prevent disease occurrence, delay the onset of disease and disability, lessen the severity of disease, and improve the health-related quality and duration of the individual's life (McKenna & Collins, 2010).

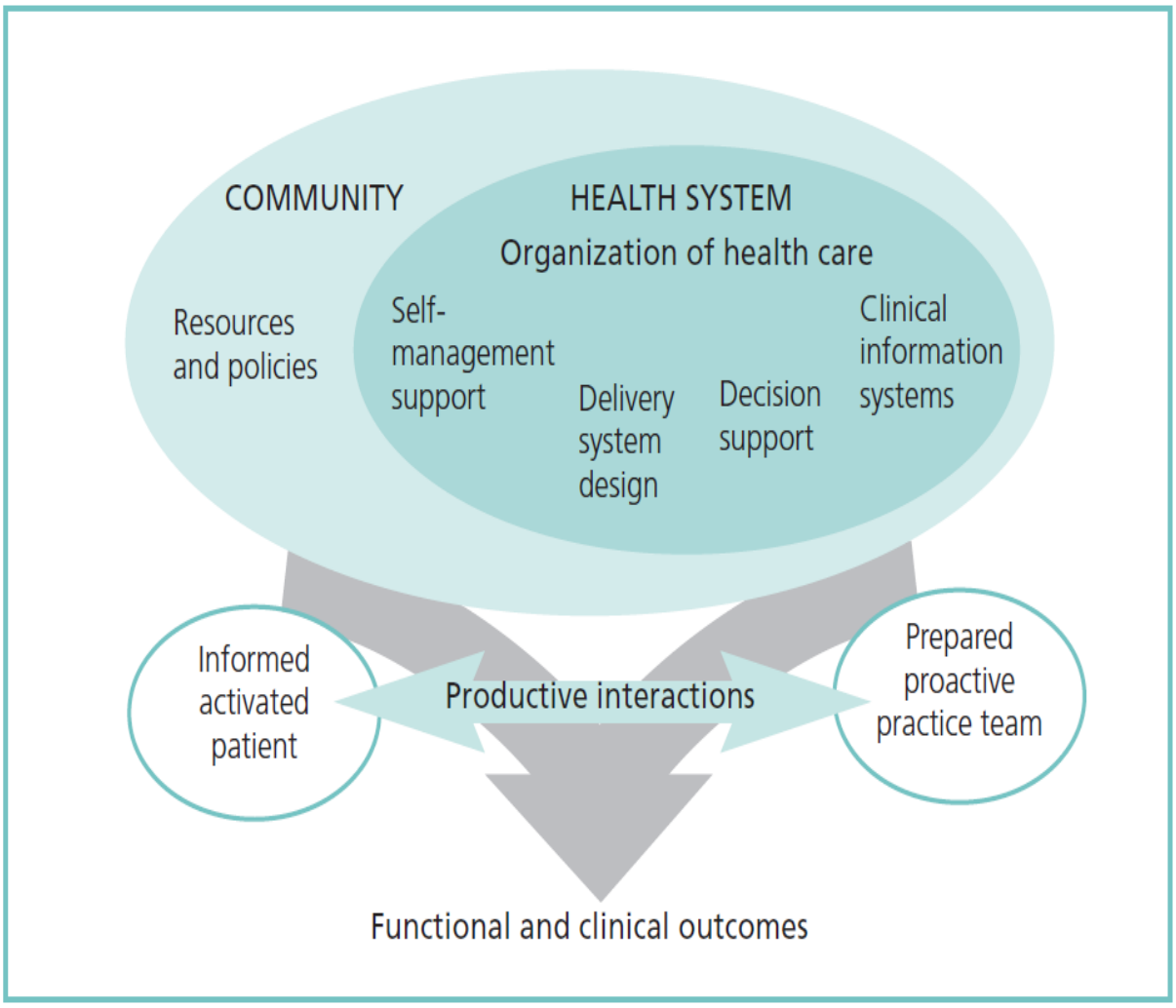

Figure 2.3: Chronic diseases management (Singh, 2008).

2.4 Self-care

One of the essential pillars of chronic disease care is that of self-care or self–management. Self-care's strength lies in the fact that it is centred on the primary individual, that is, the patient itself. According to WHO, self-care is the ability of an individual, caregiver and the community at large to support health, to prevent and control diseases and sustain health to manage sickness and disabilities with or without aid by healthcare providers (WHO, 2012). According to Dorothea Orem, self-care can be defined as behaviour that an individual learns for a particular purpose and follows a sequence of patterns and actions (Orem, 2001). For an individual to be able to practice self-care, the individual should learn some of the activities involved in taking care of their own health. Self-care comprises self-diagnosis, self-health management, health promotion and prevention, self-monitoring and self-medication and may or may not involve partnering with health professionals (Rijken, Jones & Heijmans, 2008).

Self-care eliminates the full dependency of the patient on the health professionals and empowers the patient to partner with the people around them in the community to look after their health status. Reduction of patient-health professional is very important in chronic disease management since chronic disease patients ought to manage their health status on a daily basis. The reduction of the dependency will reduce the intensity of the need for the health professionals to give attention to the patients timeously. This is very important since the number of chronic disease patients far exceeds that of the health professionals (Jing & Koronios, 2010).

Barriers to self-care

Alongside the growing disease burden of chronic conditions, there is an increased interest in the role of self-care to control disease progression; however, this approach presents a number of challenges (Narayan, Ali & Kopla, 2010).

Self-care is very essential in chronic disease management if practised appropriately. However, there are barriers which inhibit the widespread adoption of self-care. These barriers are caused by different reasons depending on factors like the geo-location of the people, cultures, level of education or even s access to information and awareness programmes.

1. Health care providers

Health care providers (professionals) can be barriers to self-care adoption by the community. Health care professionals are usually responsible for conveying the information of managing personal health to the patient and the people around the patient (Lewin *et al*., 2014). However, health care providers can lack time or appropriate skills, or may incorrectly label a patient's behaviour as "non-adherent" or "non-compliant" (Williams, 2012). In such cases, where the health care providers are not able to pass information adequately, the patient's self-care ability will be affected. In that way, health care providers can be barriers to self-care.

2. Access to resources and facilities

Self-care can be affected by the exposure level of the patient and the community to health facilities. Access to health care resources and services for the community, especially primary care, can be a significant barrier to optimal self-care. Williams, L. (2012). If this access is low, self-care will not be optimal since the patients and their corresponding caregivers will not be able to consult professionals or get some advice, knowledge and medical equipment easily.

This will reduce the ease and quality of self-care since the caregivers and patients may end up improvising and doing some practices which are not recommended.

3. Policies by facilities

Health care facilities' policies can affect the success of self-care. Facilities can find it difficult to support self-care for all types of diseases and conditions. Not all health care providers work in health care facilities that include an integrated approach to chronic care and support or advocacy for self-management (Safran, Neuman & Schoen, 2005). Some health care facilities might have policies to support self-care for patients with short-term acute diseases and not diseases that persist over a long time. Such situations can inhibit the adoption of self-care for patients with chronic diseases. In this way, the policies used by health care facilities can be barriers to self-care.

4. Physical barriers

Sometimes the adoption and success of self-care is influenced by the physical state of the patient. Chronic conditions (especially for the elderly) often result in physical disability due to reduced and lessened strength, vision, or sensation (Pun, Coates & Benzie, 2009). Physical incapacity can be a barrier to the patient's ability to take care of themselves and sustain their health to manage sickness. The dependency of the patients on the caregivers and health care professionals is high for people who are not physically capable of managing their health statuses (Jing & Koronios, 2010). Such patients will require constant check-ups and consultations with health care providers; therefore making it very difficult for the establishment of self-care in such a group.

5. Cognitive barriers

A patient's knowledge about a specific chronic condition has a powerful influence on his or her ability to perform optimal self-care. It has been reported that people with low literacy levels have more difficulty learning self-care skills (Macabasco-O'Connell *et al*., 2008). This can be a barrier to self-care since if a patient has low literacy level it might affect the extent to which he/she will be able to look after his/her health.

6. Social and cultural barriers

The involvement of a patient's family can either support or hinder patient self-care behaviours. It is helpful to take into account the role of spirituality, participation in community religion,

and cultural practices such as traditional healing to understand how family and social context will affect self-care directives (Truter, 2007).

2.5 Medication Compliance

Compliance can be defined as 'the extent to which a person's behaviour coincides with medical or health advice" (Haynes, 1979). Medication compliance refers to the degree or extent of conformity to the recommendations about day-to-day treatment by the provider with respect to the timing, dosage and frequency (Cramer, Roy, Burrell, & Fairchild, 2008). Adherence is a synonym for compliance and the two terms are usually used interchangeably (Haynes *et al*., 2000). Compliance with short-term medications is generally considered to be somewhat higher than for long-term medication regimens (Morris & Schulz, 1992). Therefore, medication compliance for chronic diseases is low since they fall in the long-term category.

It is important to first take a look at some of the reasons that are responsible for people deviating from the medical schedules they receive from their medical practitioners. Studies done by Liu, Zhu, Holroyd & Seng (2011) suggest that medical compliance applications on the Apple App store are less than 5% of the m-health applications. Another aspect that is important in determining medication compliance is a patient's persistence. According to Cramer and colleagues (2008), persistence can be defined as the amount of time that a patient takes medication from the onset to the time they stop taking medication. A patient can be regarded as persistent in taking medication if he/she consistently takes their medication as prescribed to them. Figure 2.4 shows medication compliance and persistence over a period of time.

Medication non-compliance can be categorised into four groups (Briesacher, Gurwitz & Soumerai, 2007), (Safran, Neuman & Schoen, 2005):

1. Primary: This is when a patient does not get the medication in the initial prescription;
2. Secondary: This is when a patient does not take their medication because he/she fails to refill the prescription before the next dose;
3. Unintentional: This is when a patient does not take their medication because of his/her carelessness or forgets to take the medication; and
4. Intentional: This occurs when a patient makes a conscious decision not to take their medication.

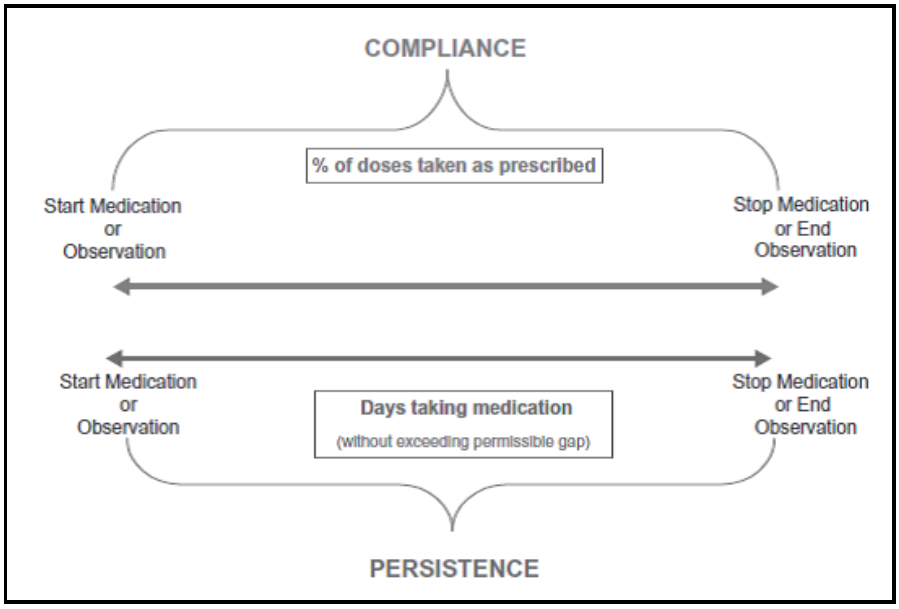

Figure 2.4: Medication compliance and persistence over a period of time (Cramer et al., 2008).

It is difficult to improve compliance of patients who intentionally miss taking their medication because they choose to deviate from the medication schedule (Lowry, Dudley, Oddone, & Bosworth, 2012). Literature shows that there is great potential for the first three categories to be addressed to improve compliance (Heisler *et al*., 2004).

Factors affecting medication compliance

There are various factors which make patients to have different medication levels. Some of the common reasons found for patients not complying with their medication regimens include the following (Qudah, Leijdekkers, & Gay, 2010), (Khan *et al*., 2010):

- The patient forgetting to take their medication;
- Deliberately deciding to disregard the doctor's directives;
- Changes in the medication schedule;
- Confusion caused by unclear instructions;
- Overwhelmed by the number of prescribed medications;
- Fear of side effects or further complications;
- Feeling that the symptoms will vanish over time;
- Using another person's pills and their corresponding schedule;

- Stopping pill intake when symptoms disappear and feel that medication is no longer necessary;

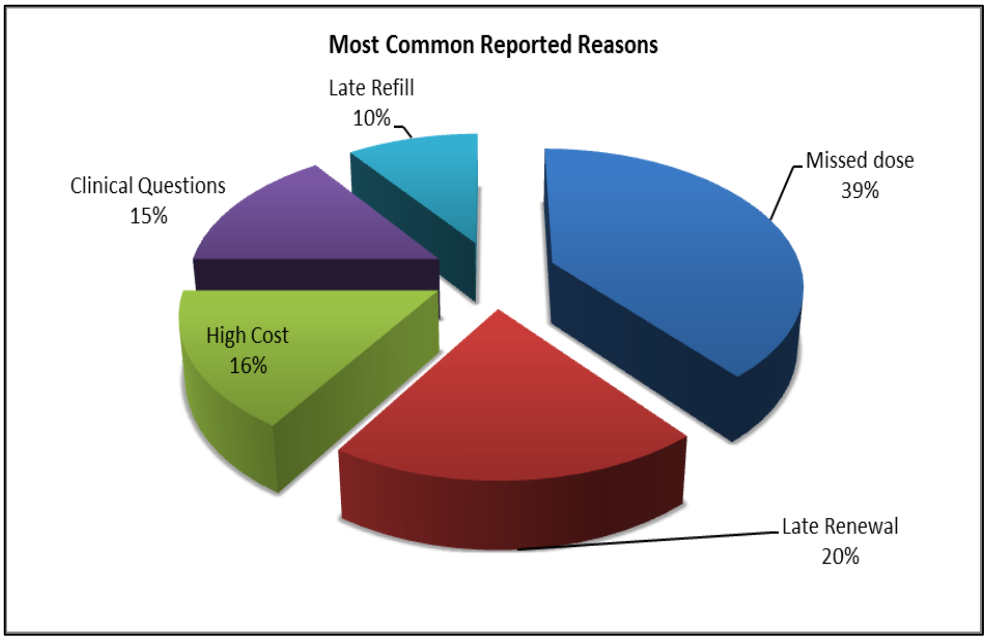

Figure 2.5: Common reported reasons for not taking medication (Express Scripts, 2012).

In 2012, Express Scripts published the results of their survey of investigating the reasons that patients reported as the ones which made them not to take their medication. Figure 2.5 shows the common reported reasons responsible for causing the patients not to take their medication. Figure 2.5 indicates that the two major reported reasons, which made patients to be non-compliant, were: missing their dose and late renewal. Missed dose was when the patient forgot to take their medication at the prescribed time. Figure 2.5 show that the other reported reasons were: refilling the medications late, patients having some clinical questions and not affording medication because of the high cost.

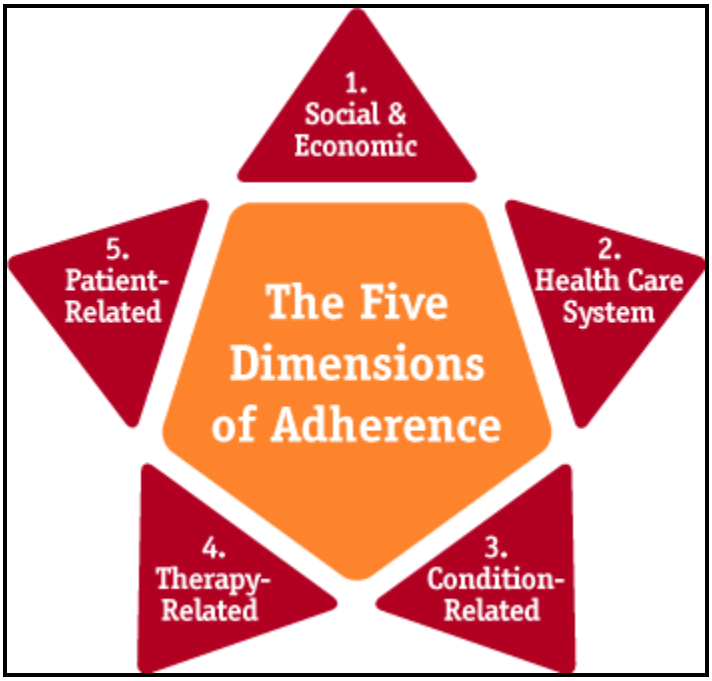

Figure 2.6: Five dimensions of medication adherence (WHO, 2003).

Adherence can be regarded as multidimensional and is affected by the five major factors which become the basis of the five dimensions of adherence (Adult Med-Ucation, 2006). Figure 2.6 shows the five dimensions that affect and determine medication adherence.

1. **Socio-economic dimension**:

The socio-economic dimension is made up of social and economic factors which can affect medication compliance. This dimension can affect medication compliance negatively in the following ways (Liefooghe *et al*., 1995), (Dick & Lombard, 2008):

- If the patient lacks a stable social support networks and good living conditions;
- Unfavorable social circumstances such as poverty, unemployment among others;
- When the cost involved with medication procurement is high;
- If transportation cost are high to medical facilities; and
- If the health literacy of the patient is low and low language proficiency.

2. Health care system dimension:

This dimension consists of the factors from the nature of health facilities' services, that that can affect a patient's medication compliance. The health care system can affect the medication compliance in the following cases (Steyn *et al*., 1997), (Lewin *et al*., 2014):

- When the health care facilities are poorly developed;

- When there is an inadequate relationship and interaction between patient and the health care providers;
- Untrained and unskilled health care workers providing services of poor quality; and
- Insufficient flexibility of the working hours of the health care facilities.

3. Condition-related dimension:

This dimension is made up of factors which can affect a patient's medication compliance because of the nature of the condition that the patient is suffering from. Condition-related dimension can affect the medication compliance in the following cases (WHO, 1997), (Dick & Lombard, 2008):

- When the patient has a complex treatment plan;
- When the medication of the medication has adverse effects on the patient; and
- When a condition does not have visible symptoms.

4. Therapy-related dimension:

Therapy-related dimension is made up of factors which are as a result of patient therapy. This dimension can affect medication compliance negatively in the following ways (WHO, 2003), (Lewin *et al*., 2014):

- The nature of the medication regimen especially in cases when the number of daily doses is large;
- When the medication has unpleasant side effects;
- When the treatment or medication interferes with the patient's lifestyle or requires changes in the behavior of the patient; and
- When the duration of therapy is long.

5. Patient-related dimension:

The patient-related dimension is made up of the patient's physical and behavioral factors, which can affect medication compliance. This dimension can affect medication compliance negatively in the following ways (Banerji, 1993), (Sumartojo, 1993), (Hudelson, 1996):

- The nature of the patient's cultural beliefs regarding the illness and its treatment;
- The Ethnicity, gender and age of the patient;
- Mental disorders or depression; and
- When the physical state of the patient is not in a good state.

2.6 Self-regulating compliance mechanisms

This research intends to make use of a self-regulating compliance mechanism as a tool to investigate how m-health initiatives can impact the way that patients take their medication. This mechanism will be in the form of a self-monitoring or self-regulating compliance system. This would imply that the patient can personally ensure pill intake by just sticking to the provided schedule. This model has a set up as shown in Figure 2.7, which illustrates the manner in which data will flow between the user and the system.

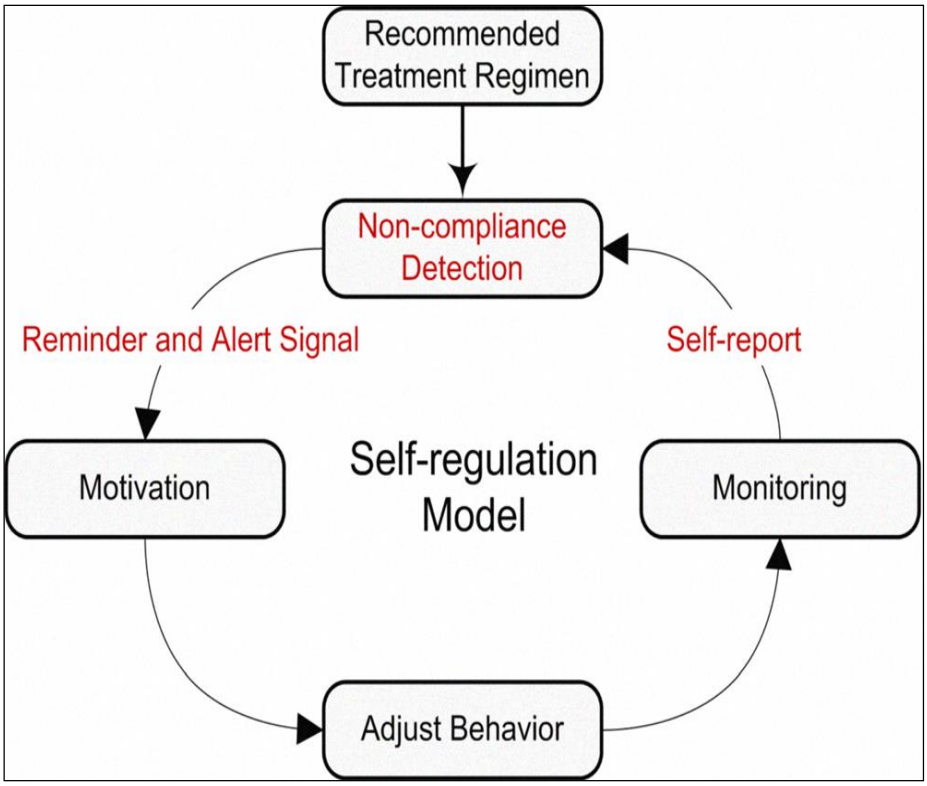

Figure 2.7: The self-regulatory medication compliance model (Chen *et al.*, 2012)

As illustrated by Figure 2.7, the basis of the model is the user since there is little or no interaction with other people. This implies that the user must be able to use the system and use it timeously for it to be efficient. Since the model consists of a vast amount of personal data, it is logical to make use of mobile phones since they provide privacy at the same time as they are pervasive, which makes them more appropriate than desktops. This is also aided by the widespread use of mobile phones in South Africa, which means that the target market also makes use of this form of technology and hence will be keen to use the system.

2.7 Conclusion

This chapter focused on the related literature of chronic and acute disease management and medication compliance in South Africa. Chapter 2 discussed the key concepts in acute and chronic diseases, how they are currently being managed and the problems associated with them. The chapter narrowed down to look at medication compliance and the problems around that area particularly for patients taking medication on a daily basis. Issues surrounding medication compliance were reviewed and the first research question, outlined in Section 1.4, was addressed. The chapter was the first of the literature chapters, which are responsible for the Problem Identification and having an in-depth review of the literature to create the Knowledge Base for DSR. The following chapter will review some of the approaches that have been to solve the problem of low medication compliance. Chapter 3 will focus on work that has been done in the mobile health domain.

Chapter 3 : M-health initiatives

3.1 Introduction

This chapter is the second literature chapter which completes the literature sections of DSR. Chapter 3 is aimed at answering the second research question by identifying the shortcomings of existing m-health approaches that have been used in disease management for medication compliance. Chapter 3 addresses the issues surrounding the field of m-health and how to use mobile phones to provide convenient solutions in the health domain. The chapter also presents an overview of the m-health initiatives that have been implemented in developing countries and their strengths and shortcomings. In particular, focus is placed on the issues surrounding work done so far in attempt to solve the issues surrounding medication compliance. During the analysis of the existing approaches and systems, the following aspects are considered important: the functionality supported, the nature of interaction supported as well as the general design and efficiency of the solution.

3.2 Popular Health technologies

There are different forms of technology that have been used in the health sector to support the facility of reminding patients to take their pills. However, before looking at existing applications, it is worthwhile to take a look at the different technologies and review some of the technologies that are efficient in solving the problem. Table 3.1 gives a summary of the different technologies used to try and solve the pill reminding problem and the respective functionality supported.

Table 3-1 gives an outline of some of the popular technologies that have been used to try and improve medication compliance. They have different capabilities based on the nature of functionalities they offer. It would be preferable to have a solution that would be easy to use and with the minimum patient effort. For the purpose of this study, the following characteristics are regarded important and formed the basis of the comparison of the different health technologies (Qudah *et al*, 2011), (Vervloet *et al*., 2012), (Burstein, 2011):

- Ease of loading the pills/pills data: Measures whether or not the technology requires constant filling or refilling with pills and whether the process is done manually or can be automated;

- Portability: Measures the size of the physical tool and determines the level of portability;
- Affordability: Measures the average price range of the various technologies and the extent to which it is affordable to the average patient;
- Identification of the pills: Measures whether the technology used will make it easier for the patient to identify the correct pills that they are supposed to take particularly if different types of pills are taken in a single dose;
- Linking with family members: Measures if the technology is capable of linking up with family members or caregivers for reporting purpose; and
- General comment on functionality: Measures the overall functionality that the technology supports for the patient.

Table 3-1: Summary of different technologies and their functionality (Qudah *et al*, 2011)

Functionalities	Technology			
	Pill Holders	Alarm based Aids	Pill Monitoring Devices	Mobile Phone based Solutions
Pill holder	✓	✓	✓	✗
Manual refill	✓	✓	✓	✗
Portable	✓	✓	✗	✓
Pill reminder	✗	✓	✓	✓
Medication schedule modification	Manual	Manual	Manual	✓ Remotely
Medication and dosages guidance	Manual	Manual	✓	✓
Data collection (E.g. Side effects response)	✗	✗	✓ Limited	✓
Data Transfer to health centre	✗	✗	✓ Limited	✓
Remote monitoring from health centre	✗	✗	✗	✓
Record date and time of Pill Bottle opening	✗	✓	✓	Manual
Medical appointment management	✗	✗	✗	✓
Education and awareness of patients about medication	✗	✗	✗	✓
Personalisation	✗	✗	✓	✓
Monitoring of vital health signs	✗	✗	✗	✓

3.2.1 Pill Holder

Pill holders are usually in the form a seven-day-pillbox or pill holder which is designed to take pills that a patient will take in a week (Abbey *et al*., 2012). A pill holder consist boxes or containers for carrying pills that are divided into different compartments with the pills and their instructions loaded manually into the different compartments. Each compartment will hold the pills meant to be taken per day or dosage depending on the size of the pill holder. For example,

a seven-day-pillbox has seven compartments which correspond to seven days in a week and each compartment takes the corresponding pills for that day. Figure 3.1 shows the appearance of a seven-day-pillbox with labelled days of the week.

Figure 3.1: Seven-day-pillbox with labelled days of the week (Abbey *et al.*, 2012)

Hayes, Hunt, Adami, and Kaye (2006) developed a pillbox called MedTracker which monitors medication compliance by extending the traditional seven-day drug store pillbox. The pill holder consists of compartments for storing pills for the seven days of the week. Each compartment can be loaded with the pills, which are meant for the patient to take on that day. MedTracker is connected to a computer via Bluetooth and all data movement is in line with this technology.

Pill holders can be used for improving medication compliance if they are used with a reminder mechanism like the SMS system. Pill holders are useful for holding the pills for a day separate from others with the hope of making it easier for the patient to identify the right pills and not get overwhelmed by taking different types of pills. However if a patient is taking a number of pills at various intervals, it might be difficult to identify the pills to take at a single dose since the pills for the day will be mixed up in one compartment.

Table 3-2: Review of pill holders

Characteristic	Comment
Ease of loading the pills/pills data	Pills placed in different compartments and pills are placed in a compartment that is separate from the rest. Loading the pills is easy and there is no need to store the data of the pills.
Portability	The device can only operate effectively if it is connected to a computer, which minimizes the portability of the device.
Affordability	There are different types of pill holders with different sizes and they have different price range. The simplest ones are the cheapest and are affordable.
Identification of the pills	Isolates the pills to be taken per day from the rest but it cannot help the patients in identifying the pills, especially for patients that took many pills at a time.
Linking with family members	The system does not link the patients with the caregivers or the family members.
General Comments	Pill holders are useful for storing the pills in different compartments and can also be used to check if the patient opened the device to take pills. They have potential of being used with other facilities, with pill holders being used for separating and storing pills in different compartments per day.

3.2.2 Alarm Based Aids

Alarm based aids consist of different compartments but each with an attached alarm for reminding the user (Vervloet *et al*., 2012). An alarm aid has compartments like a pill holder

but consists of an alarm(s). An alarm operates as a reminding mechanism and the patient will find the pills to take in the compartments.

Table 3-3: Review of alarm based aids

Characteristic	**Comment**
Ease of loading the pills/pills data	Pills placed in different compartments and pills are placed in a compartment that is separate from the rest. Loading the pills is easy and there is no need to store the data of the pills.
Portability	The device does not require connection to some external devices and is small in size which makes it portable.
Affordability	There are different types of alarm based aids with different sizes and they have different price range. The simplest ones are the cheapest and are affordable.
Identification of the pills	Isolates the pills to be taken per day from the rest but it cannot help the patients in identifying the pills, especially for patients that took many pills at a time.
Linking with family members	The system does not link the patients with the caregivers or the family members.
General Comments	Alarm based aids are useful because they can both remind patients to take pills and be used for storing pills in different compartments and can also be used to check if the patient opened the device to take pills. They are standalone devices and can exist without being connected to other devices.

Figure 3.2: Example of an alarm based aid (Vervloet *et al*., 2012).

3.2.3 Pill Monitoring Devices

Figure 3.3: Example of a Pill Monitoring Devices (e-pill, 2014)

Pill Monitoring Devices are devices that provide home-based pill reminding facilities by having voice and text alarms (Hayes *et al*., 2006). They can be connected to the internet and are capable of notifying caregivers of a violation of schedule but they are loaded manually with the dosage details.

Table 3-4: Review of pill monitoring devices

Characteristic	Comment
Ease of loading the pills/pills data	Pills placed in different compartments of the dispensers and pills are placed in a compartment that is separate from the rest. Loading the pills is easy and there is no need to store the data of the pills.
Portability	The device does not require connection to some external devices but the device on its own is big in size and hence not portable.
Affordability	There are different types of pill holders with different sizes and they have different price range. However due to the sophisticated design of the device, the prices are generally high.
Identification of the pills	Isolates the pills to be taken per day from the rest but it cannot help the patients in identifying the pills, especially for patients that took many pills at a time. However some pill monitoring devices can store pills per dosage which means the user will be able to identify pills easily.
Linking with family members	The system does not link the patients with the caregivers or the family members.
General Comments	Pill Monitoring Devices are standalone devices which users can be used for storing and reminding the patient to take the right pills at the right time. They are useful for storing pills in different compartments and can also be used to check if the patient opened the device to take pills. They have potential of being used with other facilities and technologies to produced better products.

3.2.4 Mobile Phone solutions

Mobile Phone solutions use mobile phones and allow the user to enter medication manually and the applications will then help the user to stick to the prescribed schedule. (*My Pill Reminder* is an example of such a solution).

Table 3-5: Review of Mobile Phone solutions

Characteristic	Comment
Ease of loading the pills/pills data	It involves loading the pills data on the phone. It can be done either manually on the phone at the backend server. Loading pill details on the mobile phone is tedious error-prone.
Portability	Uses mobile phones and hence the whole model is portable.
Affordability	The application on itself is usually affordable but the application requires a mobile phone to function and uses the patient's mobile phone.
Identification of the pills	They have potential of giving visual cues to assist the patient to identify the pills.
Linking with family members	They are normally linked with the family members and family members can track the activities of the patient.
General functionality	Mobile phone solutions are capable of producing solutions to different problems by making use of the phone's capabilities like alarms, sound, offering location among others. The advantage of mobile solution is that users are usually familiar with using their mobile phones already and they will be able to learn and use the mobile applications.

3.3 Reminders

Chapter 2 highlighted various reasons, which are responsible for low medication compliance. The focus of this project is addressing the problem of a patient missing a dosage due to forgetting to take the pills. Using a reminder system might help reduce or even eliminate the problem of patients forgetting to take their medication on time (Wai *et al*., 2011). Reminders are a form a simple type of intervention which makes use of the push model to send users reminders (Klasnja & Pratt, 2012). Reminders can be used in various applications, from those in which reminders are the only form of intervention to those in which reminders are a component of a comprehensive health intervention (Consolvo *et al*., 2008).

Push interventions involve information being conveyed to the user's mobile phone at a scheduled time (Klasnja & Pratt, 2012). Push interventions increase the likelihood of patients sticking to their medication schedules. In this way reminders can be used as tool to improve medication compliance.

Curioso and colleagues (2009) designed and developed an SMS reminder system to improve medication compliance for patients with HIV on antiretroviral therapy (ART). The reminders were used in this case where high levels of compliance were expected and their supporting literature outlines that the reminders were well received by the users. Patients were positive about using reminders to journal their activities (Curioso *et al*, 2009). One of the reasons was because the users felt that the reminders were not obtrusive since the sound could be disabled and the user could see the reminder the next time they used the phone. This was the case because there was a lot of flexibility on the time that the pills were taken and might not be the case with other chronic diseases.

3.4 Mobile Applications

In recent years, a number of researchers have increasingly used mobile phones as platforms for delivering their designs of health interventions (Klasnja & Pratt, 2012)

Mobile phones have grown to be an important platform for delivering health interventions. This is mainly because of the following:

1. Mobile phones have been highly adopted in the world (Pew Internet, American Life Project, 2010);

2. People tend to carry their mobile phones everywhere. A study by Asai and colleagues (2011) found that individuals were within arm's reach of their phones on average 58% of the time;

3. People have a tendency of being attached to their mobile phones (Ventä, Isomursu, Ahtinen & Ramiah, 2008); and

4. They can be exhibit context-awareness by connecting to other data sources (Hong, Suh & Kim, 2009).

Over the past years the popularity of smart phones has been increasing. According to studies done carried out by International Data Corporation (2012) the market for smartphones which are capable of running third party applications grew by 39%. There is potential for using the smartphones' capabilities in the health space.

3.4.1 Mobile health (m-health)

Mobile health (m-health) is an umbrella term that covers areas of networking, mobile computing, medical sensors and other communication technologies within healthcare. The concept of m-health refers to "mobile computing, medical sensor, and communications technologies for health care" (Istepanian, Laxminarayan & Pattichis, 2006). This field investigates using mobile technology to provide solutions in the health space. M-health builds upon earlier work in telehealth, mobile computing, and persuasive technology in healthcare settings (Istepanian & Lacal, 2003). There is still inadequacy of applications that are aimed at solving the problem of medication compliance. Studies done by Liu *et al* (2013) suggested that medical compliance applications on the Apple App store are less than 5% of the m-health apps. There is a potential of improving medication compliance for patients, especially those suffering from chronic diseases by maximising on mobile phones' capabilities. Persuasive user interfaces on the mobile device could facilitate compliance with the prescribed treatment protocol by "applying just-in-time intervention" (Kumar, Nilsen, Pavel, & Srivastava, 2013). According to studies done by Mars, Seebregts and Country (2008) they concluded the following:

"Mobile phones have given access to millions who were previously marginalised from personal communications and mobile phone penetration is estimated at 75% with approximately 90% of the country covered by mobile telephony. It is likely that mHealth will play an ever

increasing role in medical informatics, telemedicine, surveillance and healthcare education in Africa" (Mars *et al.*, 2008)

They identified the potential that lies in the field of m-health in terms of transforming the health sector of South Africa. The impact of m-health can be increased by the fact that many people in South Africa have easy access to mobile phones and hence it would be a cheaper and effective solution of making use of the technology that many people already have (Mars *et al.*, 2008).

Figure 3.4 shows a proposed scenario of the relationship between caregivers, patients and health care people. The model is centred on the use of mobile phones used by the patients themselves to take care of their health status. Figure 3.4 shows some of the links that are already in place and the ones that can be developed or have potential of being developed in the near future (Elgazzar *et al*., 2012). The model is aimed at reducing the frequency of a patient visiting a health care facility and utilise the mobile phone's offerings to make the patient more self-sustainable.

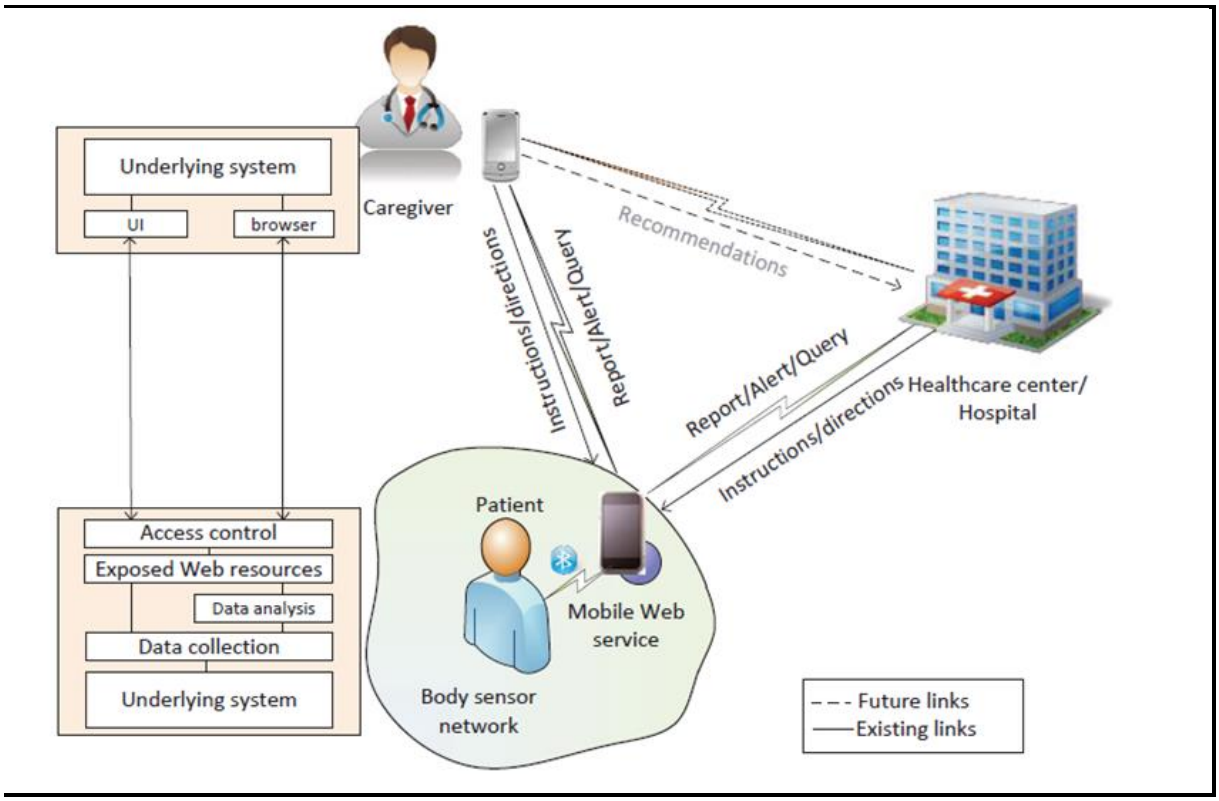

Figure 3.4: Relationship between caregivers, patients and health care people (Elgazzar *et al*., 2012)

3.4.2 M-health scenario

Figure 3.5 shows a scenario where m-health could be helpful and more empowering as compared to relying on the traditional healthcare concepts. The first case shows Bob, an elderly patient who relies on care provided by health care workers. Bob suffers from high blood pressure and has blood related conditions. These two conditions require Bob to take medication three times a day every day. Bob frequently forgets to take his medication on time and even most of the times get confused when identifying the pills to take. Sometimes he gets sudden attacks and cannot notify anyone in the case of these unfortunate events. Bob always keeps his family concerned and worried about his health and when the next attack will happen. His family takes turns to check on him timeously to minimize the possibility of sudden attacks. After a series of attacks and Bob being rushed to the hospital more frequently, Bob's doctor suggested Bob being moved into a health care facility.

The second case shows Rick, who is also an elderly patient who suffers from high blood pressure and has blood related conditions. Due to these conditions, Bob takes medication every day three times a day. Bob had problems in forgetting to take his medication on time and got confused when identifying the pills to take. Rick's family bought him an iPhone and they purchased and installed a health application from the Apple App Store. The application included having automatic reminders in the form of alarms to remind Rick to take the right pills at the right time. The reminders were easy to understand and the instructions were easy to follow, which made Rick feel comfortable with using the application. Using the application made Rick's family able to check his status and the extent to which he is compliant with his medication schedules. The application also notifies the family members whenever Rick decides to leave home so that they can track where he will be. In case of an attack, the application has an emergency facility where Rick just presses a button and the caregivers get notified so that they will respond as soon as possible. After using this application over a period of time, Rick became empowered to live independently and the doctors saw that there was no need for him to be placed in a healthcare facility.

The scenario outlines the potential that m-health has to empower patients to live independently without having to see the doctors all the time.

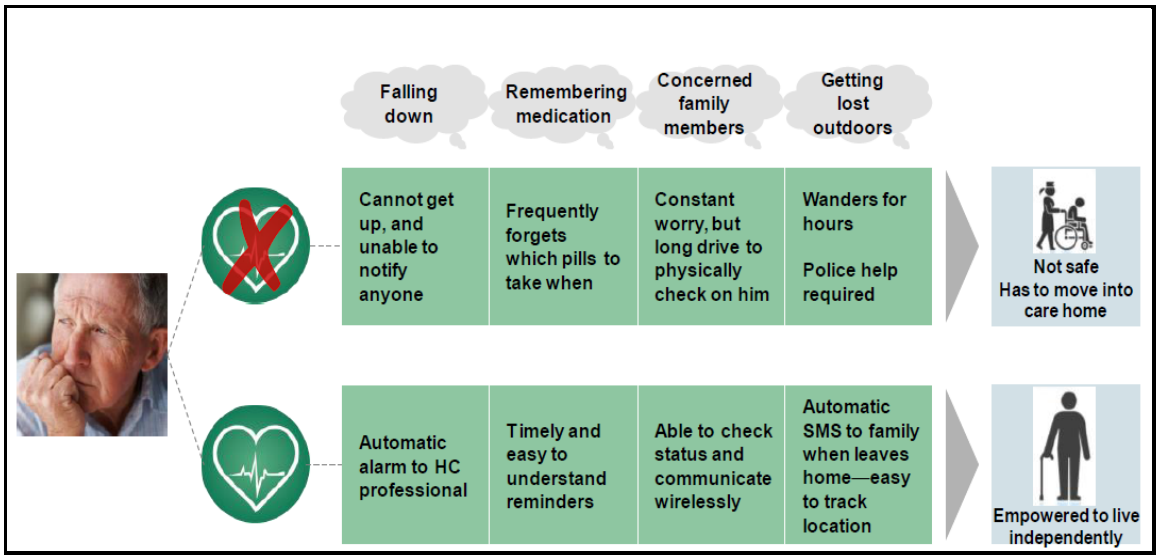

Figure 3.5: Scenario showing the potential that m-health has on a patient (Dayer *et al.*, 2013)

3.4.3 Mobile health (m-health) initiatives

The field of mobile health is emerging and some work has been done towards making some health facilities pervasive. Studies indicate that of the initiatives currently being developed, the areas of patient monitoring and treatment compliance are lagging behind (University of Cambridge & China Mobile, 2011). Figure 3.6 illustrates the adoption of m-health initiatives and their stages in America. Figure 3.6 indicates that some initiatives are still not that well developed. Treatment compliance and patient monitoring are the relevant initiatives for this research. From Figure 3.6, these two fields are underdeveloped and hence it is worthwhile researching more on these fields.

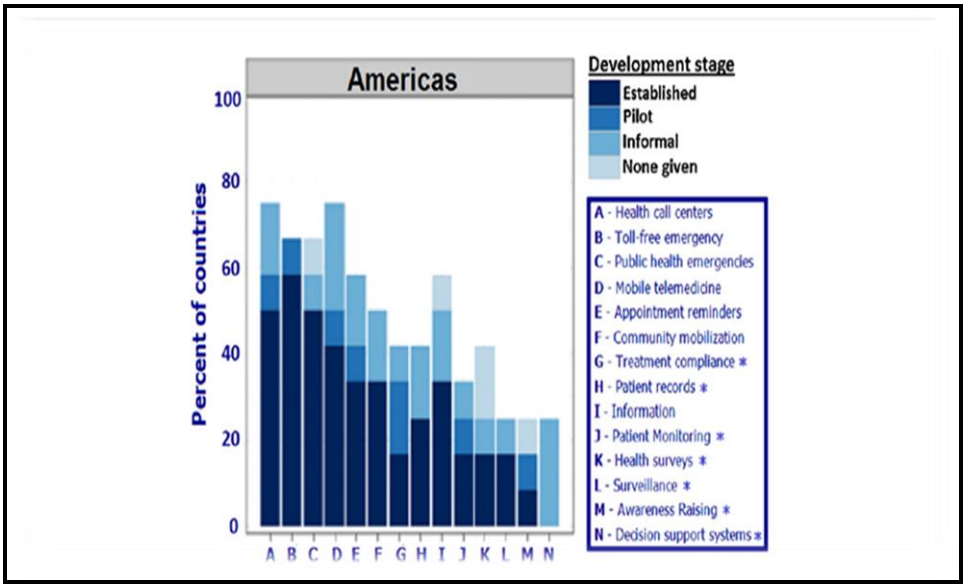

Figure 3.6: Adoption of m-health initiatives and their stages in America (Iwaya *et al.*, 2013)

3.4.4 Developing countries (BRICS & SA)

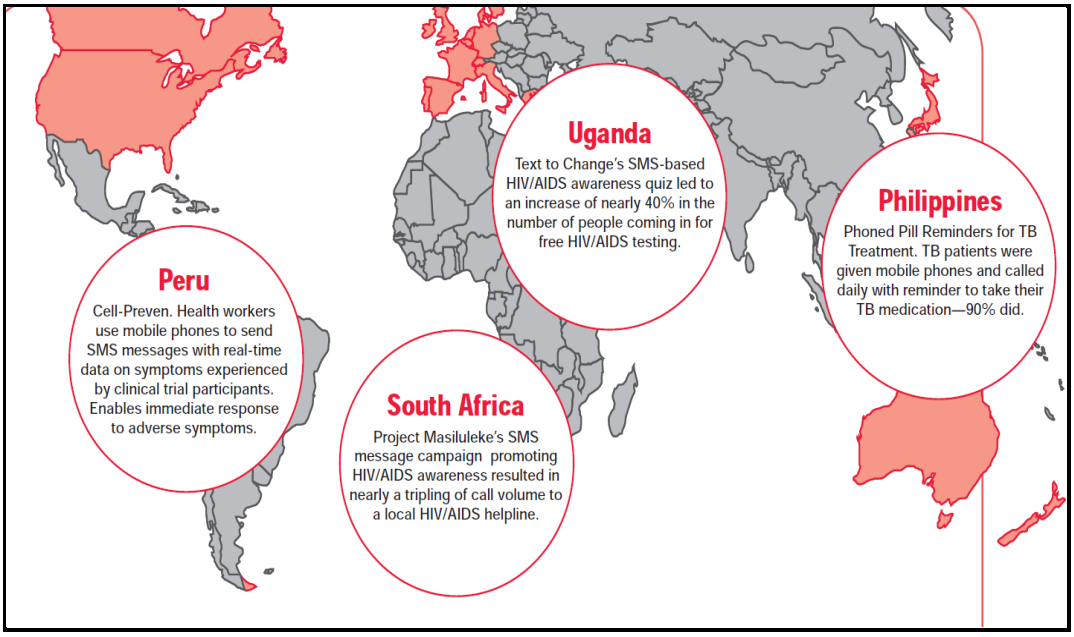

Figure 3.7: M-health initiatives in developing countries (Istepanian, Jovanov & Zhang, 2012)

Figure 3.7 shows some projects that have been carried out in some developing countries in the field of m-health. In South Africa there was an awareness m-health initiative, which was aimed at promoting HIV awareness. The project was very successful and it resulted in figures that were three times better than the initial figures. Also of interest, in the Philippines, pill reminders were used for TB patients and the project was also successful. The project resulted in 90% of the patients being successfully reminded and taking their medication as prescribed by the medical practitioners. Figure 3.7 also shows other successful m-health projects carried out around the world.

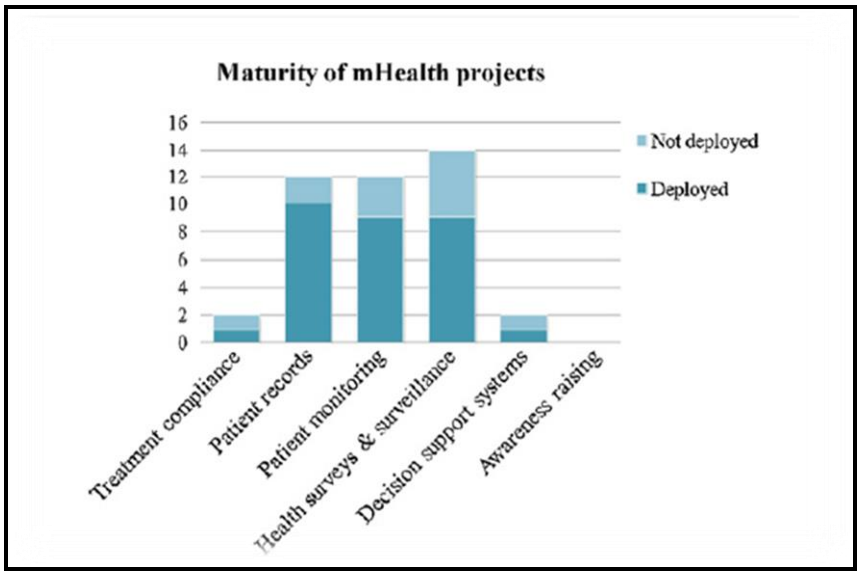

Figure 3.8: Maturity of m-health research in Brazil (Iwaya *et al.*, 2013)

Figures 3.8 and 3.9 illustrate the state of m-health research in Brazil, a developing country. These figures show that treatment compliance is one of the lowest researched areas. Since Brazil is a developing country similar to South Africa, the problems they are facing are in the same fields. Figure 3.8 indicates that in a developing country like Brazil medication compliance interventions have still not matured and have not been intensely deployed. This research focuses on the impact of m-health interventions on medication compliance in South Africa and it is necessary to investigate the impact of such solutions. Figure 3.9 also shows that approximately 5% of the m-health projects are targeting medication compliance, which shows that the work focusing in this field is not sufficient.

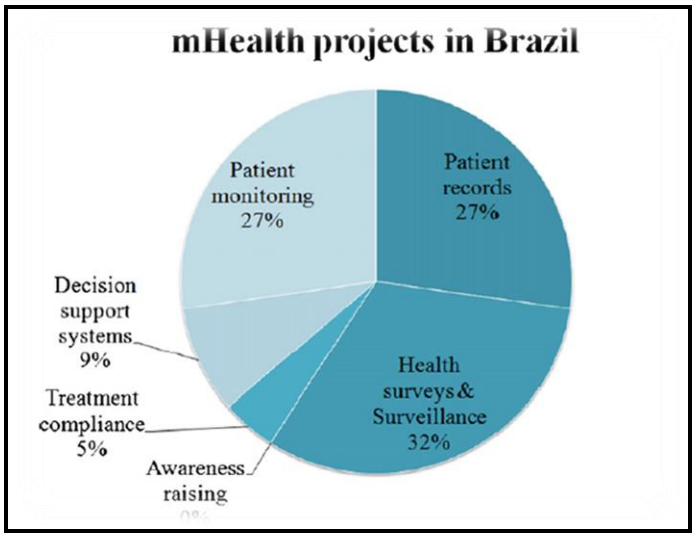

Figure 3.9: m-health projects in Brazil (Iwaya *et al*., 2013)

A number of applications that are being deployed in the m-health field are aimed at different groups. However, work done by Iwaya *et al*., (2013) shows that most of these mobile applications are not made for the patients themselves. Most of these applications are meant for the caregivers. This creates the need to investigate the viability of using m-health applications meant for the patients themselves. By having applications made for caregivers, it would mean that many caregivers would be required to monitor the patients since there are many people suffering from chronic diseases. Also, there are other chronic diseases that need less supervision from caregivers since the patient would only require to be reminded to take their medication on time. These patients would need an application designed for them that they would use to remind them to take their medication.

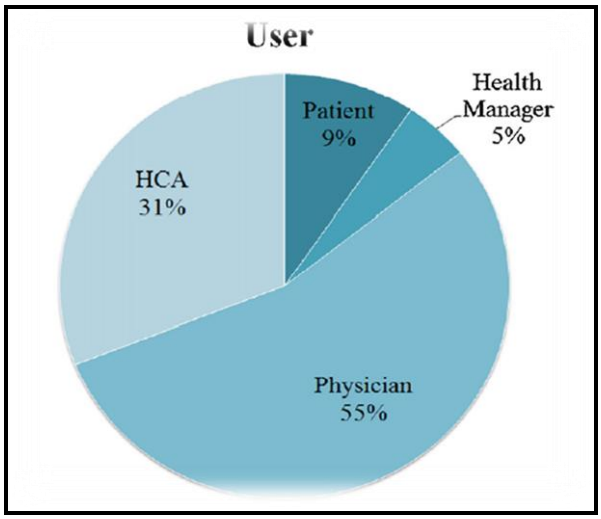

Figure 3.10: Target users of existing m-health applications (Iwaya *et al*., 2013)

3.5 Existing applications/systems

This section investigates several applications that serve to remind people of their medication schedule. These applications have some similarities in the basic functionality but differ in some of the functionality, which led to the development of different applications altogether. Analysis was based on the features and functionality, published literature and conformity to standard design principles. From such analysis, advantages and disadvantages can be deduced and the application will be judged on these aspects.

3.5.1 Selection of applications/systems

The reviewed applications were chosen based on the following:

- Availability of credible publication(s) of the application in literature;
- Relevance of the application based on the level of overlapping into the fields of m-health and medication compliance;
- Location of the solution with South African solutions being of interest; and
- Date of release of the application with the most recent applications being preferred to those produced some years ago.

3.5.2 Review of existing systems

There are several systems developed to remind people to comply with their medication schedules using different forms of technologies and with different aims. These solutions have various similarities in the basic functionality provided, but differ in some of the functionality and the medium used for reminding the patient. A review was conducted to determine which

of these systems is better with regards to support for pill reminders. The systems reviewed focused on improving medication compliance and the results were published in relevant literature. This analysis was based on the features and functionality of the different systems, results of the evaluation and the extent to which they cater for the elderly. Four systems were investigated namely, Real Time Medication Monitoring system, Wedjat, SIMPILL and *My Pill Reminder*, which was developed for the Android platform.

3.5.2.1 Real Time Medication Monitoring

Figure 3.11: Real Time Medication Monitoring system (Vervloet *et al.*, 2012).

Vervloet designed a system that uses Real Time Medication Monitoring (RTTM), an electronic dispenser and SMS reminders, to improve oral medication compliance for people with type 2 diabetes (Vervloet *et al.*, 2012). A SMS is sent when a patient forgets to take their medication and this is detected by an electronic dispenser. The results indicated that users were quite keen to adopt the technology since the patient only needs to be in possession of their mobile phones. However, the system is not intuitive and does not help the patients in identifying the pills. The system relies on the patient's interaction with the dispenser to detect if the patient took medication, which creates problems if the patient tries to interact with the dispenser at non-prescribed times. Operating such a system is expensive and receiving SMS would require the patient to manually delete them.

3.5.2.2 Wedjat

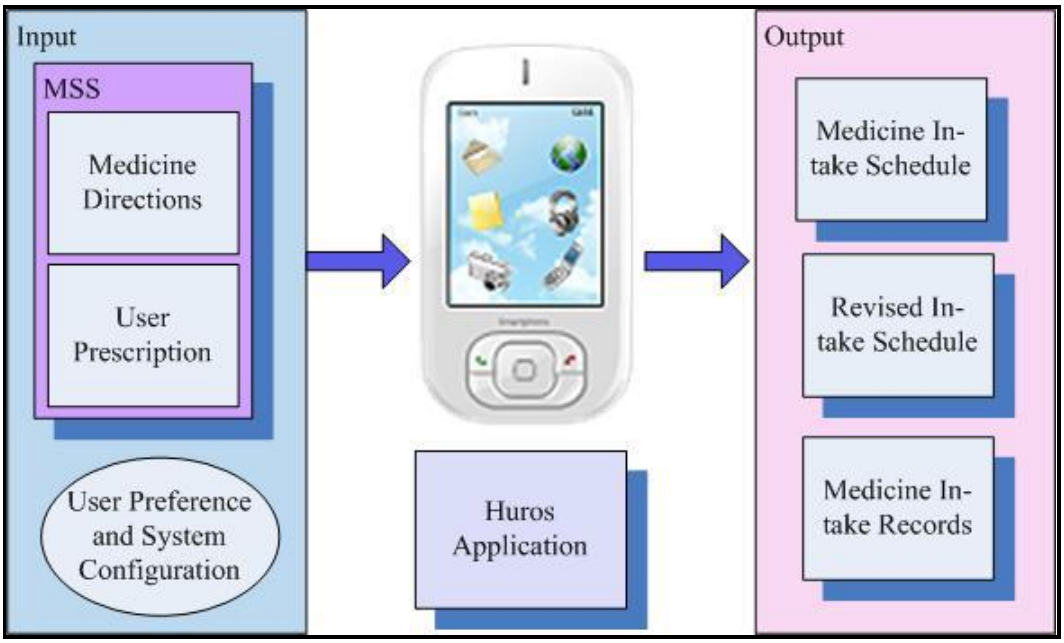

Figure 3.12: Wedjat (Wang, Tsai, Liu and Zao, 2009)

Wang, Tsai, Liu and Zao (2009) proposed Wedjat as a mobile solution to the problem of improving medication compliance. Wedjat was designed to run on the Android platform and uses reminders at the correct time, specifying the pills that need to be taken. The application is flexible but lacks visual cues to help the patients in identifying the pills to be taken. The application was designed not to take any action if the patient decides not to take their medication, which makes it unsuitable for patients with chronic diseases, who cannot afford to miss their medication. Wedjat only focuses on reminding the patient to take their medication and does not keep track of the quantity of the pills and provide alerts to re-order more pills. The application also does not have a history facility to show the level of the patient's medication compliance.

3.5.2.3 SIMPILL

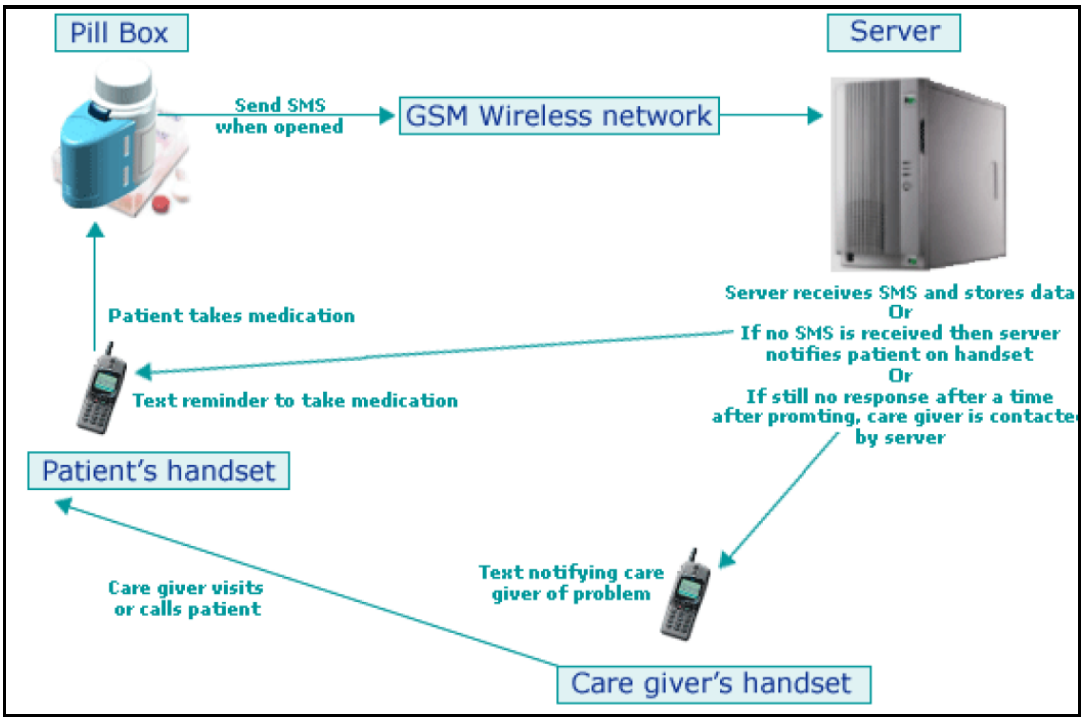

Figure 3.13: The design structure of SIMPILL (SIMPILL, 2014)

SIMPILL is an interactive pill holder/container that uses mobile phone technology to assist patients to remember to take their pills at the prescribed time. The SIMPILL container consists of an ordinary pill container with a SIM card and transmitter attached to it. The SIMPILL Medication Adherence System will monitor the patient's medication schedule and intake of medication and remind patients and caregivers as necessary by sending a text message to the patient and/or caregiver's mobile phone if the patient does not take their medication as prescribed. All monitoring and reminders happen in real-time. Figure 3.13 shows how SIMPILL works by adopting the technology used by the traditional pill holders and then incorporating some mobile technology to make it more usable. SIMPILL is not centred on the patient and does not empower the patient to make an informed decision and be able to take the pills on time; hence it focuses on medication adherence and not compliance. There is no assistance in identification of the pills for someone who takes more than one type of pills since all the pills will be stored in one holder. It also does not support placing of an order at the pharmacy before the pills get used up.

3.5.2.4 *Mye Pill Reminder*

The author developed the *My Pill Reminder* application in 2012 as a possible solution to the problem of medication compliance. The application was designed for elderly patients to remind

them to take their pills on time. This mobile application used the self-regulatory medication compliance model discussed in Section 2.6. A preliminary user study was conducted using convenience sampling since suitable participants could not be used because there was not ethical clearance. However, it was not fully functional and it was not connected to an external pills database with the pills used in South Africa. The application only stores a history of how the patient was taking medication for seven days and then deletes the patient's history afterwards. The *My Pill Reminder* had administrators in the form of caregivers who did the data management for the patient, which was identified by the preliminary user study to be inconvenient and intruded on the patient's privacy. The preliminary user study together with some expert reviews identified that the application was useful and had the potential to improve medication compliance for patients with chronic diseases.

3.5.3 Strengths and weaknesses of Existing applications

Table 3-6 shows a summary of the supported functionality of all the reviewed applications. From the summary, the application's strengths and weakness can be identified based on the level of support provided to the patient

Table 3-6: Summary of reviewed existing systems

Functionality	Wedjat	RTTM	SIMPILL	MPR
Ease of loading the pills/pills data	Not supported	Pills placed in different compartments	All pills loaded in one holder	Not supported
Portability	Yes	The connected dispenser makes it not portable	The pill holder makes it not portable	Yes
Affordability	Yes	Not affordable	It is very expensive due to the technology it uses	Yes

Identification of the pills	No visual cues offered	No visual cues offered	No visual cues offered	Visual cues provided
Linking with family members	No	No	Yes	Yes
Platform	Android	All platforms	All platforms	Android
Checks if the patient has actually taken pills	No	No	No	No
The application lets the user know when the pills are about to run out.	No	No	No	Yes
The application allows the user to place an order for pills.	No	No	No	Yes
The application keeps track of the user's history of how they have been taking their pills	No	No	Yes but the user cannot see it	Yes
The application allows the user to back up data as well as restoring it.	Yes	No	No	No
The application is easy to learn and use.	Yes	Yes	Yes	Yes
The application can allow the user to snooze a reminder.	No	No	No	Yes
The application displays clearly the instructions and the pre-requisites of a pill.	Yes	No	No	Yes
The application ensures more battery life by using less battery capacity.	No	Yes	Yes	No, it uses a service that is always running in the background

Table 3-6 shows a summary of the strengths and weaknesses of the reviewed applications. The applications were reviewed to investigate which of the applications supported most of the functionality which is required to support medication compliance. Of the four applications reviewed, *My Pill Reminder* supported more functionality than the other three applications. RTTM supported the least functionality. Wedjat and SIMPILL supported six and five functions respectively, which means that they required a lot of changes to solve the problem of medication compliance. The application which supported most of the required functionality was regarded as the best choice. The *My Pill Reminder* application was therefore regarded as the best of the reviewed applications and required less changes as compared to the other three applications in order to be used as a tool to support medication compliance.

3.6 Conclusion

The chapter outlined some of the work done in the emerging field of m-health. Chapter 3 also highlighted how some of the problems outlined in Chapter 2 have been solved as well as pointing out some of the unsolved areas. The chapter discussed some related applications as well as the reasons behind their development. Analysis of these applications was based on the features supported, reviews from users as well as reviews from experts. It also highlighted features, strengths and weaknesses of these applications. It is important to be able to determine the shortcomings of these applications and then incorporate their solutions in the solution of this research.

Since the literature reviews have been completed, the next step is to move into the process of re-designing the existing mobile application. However, before re-designing the mobile application, the current version has to be first evaluated to get feedback from patients how they feel about the application. Chapter 4 will discuss the pilot field study to evaluate the first version of the application. The feedback from Chapter 4 and the strengths identified from some of the m-health interventions in this chapter will be used to define the requirements of the second version of the application.

Chapter 4 Pilot Field Study

4.1 Introduction

It is very unlikely to design an application, which works perfectly and meets all of the users' needs and expectations at first attempt. This always creates the need to have the designed evaluated by the users to investigate the extent to which it satisfies them. Evaluating the design can also be instrumental in outlining the strengths and weaknesses of the design, which can facilitate improvement of the user experience and the usability. The previous chapters focused on elaborating the problem that the research intends to address. Chapter 3 investigated various types of m-health initiatives that can be useful in supporting medication compliance and patients with chronic diseases. One of the proposed solutions was the *My Pill Reminder* application, which the author previously developed to support elderly people with chronic diseases.

This chapter investigates the process of evaluation of the proposed design by actual patients suffering from chronic diseases. Chapter 4 also looks at the results of the user study, which was previously carried out using a convenient user sample. The chapter also outlines the pilot field study that was carried out in Port Elizabeth using patients suffering from high cholesterol problems and/or high blood pressure. The design of the pilot study is discussed in detail, the selection and the user profile of the participants, the method of the study and the data gathering methods used. The collected data was then analyzed and conclusions were drawn from the results. The chapter also outlines the usability issues and the additional requirements identified by the users.

4.2 *My Pill Reminder*

A mobile application, called *My Pill Reminder*, was designed and developed for patients with chronic diseases to remind them to take their pills on time. *My Pill Reminder* is the proposed tool for supporting chronic disease management by improving medication compliance and self-care. This is because this mobile application is a self-regulatory medication compliance mechanism that aims to make the patient develop a pattern of taking their medication at the prescribed times. *My Pill Reminder*'s main objective is to remind the patient to take the right pills at the right time in the right amount. The application also assists patients, particularly elderly people with identifying the exact pill especially if the pills are almost the same in appearance.

The *My Pill Reminder* Application assists patients in identifying the pills by providing visual cues whilst the patient is taking their pills. *My Pill Reminder* reminds the user using text, pictures and audio whenever the user needs to take pills and also ensures that they take the right pills. The application has the functionality of tracking the quantities of the pills which are in the patient's prescription and automatically reordering pills from the pharmacy. The application also tries to prevent emergencies as a result of the user not complying with the medication schedule by notifying family members and caregivers

4.2.1 Functionality of *My Pill Reminder*

The functionality of the developed *My Pill Reminder* is listed as follows:

1. The system reminds the patient to take pills;
2. The system notifies the caregiver(s) of a deviation in taking the pills;
3. The system places an order when the pills are about to run out;
4. The patient contacts a caregiver;
5. The patient views pill details;
6. The patient views upcoming reminders;
7. The patient adds/remove pills to a reminder;
8. The patient edits upcoming reminders;
9. The patient views his/her history;
10. The caregiver loads a prescription from the Pills database;
11. The caregiver manages pills and dosage;
12. The caregiver edits pills and dosage details; and
13. The caregiver deletes a pill from the current pill.

4.2.2 Design of *My Pill Reminder*

My Pill Reminder was developed to run on Android mobile phones. The application was designed to be simple thereby making it as easy to learn and use as possible. The design of the application was in such a way that it adhered to the Android design patterns and principles. Using Android patterns and principles was done to allow transfer of skills and knowledge for those who already use Android phones. *My Pill Reminder*'s user interface was designed in such a way that from the Home screen, there is direct access to the key functionality screens. The application also supports easy navigation to the Home screen from the different screens by placing the link to the Home screen in these screens.

Figure 4.1: User Interface Design for *My Pill Reminder*

Easy navigation within the application was maintained by having the Home icon on each screen, which redirects the user to the Home screen. Figure 4.1 represents the user interface design and also shows the navigation from the Home screen to key functionality screens.

Figure 4.2 illustrates the design for taking a pill by the patient. The reminder was designed to pop up on the device's notification area. After the patient gets the reminder on the Notification Area; the patient is then redirected to the Reminder screen. The Reminder Screen consists of the list of medication that the patient has to take at that particular time. Figure 4.2 shows the

options that the user has including the facility of offering visual cues for assisting with identification.

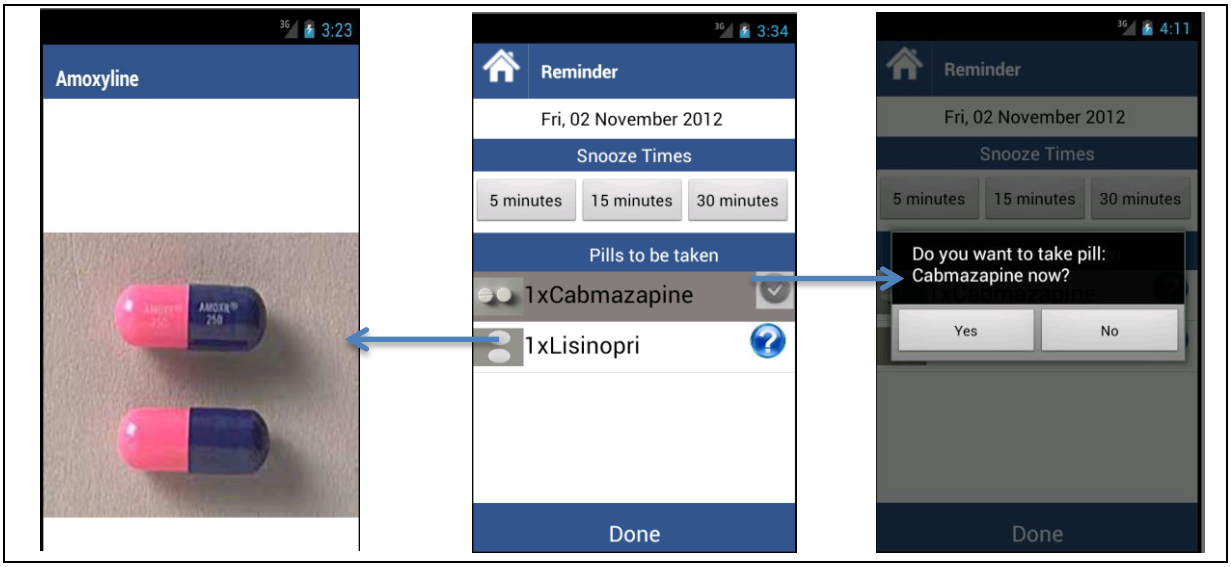

Figure 4.2: Reminder screens for *My Pill Reminder*

4.2.3 Previous User study

A user study was conducted on the *My Pill Reminder* application in a controlled environment to investigate how usable the application was. The major objective was to measure the performance of the application, that is, its efficiency in terms of time and effectiveness in terms of task completion. The user experience derived from using the application was also determined as well as obtaining a summary of the positive and negative aspects from different users. The user study was conducted in a controlled set-up. The study used a convenience sample since suitable participants could not be used because of complications with lack of ethical clearance to test using actual patients with chronic conditions. The sample size was eighteen. The user study was conducted in the usability laboratory where the users were brought into the lab and asked to perform a set of tasks whilst their performance was being measured. Post-test questionnaires were also used to gather satisfaction feedback based on their experience.

This study focused mainly on getting quantitative data and thus it was important to use a bigger data sample. Figure 4.3 shows the overall usability score measured from the user study. The averages of the metrics for all the participants were all greater than 85%, which indicates that the application was usable. The overall usability score was calculated to be 88.94% which shows that the participants managed to use the application well and were also satisfied by it.

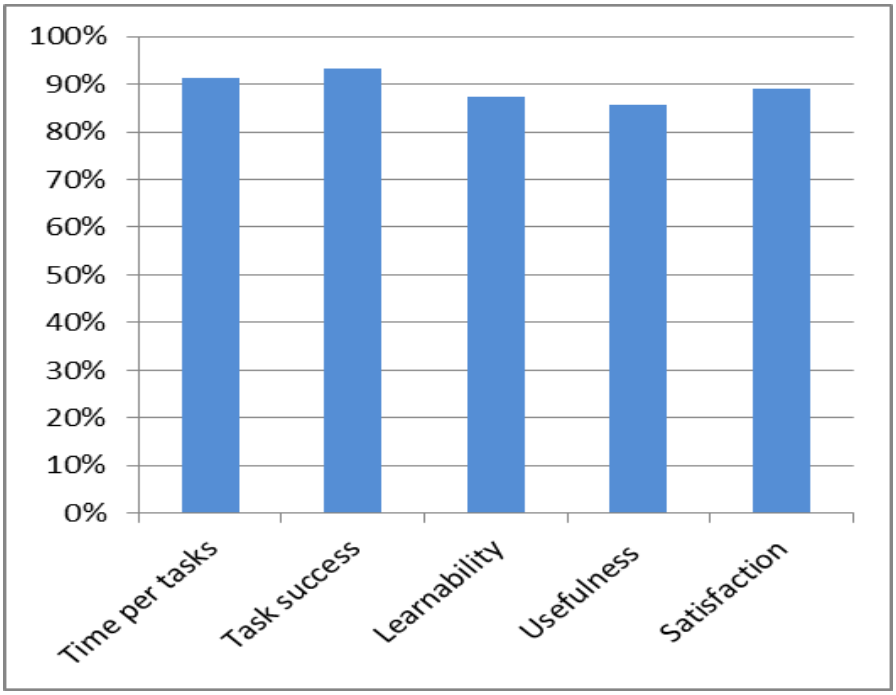

Figure 4.3: Graph illustrating the overall scores of the different usability metrics (n=18)

4.2.4 Overall usability of the application

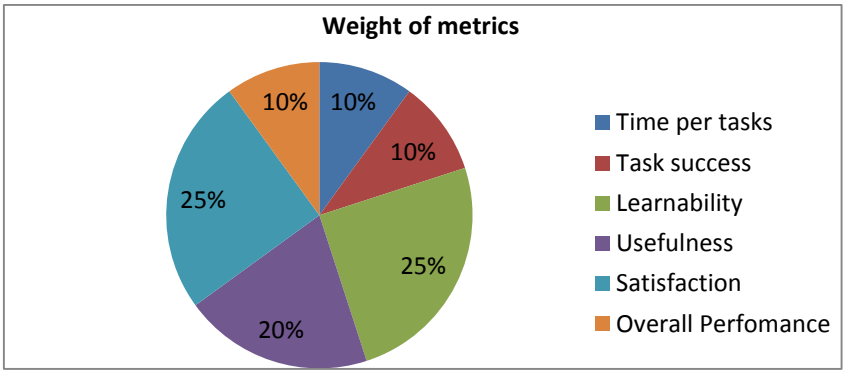

Figure 4.4: Weights of the contribution made by each metric to the overall usability score

Figure 4.4 shows the contributions made by each metric to the overall usability score. The metrics were assigned different weights based on the goals of the usability test and the level of relevance of the metric with regards to the application's requirements. Usefulness (20%) and satisfaction (25%) had more weight since the evaluation was more concerned about the impact the application might have on elderly users. Using the weights shown in Figure 4.4, and the results recorded in the study, a usability score was determined using Table 4-1.

Table 4-1: Overall usability score from all the participants based on the investigated usability metrics (n=18)

Participant	Time per task	Task success	Learnability	Usefulness	Satisfaction	Performance	Average
P1	92%	100%	56%	72%	80%	71%	79%
P2	98%	100%	88%	92%	92%	93%	94%
P3	92%	75%	76%	96%	80%	71%	82%
P4	90%	92%	92%	80%	96%	97%	91%
P5	96%	100%	92%	64%	100%	94%	91%
P6	87%	100%	100%	84%	100%	100%	95%
P7	85%	94%	80%	96%	84%	86%	88%
P8	100%	94%	92%	92%	96%	91%	94%
P9	90%	92%	96%	88%	100%	94%	93%
P10	84%	95%	96%	88%	84%	91%	90%
P11	-	94%	76%	68%	48%	71%	72%
P12	-	100%	80%	92%	84%	89%	89%
P13	-	94%	100%	100%	100%	100%	99%
P14	-	89%	56%	60%	48%	74%	65%
P15	-	83%	80%	84%	76%	77%	80%
P16	-	100%	80%	100%	88%	87%	91%
P17	-	94%	72%	80%	72%	74%	79%
P18	-	83%	80%	84%	84%	77%	82%
Averages	92%	94%	86%	85%	92%	89%	88.94%

Table 4-1 shows the overall usability score from all the participants based on the investigated usability metrics and their corresponding weights. The average ratings of the metrics for all the

participants were all greater than 85%, which indicates that the usability of the application was good. The overall usability score was calculated to be 88.94%, which shows that the participants managed to use the application well and were also satisfied with it.

4.2.5 Suggested Changes

Any issue, which had an appreciable number of errors or difficulties in execution and was recurring, was regarded as a usability issue. From the post questionnaire, most participants suggested that the **Home icon** should not be used in the Administration section since it will confuse people since they will not be able to deduce if it means the application's Home or the Administration Home screen. This was pointed out by most administration participants and can be regarded as a usability issue and might need to be changed. This was the major suggested change from the participants. However, other suggestions were also made which include the following:

- *More searching options*: Searching for a caregiver should allow the user to also search using the number rather than only using the name only. Some users are used to searching using different criteria and thus suggested that change. This was not pointed by many people and it is not an issue which need immediate action but it is worth mention that, it would be a nice feature to have.

- *Search box always there*: The was also some suggestions that the search box ought to be visible only if the list is big and should be invisible when there are few things which might not need the search box. This was also not mentioned many times but the suggestion is very essential and the rectification will be necessary.

- *Detailed error messages*: The evaluators suggested that the error messages must be displayed clearly and give the user the option of closing it. These users preferred having standard error messages like the ones used in desktop applications or websites. This suggestion is against Android patterns since Android patterns impose the use of toasts and thus this cannot be rectified. However, further research can be done to investigate how best error messages can be displayed in Android.

- *Label not visible*: Several users indicated that it was very difficult to notice and to read the label on the **Manage Quantities** screen. They insisted on having the color more dominant to the other content on the screen. This suggestion was well noted but some

people managed to see the label which indicates that this issue was subjective to the participant and might need more users to draw a solemn conclusion. From the evaluation, several usability issues were identified. From the post questionnaire, most participants suggested that the Home icon should not be used in the Administration section since it will confuse people since they will not be able to determine if it means the application's Home or the Administration Home screen. This was pointed out by most administration participants and can be regarded as a usability issue and may need to be changed. That was the major suggested change from the participants. However, other suggestions were also made, which included the following:

- *More searching options:* Searching for a caregiver should allow the user to also search using the number rather than using the name only. Some users are used to searching using different criteria and thus suggested that change. This was not pointed by many people and it is not an issue which needs immediate action but it is worth mentioning.
- *Search box always visible:* The was also some suggestions that the search box ought to be visible only if the list is big and should be invisible when there are few things which might not need the search box. This was also not mentioned many times but the suggestion is useful and the modification is necessary.
- *Detailed error messages:* The participants suggested that the error messages must be displayed clearly and give the user the option of closing the message box. The users preferred having standard error messages like the ones used in desktop applications or websites. This suggestion is against Android patterns since Android patterns propose the use of toasts and thus this cannot be rectified. However, further research can be done to investigate how best error messages can be displayed in Android.
- Label not visible: Several participants indicated that it was very difficult to notice and read the label on the Manage Quantities screen. They insisted on having the color more dominant than the other content on the screen. This suggestion was noted but some participants managed to see the label, which indicates that this is not a serious issue.

From the design of the application, the following guidelines were derived and illustrated in Table 4-2:

Table 4-2: Guidelines for mobile health apps for the elderly (Mukandatsama & Wesson, 2013)

Functionality	**Principle**	**Guideline**

Text display	Accessibility, Visibility	Use large fonts, with visual cues and good color contrast.
Text entry	Error prevention, Flexibility	Use alternative text input methods, including options and lists.
Navigation	Consistency, Predictability	Use a simple navigation scheme, with minimal levels and clear icons. Include a Home icon.
Feedback	Visibility	Provide feedback on options selected and data entered.
Reminders	Ease of use	Provide audio and visual reminders.
Notification	Error prevention	Notify caregivers when patient fails to take medication.
Reordering medication	Ease of use Error prevention	Automate re-ordering of medication before it is needed.
History	Visibility	Provide a history of medication compliance for the patient.

4.3 Initial field study

The section describes the pilot field study which was carried out with the *My Pill Reminder* application.

4.3.1 Objectives of evaluation

The mobile solution focused on learnability and ease of use. This influenced the focus of the field study to investigating if the chronic patients using the application feel that the mobile solution is easy to learn and to use. It was essential to ensure that the application is very

usable and satisfies the needs of the potential users. The objectives of the field studies are summarised as follows:

- To determine the extent to which the application is easy to learn and to use;
- To investigate if the users feel the application is useful;
- To identify usability issues of the application;
- To identify possible changes according to the users; and
- To investigate the level of user experience and satisfaction derived from using the application.

4.3.2 Participant Selection

Choosing the participants is an integral part of this study and thus it required extreme care in order to obtain good quality and representative results. Since this is a mobile solution, the participants ought to have some experience with using a mobile phone since this could bias the results. The participants were derived using three specific conditions: Hypertension and high cholesterol and were all from Port Elizabeth. The participants were adult volunteers from the Humewood Golf Club in Port Elizabeth.

Some of the characteristics of the participants were as follows:

- Age - 18 year and older;
- Conditions - Hypertension and High cholesterol;
- Attitude toward technology - use mobile phones;
- Familiarity with the medical terminology and exposure to medication procurement; and
- Location - Port Elizabeth.

The sample size of the study was six participants. To encourage the participants to take part in the study, some incentives were given to the participants after completing the study.

Figure 4.5 shows the demographics of the participants used during the initial field study using a pie chart. Figure 4.5 indicates that 83% of the users were male participants and 17% were female. Figure 4.5 also shows that there were two major age groups, namely the 65+ years group and the 41-65 years group. Only 17% of the participants were younger than 40 years. The mobile experience graph shows that 83% were intermediate mobile users who represented people who have been using mobile phones for an appreciable amount of time. It was expected that the intermediate mobile users would be able to complete tasks and take less time to

complete the tasks as compared to the other groups. This will be verified in the sections to follow.

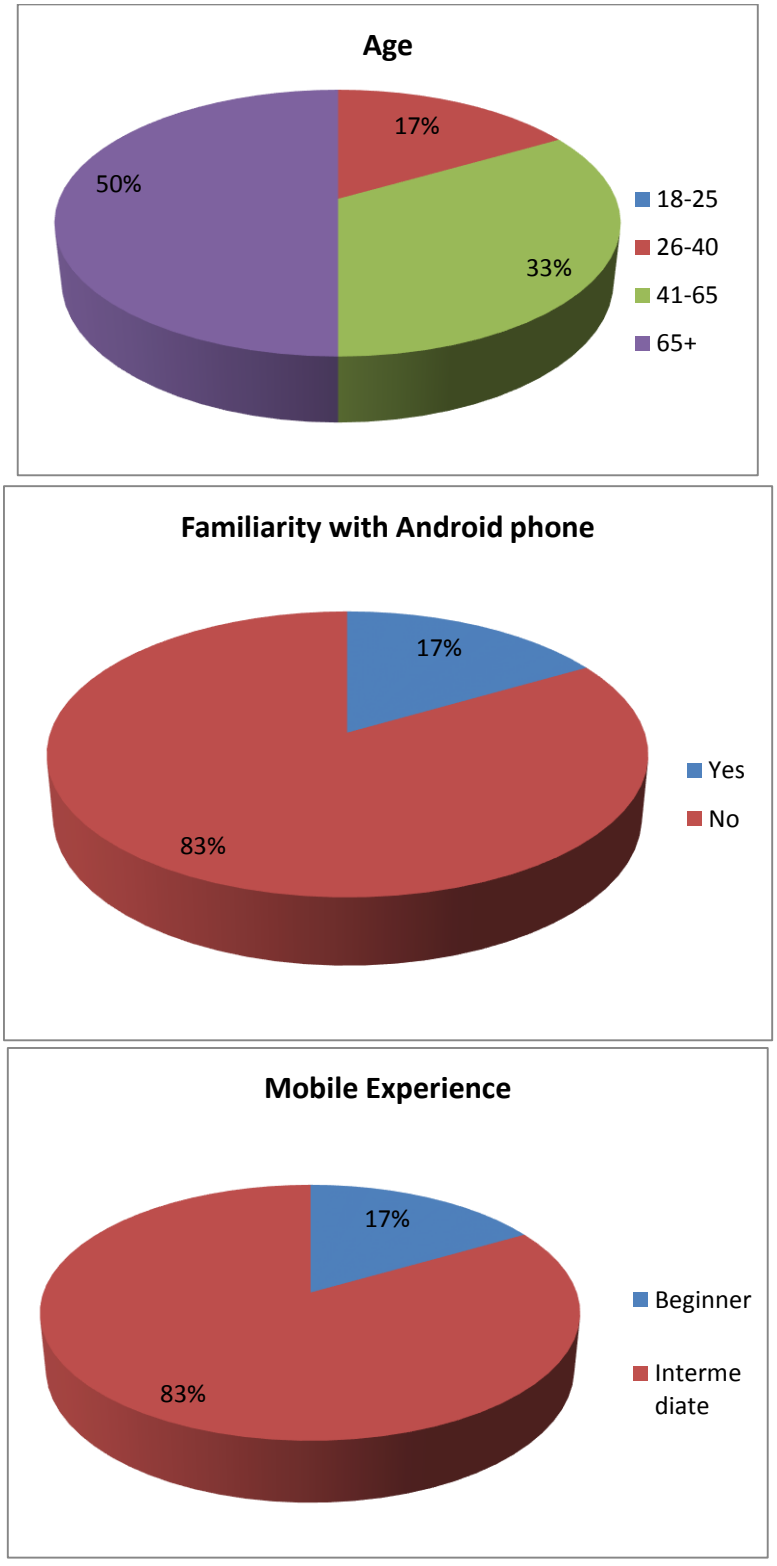

Figure 4.5: Demographics of the participants (n=6)

4.3.3 Metrics

To conduct an effective field study, the evaluator needs to decide on the metrics to measure and use them in the analysis stage. In order to identify the extent to which the *My Pill Reminder* Application is usable and how it ensures that its users have a pleasant user experience, the study should have a mechanism for measuring some qualitative variables, which express how participants feel about it. These metrics were chosen in such a way that enables conclusions to be drawn which are in line with the overall objectives of the field study. Participants were asked to rate the *My Pill Reminder* application on the following areas using a 5-point Likert scale:

- Ease of learning and use;
- Usefulness;
- Satisfaction; and
- Performance.

4.3.4 Methods

Before the start of the evaluation, the author volunteered to give a small tutorial to the participants who were not familiar with some Android patterns. However, the tutorial was done using another application (not *My Pill Reminder*) so as to prevent the learning effect. The mobile phone was loaded with the application and given to the user. Each participant had to use the application for three continuous days. The participants were given the author's contact details in order to get clarity whenever they were unsure or confused. A post-test questionnaire (PSSUQ) was used to obtain data from the participants. The data was analysed both qualitatively and quantitatively to make conclusions. The questionnaire made use of a 5-point Likert scale to capture the user satisfaction ratings. The questionnaire also enabled the user to provide comments of what they liked most about the application, what they did not like as well as their general comments after having used the application. The open ended-questions of the questionnaire were used to gather information that was used as the basis of the qualitative data.

4.3.5 Instruments

To carry out the field study, a standardized set of instruments was used, to necessitate getting consistent feedback from the users. The study used Samsung Galaxy S4 mobile phones with the *My Pill Reminder* application installed. The mobile phones also contained some basic tutorials, which explain the basic Android patterns and their corresponding interactions relevant for using the application. Logging software was incorporated in the application in

order to be able to track the usage and how the chronic patients were taking their medication, which was exported at the end of each participant's field study.

One of the usability questionnaires that are used for getting evaluation feedback from users is the Post-Study System Usability Questionnaire (PSSUQ) (Lewis, 1995). This questionnaire allows one to know how the participants feel after having performing some tasks on the application. The PSSUQ was used for obtaining feedback from the participants after using the mobile solution. PSSUQ was chosen as an instrument because it provides a comprehensive insight into the overall satisfaction of the users after using the mobile solution. The feedback from the participants will determine how the participants felt the application was in terms of effectiveness, good utility, usefulness and learnability.

4.3.6 Data analysis methods

The metrics will be used in the process of analyzing the performance of the application. The analysis will then translate the results in order to derive a logical conclusion with regards to the application. Statistical methods will be employed to make the data more useful easier to interpret. This will involve separating the data into two groups namely: Quantitative and Qualitative data. For quantitative analysis, the data will be quantified and then interpreted after being manipulated mathematically and statistically. The visual aspect will also be incorporated by making use of some graphs and charts to represent the data to facilitate easy interpretation. Some of the data such as problems might be interpreted qualitatively, for example, the areas where the participants discuss the problems they faced or when they give possible solutions.

4.4 Results

After using the application in the study, the participants provided feedback by completing a questionnaire. The participants were also interviewed to get an in-depth view of how they felt whilst using the application. The data from both the completed questionnaires and interviews were categorized and analysed qualitatively and quantitatively.

4.4.1 Qualitative results

The feedback from the participants of the field study was noted down and formed the basis of the qualitative analysis. From the feedback, several themes were derived and the frequency of the comments was also noted. A theme was regarded as a category, which was chosen by having an appreciable number (more than one) of comments in that particular category. The

categories were derived from analysing each comment and deciding to which the aspect comment referred. Each comment was assigned to a category based on its nature. After assigning all the comments to categories, the categories which had a frequency of more than one were used to form themes. Each theme was indicated using a colour, implying that all of the comments that have the same colour fall within the same theme and referred to the same aspect.

The themes with the highest frequency were also noted and further analysed. The comments that were common from the majority of the participants relating to the problems they encountered in using the *My Pill Reminder* application were regarded as usability issues. These results are tabulated in Tables 4-3 and 4-4. Comments which fell within the same theme were assigned the same colour and white was used to indicate that a theme was not assigned to a comment. The comments were split into two groups: positive comments and negative comments. Table 4-3 indicates a summary of the comments that identified positive aspects of the *Mobile Pill Reminder* application or the features that they liked.

Table 4-3: Summary of positive aspects (n=6)

Participant comment	Frequency	Theme
History facility is useful and helps me	5	
Very easy to use	5	
It was very easy to learn	6	
History facility enabled viewing trends in taking pills	2	
Use of different colours highlighted important information	2	

Two major positive themes were identified from the comments. These two themes are indicated by the black and green colours in Table 3. All the negative comments were outlined in Table 4-4. Table 4-4 shows a summary of negative aspects or the features that the participants did not like and felt that there is a need for improvement. Two themes were identified which are

indicated by the red and purple colours in Table 4-4. From the themes, additional functionality can be deduced as well as the usability issues of the current application.

Table 4-4: Summary of negative aspects (n=6)

Participant comment	Frequency	Theme
Reminder needs to be more intrusive and must be louder and longer	4	
Light must associate the reminder	2	
Flexibility needed in taking the pill (before time)	1	
Reminding you to take the pills before you take off from home	1	
Going direct into the Reminder screen	3	
Eliminating the use of the Notification area	3	
Touch screen phones were complicated	2	
Reversal of actions in taking pills	2	

4.4.1.1 Discussion of qualitative results

From Tables 4-3 and 4-4, there were several themes and corresponding comments that were common in most of the participants' feedback. The themes are as follows:

1. The application was easy to learn and use:

   The participants managed to learn and use the application by themselves after being given a short tutorial on key Android features and interactions. This theme is indicated by the green colour in Table 4-3. The participants felt that the application was easy to learn and also easy to use. The *My Pill Reminder* application was designed with one of the primary goals being ease of use. This ensured that the design was as simple as possible and the participants felt that the application was indeed easy to use.

2. The application was useful:

The participants also highlighted that they felt that mobile application could be useful in managing their chronic conditions. Two of the participants liked the functionality of being able to view the history of how they have been taking their pills whilst most of the participants indicated that the history facility was very useful to them. This theme is indicated in Table 4-3 by the black colour. The history facility was designed to enable the user to be able to view how they have been taking their medication in the last seven days. The goal of the facility was to make the use able to track the manner in which they take their medication.

3. The reminder must be more noticeable:

   Most of the negative comments were in the "reminder theme". The reminder was designed to be consistent with the user's settings on the phone, which could be soft if the user has set the settings in that manner. The reminders were designed to pop up on the Android Pull-Down Notification Area. This theme is indicated in Table 4-4 by the red colour. Most of the participants indicated that they were not satisfied by the design of the reminders. Participants' comments suggested that the reminder should be louder, the light must flash and it must repeat several times to increase the chances of the participant noticing the reminder. The comments also highlighted that the participants would like more flexibility and options in taking their medication. Participants would like the inclusion of a facility to take their pills before the time set on the application, in the event that they want to take their medication earlier. One of the participants also wanted to be reminded to take medication with him to his workplace, so that he would not forget the medication at home.

   The most important functionality of the application was being able to remind the participant to take their medication successfully. However, as shown by this theme, the participants were not reminded satisfactorily and the application did not fully meet their expectations. It is important to note, as mentioned earlier, that the reminders were designed by adhering to Android design patterns and guidelines. By referring to Figure 4.5, which shows the demographics, it can be seen that most of the participants were not familiar with Android phones. This is a possible explanation why they were not satisfied by the design of the reminders. However, there has to be a compromise between adhering to design patterns and principles and being user-driven. The design

of some aspects of the application needs to take into account to meet the expectations of the users especially the most critical ones.

4. Eliminating the use of the notification area:

   Another usability issue pointed out was the use of the Notification area to access the reminder. From Table 4, this theme is represented by the purple colour. As shown by Table 4, a number of participants were not satisfied by the use of the Notification area. Android platform uses the Notification area to display and store all the notifications that the user need to look at. This theme was as a result of those participants who were not familiar with using Android phones or with Android patterns. Participants would prefer the reminder to appear as a pop-up dialogue, which is inconsistent with Android patterns. The participants did not like the extra step of first dealing with the notification before being redirected to the Reminder screen. The participants pointed out that they would prefer the reminder to be presented in such a way that they are taken directly to the Reminder screen when it is time to take their medication.

There were also other comments that were made by participants but were not allocated to themes. Some of these comments came from one or two participants and were mainly dependent on the demographics of the participant. For example, two of the participants felt that the touch-based mobile phones were complicated and difficult to use. These comments could be regarded as influenced by the level of mobile experience, particularly with touch-based smart phones.

4.4.2 Quantitative results

The feedback from the questionnaires were tabulated in Microsoft Excel and analysed. The data was categorised based on the question numbers in each of the questionnaire section. Appendix A shows the questionnaire used in the study comprising the structure and the various questionnaire sections. Each participant's rating for each of the questions was recorded based on the Likert rating they assigned. The Likert scale was up to five and a low rating was indicated by a low chosen number whereas a large rating was indicated by a large number. The results were meant to investigate learnability, usefulness, satisfaction, and the overall performance of the application.

4.4.2.1 Learnability

The learnability section of the questionnaire looked at the feedback from the participants regarding how easy it was to learn and to use the application. During the field study, the participants were expected to be able to decide which actions to take in order to complete the tasks without assistance. The ability of the participants to perform and complete the expected tasks easily gave an indication of how much the mobile application was easy to learn and to use. Figure 4.6 illustrates the average ratings from the learnability section of the questionnaire from each of the participants.

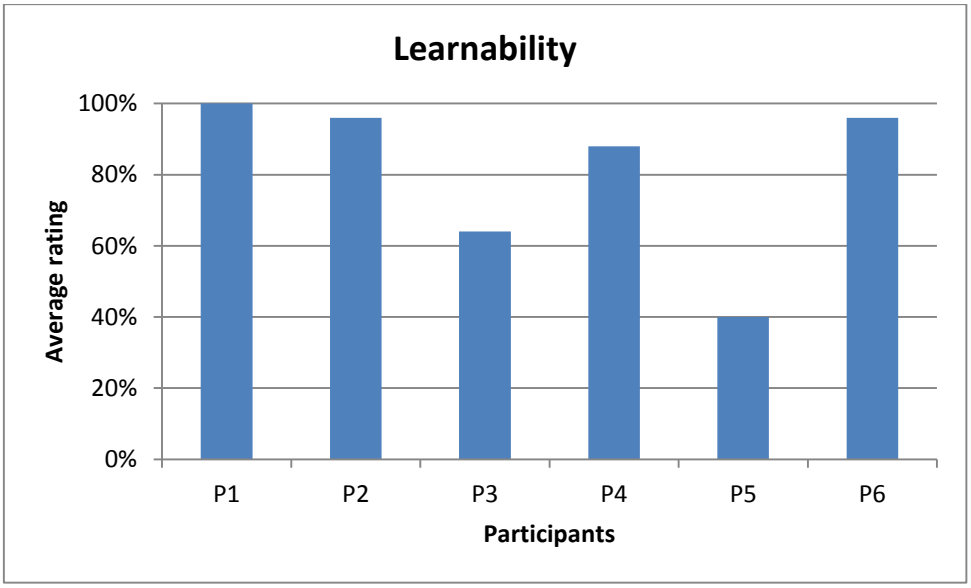

Figure 4.6: Learnability ratings from all the participants' reviews (n=6)

Figure 4.6 shows that the most participants felt that application was easy to learn and to use. Figure 4.6 indicates that there was one participant, Participant P5, who felt that the application was not easy to learn. The possible factor that might have influenced this participant to give a low rating can be found from the demographics. The participant was not familiar with using Android phones, which might have made the participant to struggle with operating an Android phone. Since the participant was not familiar with Android phones, he had to learn the key Android features and interactions to be comfortable with using the application. Figure 4.6 also shows that the other four participants felt the application was easy to learn and to use as shown by ratings greater than 80%.

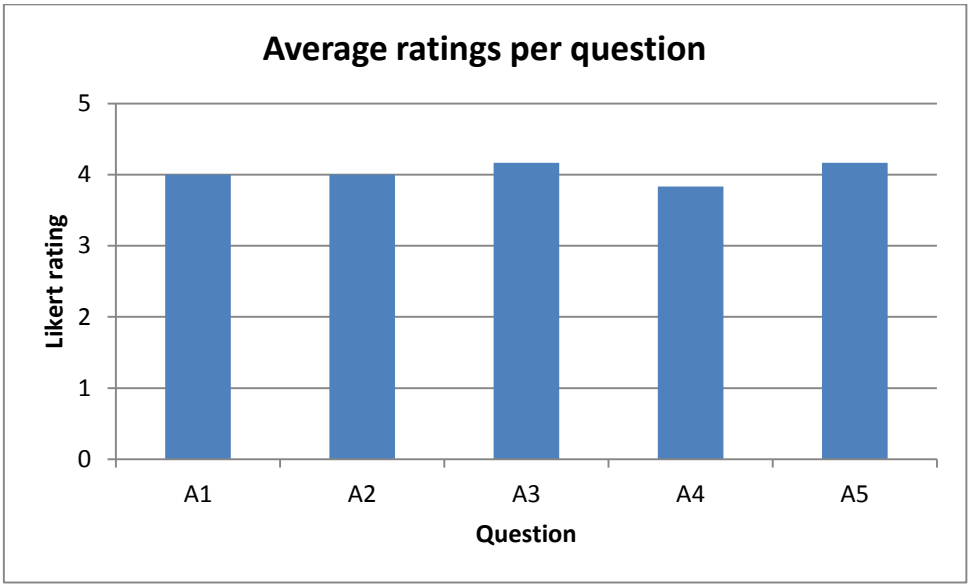

Figure 4.7: Learnability ratings per question (n=6)

Figure 4.7 shows the average Likert ratings per question in the learnability section (section A of the questionnaire). All the ratings from the participants were recorded and the average ratings were calculated and represented in Figure 4.7. Figure 4.7 shows that the average ratings of all the questions were greater than three and a half. Four of the questions had an average of four or more out of the maximum possible of five.

4.4.2.2 Usefulness

The field study also investigated how much the participants felt the application was useful. The usefulness section of the questionnaire, section B, had questions which focused on how much the participants felt the application can assist them in complying with their medication schedule. This was one of the most important metrics since usefulness was one of the major objectives of the field study. Figure 4.8 illustrates the average ratings from the usefulness section of the questionnaire.

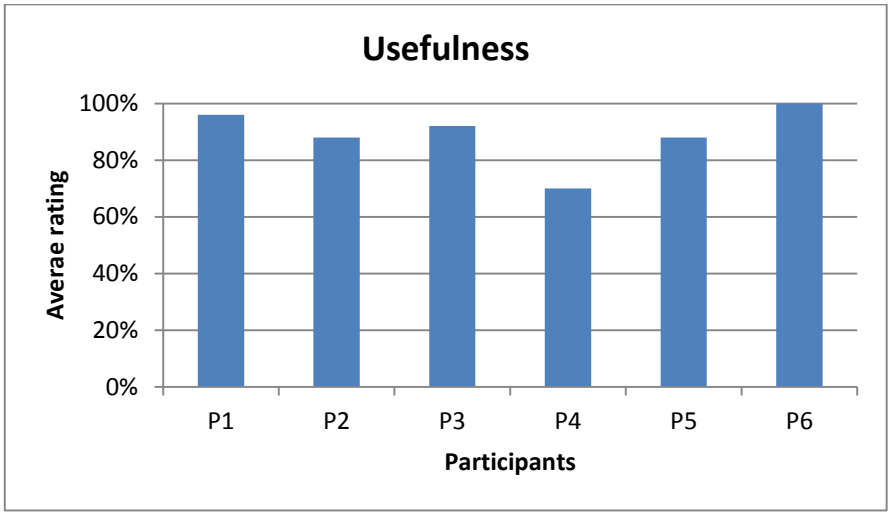

Figure 4.8: Usefulness ratings from all the participants' reviews (n=6)

Figure 4.8 shows that the participants generally felt that the application useful. This is indicated by the high average values in Figure 4.8. All the participants, except for one, had an average rating for the section greater than 85%. Figure 4.8 indicates that there was one participant who gave an average rating of 70% which was relatively lower than the other participants. The possible reason why Participant P4 gave a lower rating was because the participant had other expectations of such an application. It can be concluded that the section the participants felt that application was useful in supporting them to comply with their medication schedules. Figure 4.9 shows the average Likert ratings per each question from the usefulness section. The average ratings were high, which shows that the participants felt that the application was useful. Figure 4.9 also shows that the average ratings of all the questions were greater than three and a half.

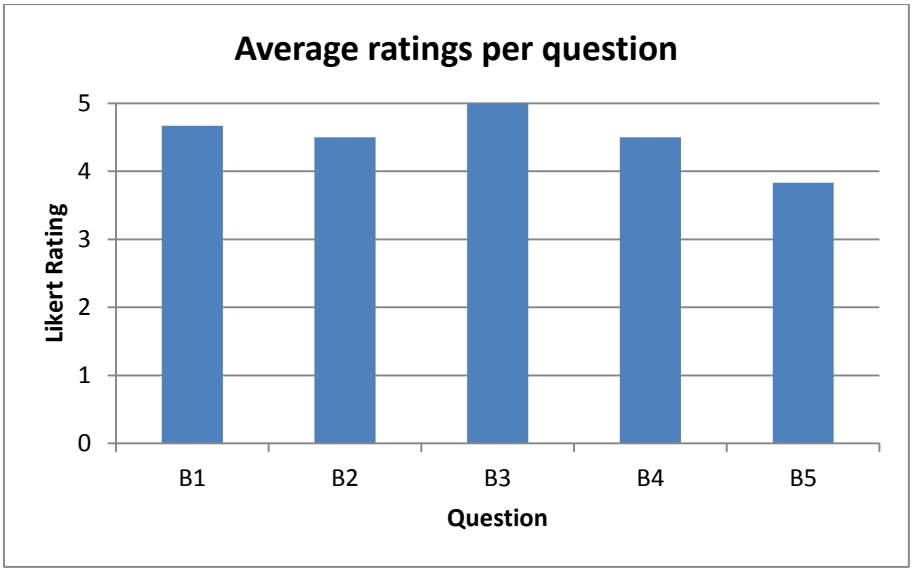

Figure 4.9: Usefulness ratings per question (n=6)

4.4.2.3 Satisfaction

The field study also investigated the participants' satisfaction level after using the application. The satisfaction was mainly dependent on whether the application met the participants' needs and the user experience whilst using the application. Figure 4.10 illustrates the average ratings from the satisfaction section of the questionnaire. Figure 4.10 shows that the participants were generally satisfied with the application. All the participants had an average satisfaction rating greater than 70%. Figure 4.10 indicates that there were three participants who gave ratings which were slightly lower than 80%. This shows that the application did not fully satisfy them and there are aspects that did not meet their expectations.

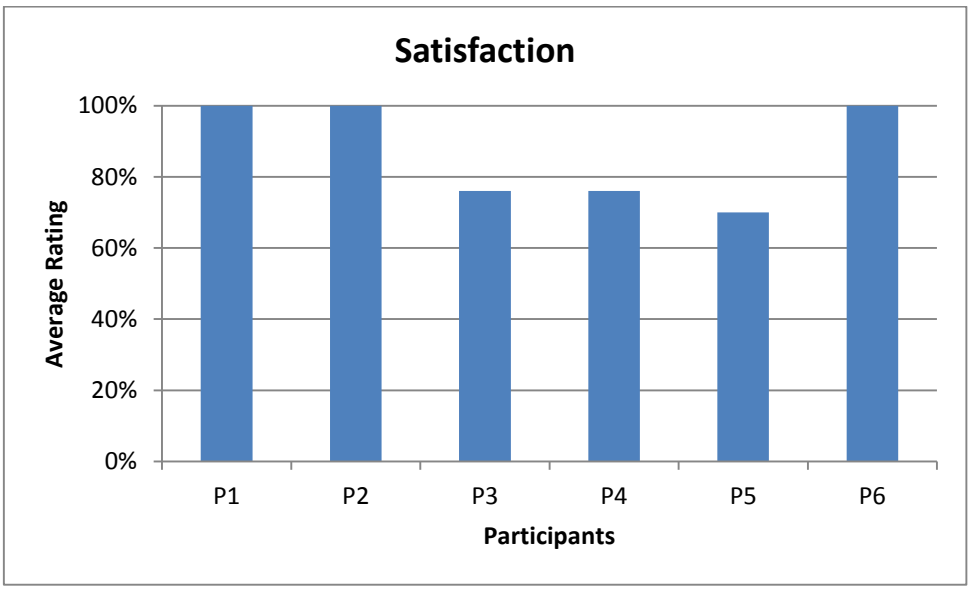

Figure 4.10: Satisfaction ratings from all the participants' reviews (n=6)

Figure 4.11 shows the average Likert ratings per question of Section C of the questionnaire. The average ratings were high indicating that the participants were satisfied by the application. Figure 4.11 also shows that the average ratings of all the questions were greater than four. Figure 4.11 indicates that the feedback from all the questions regarding satisfaction got a positive response greater than 80%.

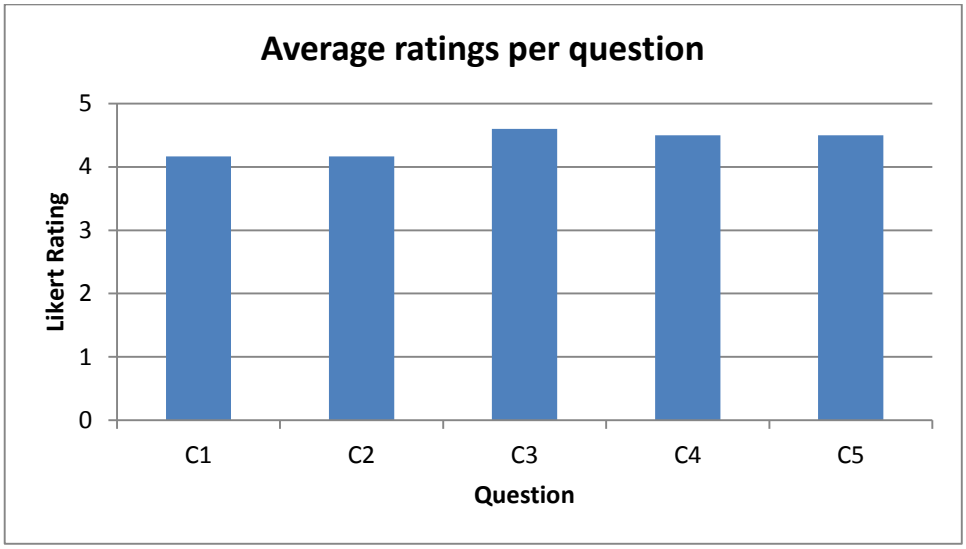

Figure 4.11: Satisfaction ratings per question (n=6)

4.4.2.4 Application's performance

The performance section of the questionnaire looked at how the participants felt about the performance of the application. Figure 4.12 illustrates the average ratings from the performance section of the questionnaire. It can be seen from Figure 4.12 that, the participants were satisfied with the application's performance except for Participant P3. All the participants had an average rating of the section greater than 60% except for Participant P3. Participant P3 had no experience with Android phone, which could have influenced the low rating.

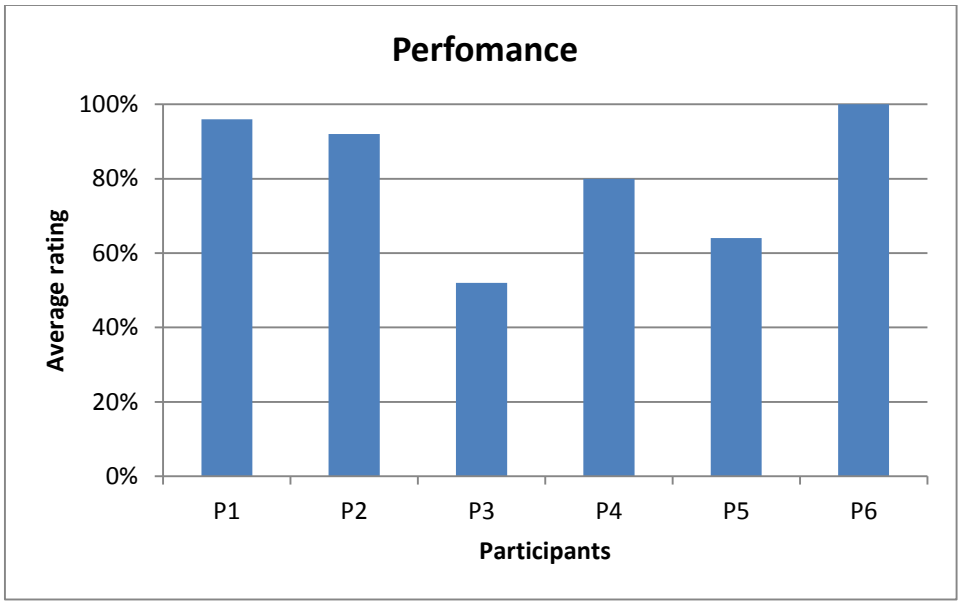

Figure 4.12: Overall system performance ratings from all the participants' reviews (n=6)

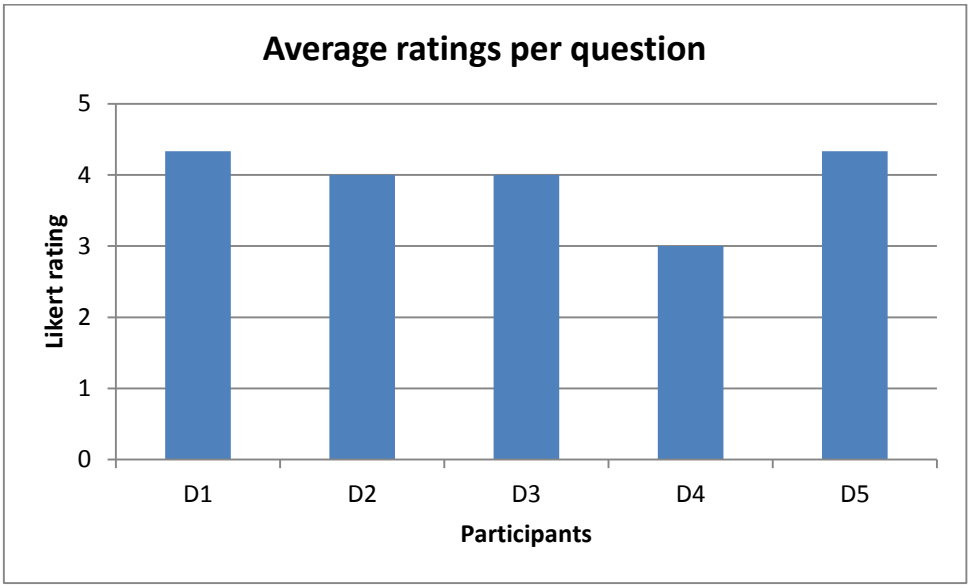

Figure 4.13: Overall system performance ratings per question (n=6)

Figure 4.13 shows the average Likert ratings per question of Section D from all the participants. The average ratings were high, which shows that the participants were satisfied by using the application. Figure 4.13 also shows that the average ratings of all the questions were greater than three. Four of the questions had an average of four or more out of the maximum possible of five and only one of the questions had an average less than four. Question D4 had a relatively lower rating than the rest because the participants did not like the error messages that were provided.

4.5 Conclusion

The chapter investigated the extent to which the *My Pill Reminder* application can support medication compliance through a user study and a field study. The participants felt that the application was successful in reminding them to take their pills. Chapter 4 highlighted that when designing mobile solutions, there is a need to reach a compromise between being user-driven and following the standard design principles and patterns. The demographics of the field study indicated that most of the participants were elderly people suffering from chronic conditions. From the metrics measured, it was found that the application was usable but had some usability issues. The results indicated that the participants were highly satisfied with the application as shown by their positive comments.

This field study had several limitations. Firstly, the field study had a sample size of six participants and using a larger size could have increased the quality of the results. Secondly,

giving the participants second phone affected the study because they were not using the phones they use every-day. Being given a smart phone also introduced novelty effect and excitement which possibly affected the feedback they gave at the end of the study. Also, the length of the field study was short. Conducting a longer field study might produce more representative and conclusive results. The chapter was successful in pointing out the usability issues, additional functionality and the changes that need to be done to make the application support the patients. This creates the need for the application to be re-designed and implemented, which is discussed in Chapter 5.

Chapter 5 Re-design and Implementation

5.1 Introduction

As mentioned previously in Chapter 1, DSR methodology makes use of iterative development and cycles. This is one of the DSR's pillars of success because it allows the artifact to be improved before it is deployed. The refining process is done through evaluation of the artifact and then addressing identified issues. Chapter 5 focuses on outlining the process of re-designing and implementing the *My Pill Reminder* application. The major goal of the chapter is the process of re-designing the *My Pill Reminder* application based on the literature review findings and evaluations. This is achieved by addressing the usability issues and additional requirements and also taking the literature review into account. Chapter 4 focused on the pilot field study and pointed clearly how users felt about using the application.

According to Hevner *et al.* (2007), the artifact developed and used within DSR methodology must be viable and sufficient to be used as the basis of conclusions. DSR puts more emphasis on optimizing the solution rather than focusing on the initial requirements and design. DSR also emphasizes on iterative and incremental development which necessitated this application to be redesigned. This chapter addresses the fourth research question identified in Chapter 1, namely; *"How should the existing version of My Pill Reminder application be re-designed to support medication compliance?*" Chapter 5 outlines the additional and updated functional and non-functional requirements with the motivation for the changes made. The chapter also outlines the updated Task Analysis and UML Class Model. Chapter 5 also looks at the evolving patterns of Android and how they can be applied to the artifact to improve the application and solve the usability issues identified. The chapter also outlines the process and the major issues involved in redesigning the Data management, User Interface, flow re-designs for example, making it context aware and the Algorithm re-design.

5.2 Updated requirements

5.2.1 Initial functional requirements

During the evaluations, the original requirements were evaluated. The initial requirements were deduced by carrying out a literature review and identifying the problems that were common with elderly people. To ensure that the requirements were relevant to patients with chronic

diseases, the feedback from the evaluations was thoroughly examined to find issues with the initial requirements. Using the information from the user study, field study and an in-depth literature review, the results of the initial requirements were tabulated in Table 5-1. The table outlines the functional requirements and their corresponding feedback and the comments of the feedback and relevance of the requirement in the redesign.

Table 5-1: Review of the functional requirement of the first design of the application

Requirement	Feedback	Comments
The application must be able to remind the user to take pills at the scheduled time.	The application was successful in reminding the patient to take the medication. This was illustrated by the level of success in the task completion in the user study. However as shown in Section 4.4, some of the participants were not entirely satisfied with the way this functionality was implemented.	The primary goal of the *My Pill Reminder application* is to remind the user to take their medication at the prescribed times. The reminder requirement is therefore very essential for the application. Since the reminder requirement is very important, this functionality must be maintained even in the redesign of the *My Pill Reminder application.* However, since some of the participants were not fully satisfied by the initial implementation of this functionality, it might be necessary to alter the nature of the implementation to optimize this functionality.
The application must specify the type and quantity of the pills to be taken by the user	The application was successful in assisting the users in taking the correct type of pill and the corresponding quantity of the pills. The functionality of specifying the type and quantity of the pills was done in more than one way which made the users' to be satisfied by the functionality.	To remind the user to take their medication, it is necessary to inform them of the type and quantity of the pills to be taken. This functional requirement is instrumental in reminding the users effectively to take their medication. Since specifying the type and quantity of the pills is important, it is necessary to keep

		this functional requirement in the redesign.
The application must be able to provide audio reminders	The application used audio reminders as a way of grabbing the participant's attention to take their medication. The application used the default audio output assigned for the user's notification. Section 4.4 illustrated that the participants were not fully satisfied by the implementation of the notification sound. This resulted in the audio reminders not being able to successfully reminding the participants to take their medication.	Most of the users pointed out in the field study that the audio reminders were not loud enough to grab their attention. This because the first version of the application was designed to make use of the default notification sound, which is usually soft. The participants indicated that they would still require audio reminder but they need the implementation to be modified to make it louder.
If the user does not adhere to the schedule, the application must notify the caregivers, family member or even the family doctor	During the evaluations, most of the participants adhered to their schedules. Sticking to their schedules resulted in the caregivers not being contacted since application. From the feedback, participants indicated that they like this functionality.	Since the application intends to support medication compliance, it has to take precaution measures in order to minimize the possibility of a patient missing a schedule unnoticed. This functional requirement is important and is necessary especially if the patients get to use the application over a long period of time.
The application must provide visual cues which will allow the user to find the type of the	The participants for the field study did not use this facility a lot since most of them were not taking many different types of pills. Other participants indicated that they liked this	Provision of visual cues was included in the application to assist the participants who take different types of medication and might get confused whilst identifying them. In the field study, most of the participants already knew how the pills

pill they should take	functionality since it helped them to be sure of the pills they were taking.	looked like and therefore did not use this functionality a lot. This functionality is important and must be kept because it supports the users who cannot remember all the pills they are taking and get overwhelmed (Qudah *et al*., 2011).
The application must be able to order pills approximately forty-eight hours prior to their depletion	None of the participants got to use this functionality since they only used the application for a short time. However from the general feedback, the participants thought that it is a facility that would be useful.	The requirement of re-ordering the pills can be useful when the patient uses the application over a long period of time. The functionality will be maintained since it was not evaluated to determine if it is practical and relevant. The feedback that was given by the participants in the field studies was based on how they feel with regards to this functionality.
The application must allow the user to confirm taking of medication	Confirming whether the participant has taken the pills or not is one of the pillars of the application in order to determine if the patient is taking the pills on time. From the field study, the participants expected the functionality to be more flexible than the original. The participants also wanted the application to allow them to reverse their actions during taking the medication and being able to confirm taking their pills before the time set for their schedules.	The patient confirming taking the pills is the only way that the application will be able to know that the patient is sticking to their schedule. During the field study, the participant were able to confirm whether taking their medication or not through this functional requirement. However, as indicated in Section 4.4; the participants suggested making changes to make this functionality more user-friendly and flexible. Therefore, the functionality of the user confirming taking pills will be maintained in the re-design the implementation will be modified.

5.2.2 Additional and Updated requirements

Section 4.4 presented and discussed the results of the field study. From these results, there were additional requirements that can be derived from the participants' feedback and the usability issues identified. Section 5.2.1 outlined the initial original functional requirements but as illustrated by Section 4.4, these functional requirements are not sufficient and have some shortcomings. This section outlines the additional requirements that were derived from feedback from user study and field study and literature review. The additional requirements are as follows:

1. The application must store history on a back-end cloud server;
2. The application must be connected to pills database on a server;
3. Reminders must be more intrusive, louder and longer;
    - Light must be associated with the reminder;
    - To recur within an hour before notification of violation; and
    - Expanded to be both on the Notification area and as a pop up.
4. The application must be flexible in taking the pills (especially before time);
5. The application must give location-based reminders when the patient is leaving home;
6. The application must allow reversal of actions in taking pills;
7. The application must cater for inputs of various data types; and
8. The application needs to check if the patient is still conscious and has not collapsed.

5.2.3 Non-Functional Requirements

- The application must automatically remind the patient at the scheduled time;
- The application should respond instantly to the user's request;
- The application must run in the background all the time except when it needs to give an alert or when the user wants to use it;
- The application must be able to run on Android mobile phones; and
- The application must provide accurate medication details and all the necessary information at the prescribed time.

5.2.4 User Interface

- All the content (text, graphics, buttons and lists) must be clearly visible;
- The application must allow easy reversal of actions should a user make a mistake;

- Navigation from one screen to another must be easy;
- The application must provide feedback whenever an action is done;
- The design of the screens should be consistent and similar; and
- The application must provide clues, hints and information that will enable the user to know how to operate it.

5.2.5 Usability Requirements

- The application must be easy to learn and easy to use;
- The application must be easy to remember and thus prevent the user's memory overload; and
- The application must be efficient and be able to deal with a user's errors efficiently.

5.2.6 Database Requirements

- The data must be up-to-date and accurate and must be editable;
- The data on the backend server and the one on the phone's database must be always be synchronized;
- The application must have access to the prescription of the patient on the backend server; and
- The basic information of the user must be kept as well as the caregiver, family members and family doctor's details.

5.3 Task Analysis (updated)

Task Analysis refers to the process of analyzing and expressing the kind of learning that one expects the users to be able to perform (Janssen, Tessmer, and Hannum, 1999). It is an essential step in which goals and tasks are explicitly defined to give a detailed and clear outline of the steps to be followed. Task analysis will illustrate the relationship between the actors and the tasks that ought to be performed in order to achieve their goals whilst using the application. The additional functional requirements identified in Section 5.2 can be represented by Figure 5.1. Figure 5.1 illustrates the relationship between the tasks and the actors who performs the tasks. The tasks have three possible actors: the system, the patient and the administrator. The task marked in red, (take pills) indicates a task that was already implemented in the first design of the application but which the participants requested for

it to be expanded. Figure 5.1 shows the task of taking pills being extended to be more flexible in order to support the user's needs.

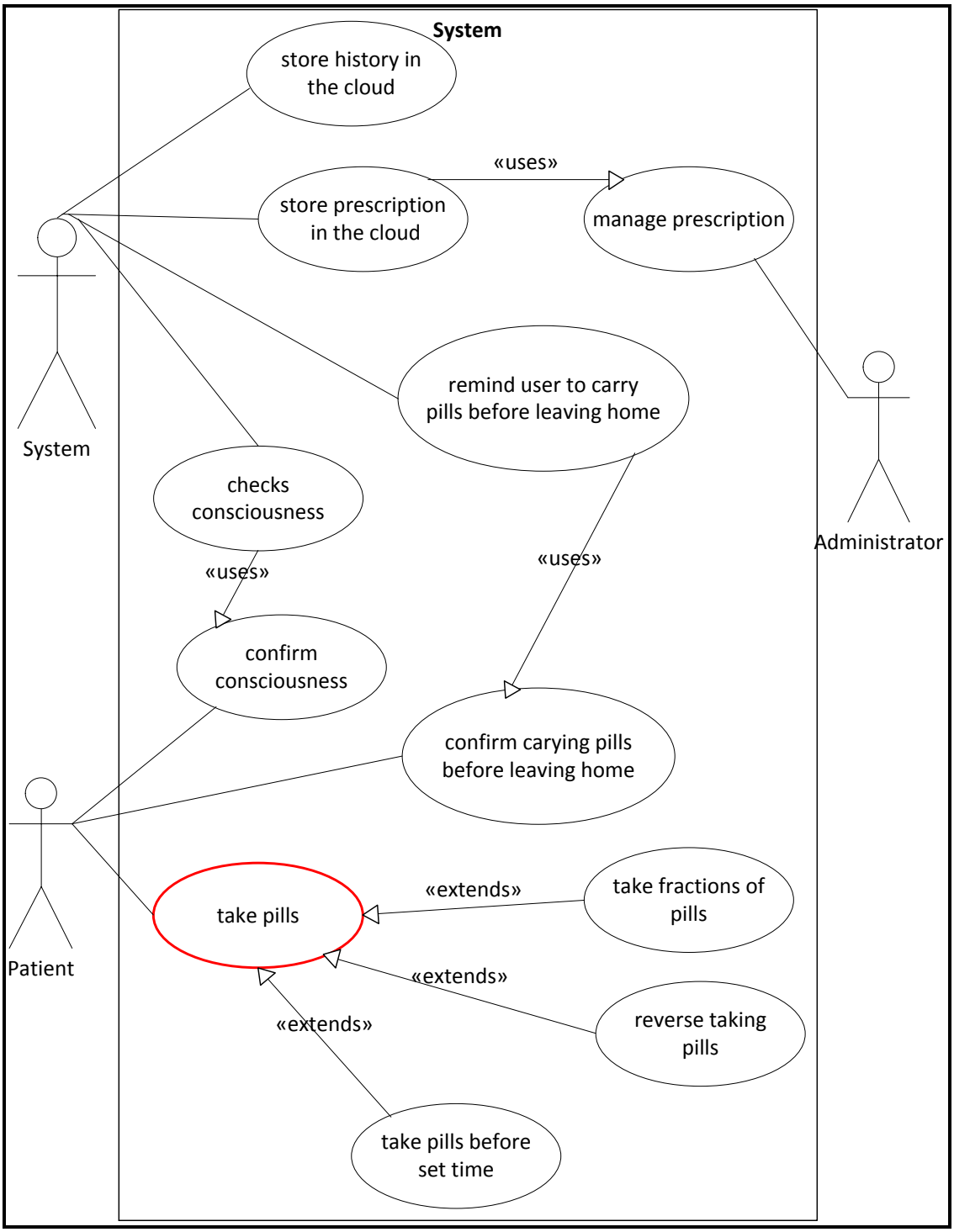

Figure 5.1: Use case diagram for the additional requirements

5.4 Phone compatibility

To modify the application, Android Software Development Kit (SDK) was used. The SDK used supported Android Application Programming Interface (API) level of at least 2.1 with a

corresponding SDK version of 8 and up to an API level of 4.1 with a corresponding SDK version of 16. Since the application targets various users in South Africa, it is logical to also cater for affordable phones that can be used by many people, which explains supporting SDK version 8. The application targets the most recent SDK level (16), which is used by the latest Android phones but will support basic phones as well. Supporting various API levels increased the portability of the application was to the Android phones currently on the market.

5.5 System Architecture

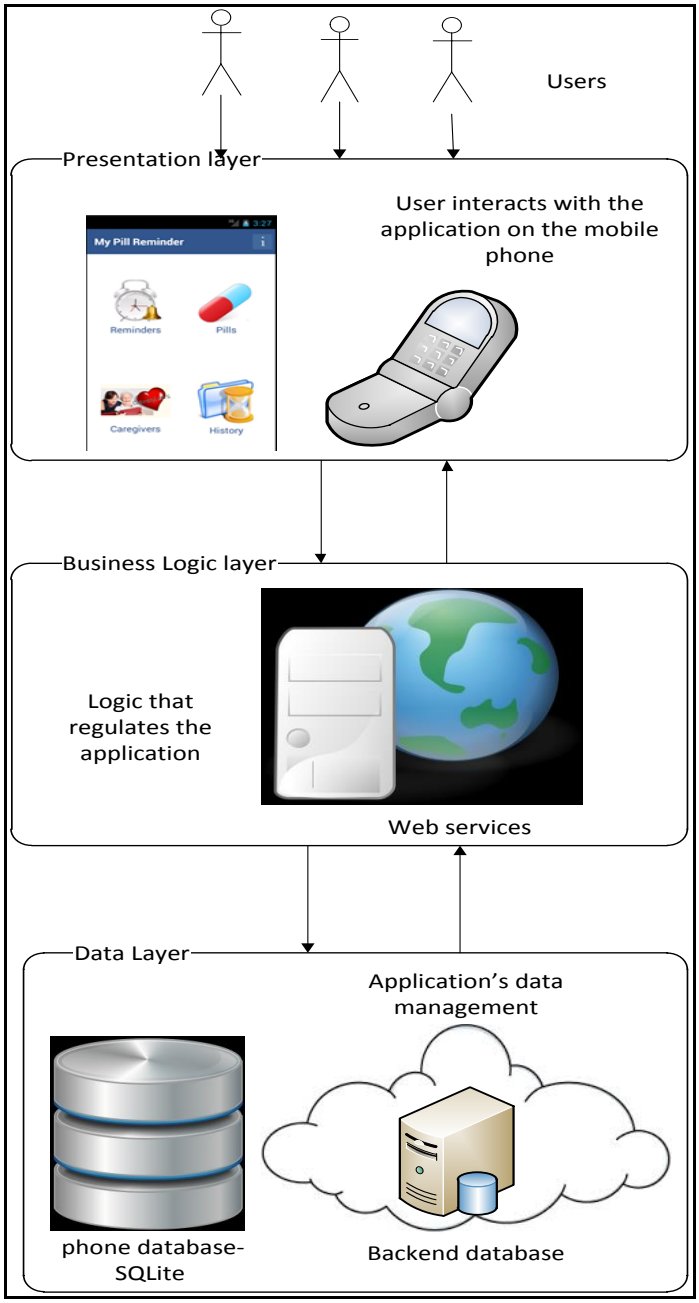

Figure 5.2: Model of the solution

The redesign of the *My Pill Reminder* application used three-tier architecture to make the software modular and easy to manage changes. Using three-tier architecture separated the application logic into three logical layers. Having the application split into three separate logical layers allowed manipulation of a layer separately and without affecting other layers' logic. The first logical layer of the application was the Presentation layer, which comprised of the user interface, layouts and their corresponding styles, menus and constant values and was responsible for direct interaction with the user. The middle layer consisted of the logic layer which encapsulated all of the business rules and supported the processes that took place in the Presentation layer. The third layer was the Data layer, which was the layer that stored the data that was used within the application and for constructing and accessing the database. Using three-tier architecture, made it is possible to make changes in one layer and not affect the other layers. Figure 5.2 shows how the architecture was used in the redesign of the application.

5.6 Re-Design

5.6.1 Data management re-design

The application stored the information necessary to make it operational on two data repositories. These data repositories were: a local database on the phone's internal memory and an external database on a backend server.

The application stored some of its data locally on the mobile device of the user. The data stored locally on the device was the minimum data necessary for the application to function. This information included the reminders' information and the pills currently on the patient's prescription. Since the application was developed to support the Android platform, a SQLite database was be used for local storage of the data. SQLite was selected for *MyReminder* because it is not memory intensive. SQLite was useful due to the fact that it is a lightweight database which exhibits fast and efficient data retrieval (Wai *et al*., 2011). Another advantage of this type of a database is that it is versatile since is independent of the operating system used. Due to the risks that can be caused by wrong data capturing of medication, the application was connected to an external database to load the data. The external database was used to load the relevant data to the phone's local database as specified by the pharmacist/doctor. Figure 5.3 shows the database schema to support storing the information locally to make the application operational.

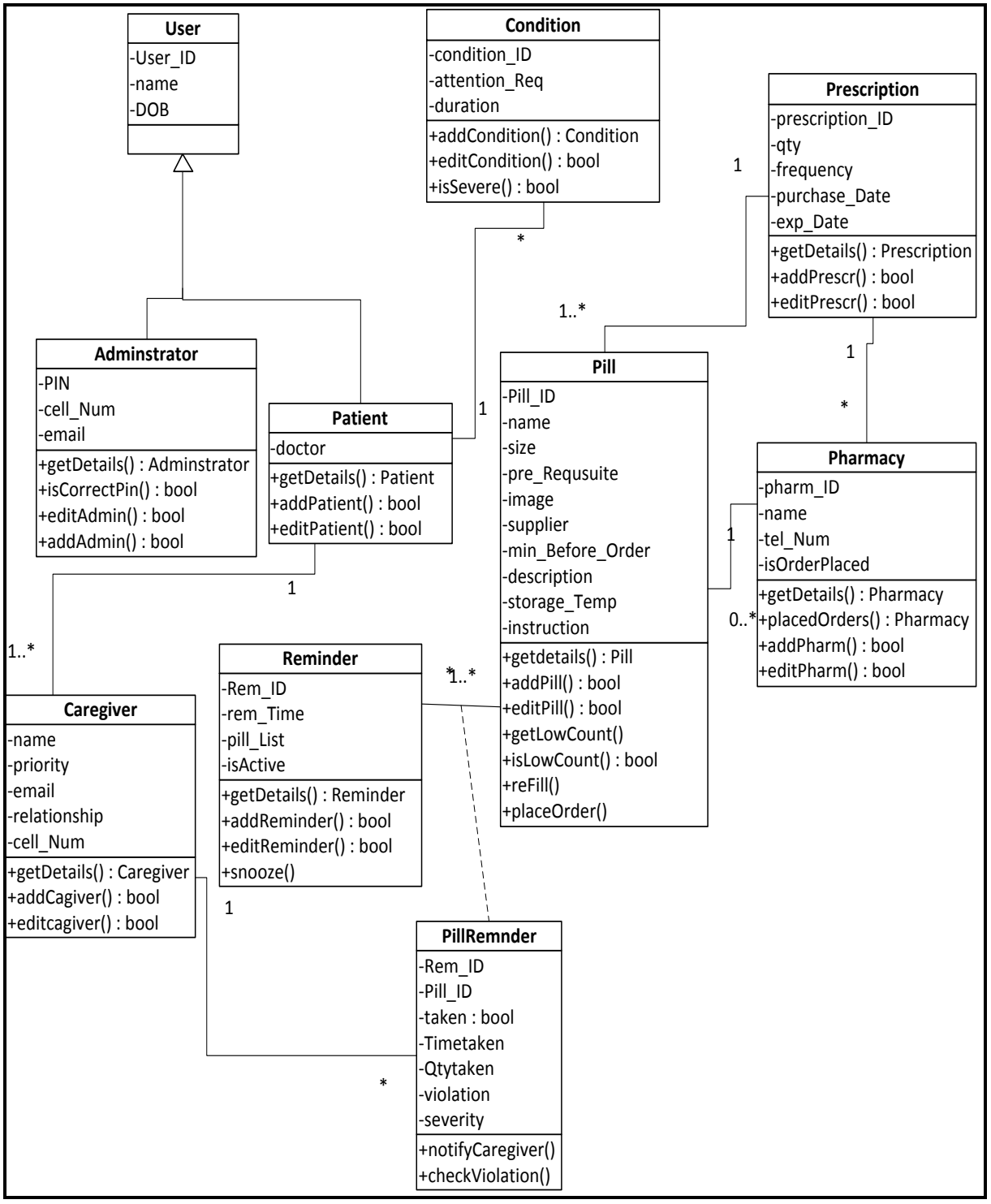

Figure 5.3: UML class diagram showing data to be saved on the mobile phone

The application also used an external backend server for storing data in addition to the SQLite database. Due to the simplicity of the data that needed to be stored, MySQL database was chosen. MySQL is a relational database which supports multiple users simultaneously and basic data storage, retrieval and basic database functionality (Hayakawa *et al.*, 2013).The

system is a multi-user system; therefore the database should also be able to respond to several simultaneous users. The backend server needs to be reliable and operational every-day. MySQL was chosen because of some its properties favorable to the designer with regards to the project. Some of the properties of MySQL include the following: (Android developers, 2014), (Hayakawa *et al*., 2013), (Garcia-Sánchez, *et al*., 2013), (Khan *et al*., 2010)

- Multiple user processes capability- The *My Pill Reminder* application requires the server to be able to support processes done simultaneously. This property eliminated the possibility of using other databases like Microsoft Access. MySQL is capable of supporting users making database requests simultaneously;
- Cost- MySQL is free and therefore one does not incur some expenses to obtain licenses to use this database. This attribute of MySQL made it very favorable for the designer since the system was not designed for commercial use and thus there was a need to minimize the costs as much as possible but still maintaining the quality of the system's processes;
- Platform Versatility- Since the application was designed for Android, it used Java for programming purposes and therefore the database used had to be compatible with Java. Unlike other platform dependent like SQL Server which can only run on Microsoft platform, MySQL is versatile with in terms of the platforms it can support. MySQL is compatible with being integrated with Java which made it a good for this project; and
- Simplicity- MySQL was built with a command-line setup and can exhibit scripting which makes it possible not to rely on the full blown GUI for carrying out all the designing. This makes MySQL to be flexible in manipulating it and can allow the user to design the database in the way that they are most comfortable with. Also, sine MySQL is a relational database, it makes creating and managing the database very easy unlike other databases like NoSQL or unstructured databases which require more attention in setting up and managing it to run smoothly.

The server was primarily used as a data repository for storing data of the patient over a long period of time. The SQLite database on the phone's internal memory only had the current information and the rest was stored on the server. The server kept history of each participant to monitor how each patient was taking their medication. The server also kept track of the prescriptions with all the medication details. At the end of each day the information captured by the mobile application from the patient will be uploaded to the server and stored. The server is responsible for capturing the prescription of the patient and ensuring that it stays up to date.

Every-time there is a change in the prescription for a particular user, the changes will be pushed on to the application synchronizing the mobile phone with the server. Figure 5.4 shows the database schema for the server. Figure 5.4 also includes the table which was used during the field study. This table is called the ASQ table and it is marked in red in Figure 5.4. This table was used for storing daily feedback from the patients every-day, during the field study so that they could express their daily experiences with the application.

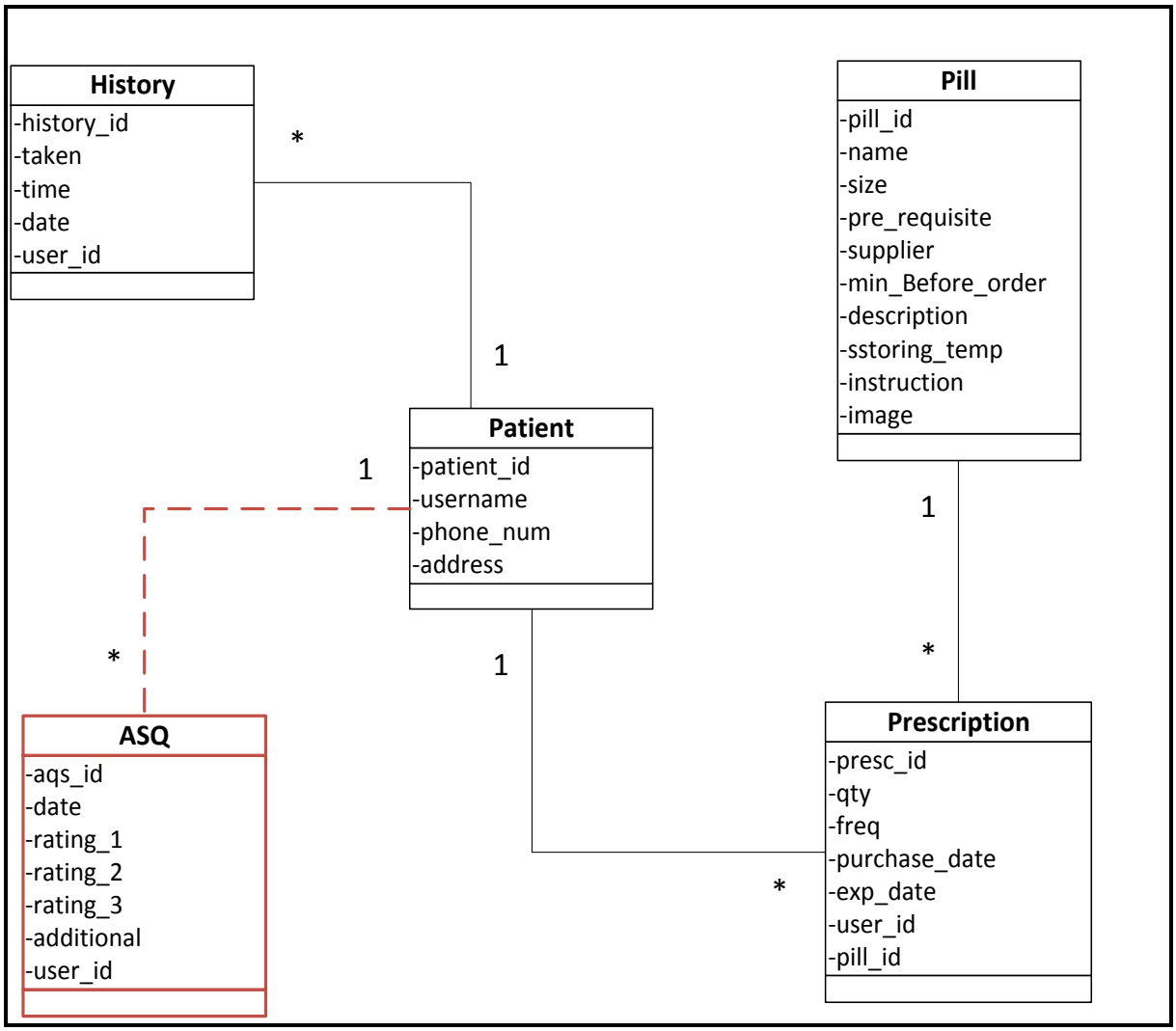

Figure 5.4: UML class diagram for the backend server

5.6.2 User Interface re-design

One of the greatest factors that influence user experience of a mobile application is its visual design and the interaction with user (Kharrazi, Chisholm, Annandale, & Thompson, 2012). The *My Pill Reminder* application focused mainly on having a simple and visual user interface. The goal of having a well-designed user interface was to make it easy for the users to complete their

tasks easily and to reduce memory overloading whilst using the application. The design process was done following the Android patterns since application was designed for the Android platform (Iwaya *et al*., 2013), (Shabbat *et al*., 2010). By following the Android patterns, the application's interface and flow of tasks will be similar to other Android applications thereby promoting transfer of their knowledge. The evaluations of the first design of the application discussed in Chapter 4 pointed out the users were satisfied with the design of the use interface. Therefore, it was not necessary to make huge changes to the overall design of the application.

Android Patterns Adherence

The Back button on Android mobile devices is an integral feature which should be catered for during the implementation of a mobile application. To make use of this button, Android uses a stack of activities and thus by pressing it, the previous screen will be displayed (Biswas & Asif, 2013). *My Pill Reminder'*s implementation made use of activities since it is the way that will support the Android mobile device hardware's functionality. For each key task that was performed, an activity was used. Instead of using the normal threads and then interrupting them at defined intervals, the application used services. Services are processes which can run in the background even if the application is closed and are managed by the phone (Services, 2014). Services were used for notifications and managing reminders where normal multithreading would have caused more power consumption. The *My Pill Reminder* application also created some constants that were separated from the code that can be edited easily without affecting the code and also prevented hardcoding. These constants included all the strings used within the program, the styles used in the layouts, the menu items used for menus, the arrays used for contextual menus and drop down menus. This eliminated the traditional ways of inputting some values in the program.

By taking a closer look at the Android patterns, a dashboard layout was maintained for the Home screen in the new design of the application (Beckley, 2011). The design maintained having direct link between the main screens and the Home screen. On each screen, a Home icon was included, which would take the user to the Home screen in a single step (Android developers, 2014). Action bars were also included on all of the screens which support major functionality, and consist of icons to access the major screens directly. In addition to the support ease of navigation from the Home screen, the redesign incorporated the navigation drawer.

The navigation drawer or sliding menus consists of a panel that makes transitions from the left side of the mobile phone's screen and thereby also displays the major options for navigation of the application (Creating a Navigation Drawer, 2014). The navigation drawer can be brought up the screen by the user either pressing or tapping on the application's icon on the left side of the action bar or by the user swiping from the left side of the screen towards the right side.

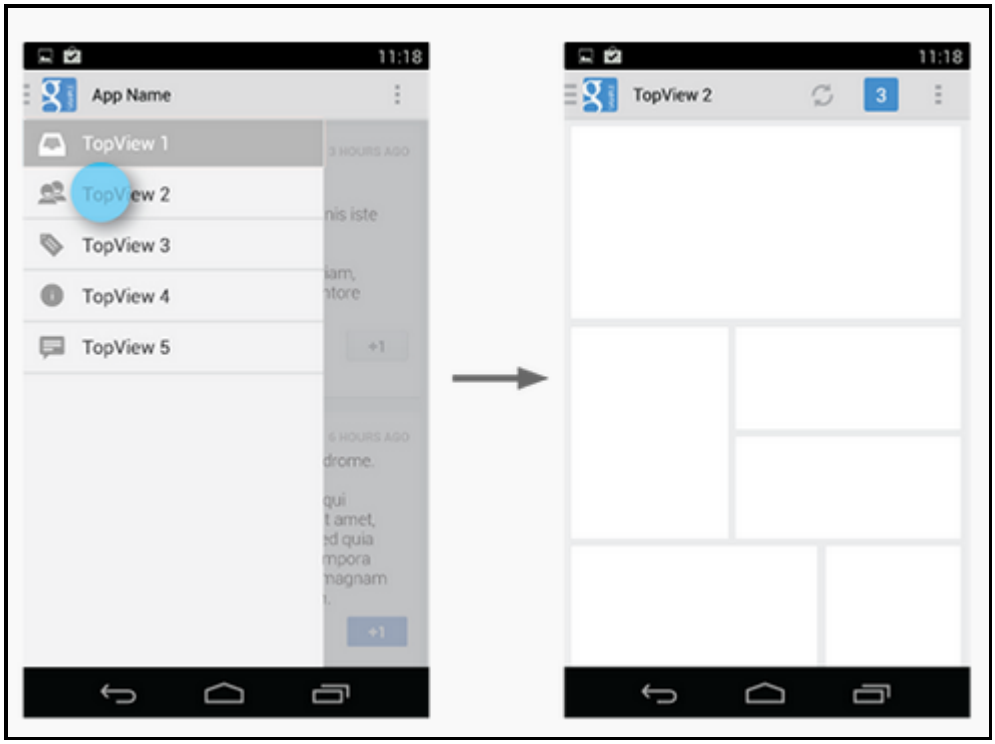

Figure 5.5: Schema of the navigation drawer (Creating a Navigation Drawer, 2014)

Figure 5.5 illustrates the schema of the navigation drawer. Figure 5.5 also shows the interactions that the user will exhibit whilst using the navigation drawer. The navigation drawer was designed to incorporate the action bar. The left part of Figure 5.5 illustrates the drawer and the navigation options. Selecting a navigation option will result in navigating to the selected screen and updating the title on the action bar. The navigation drawer by default uses fragments to display the contents of the screens. Navigation drawer allows easy navigation from one screen to another directly without having to follow a set of steps.

The navigation drawer was used in the redesign of the *My Pill Reminder* application as a way of providing easy navigation to screens user would like to navigate to, easily. The navigation options were adapted from the options that were part of the menu facility on the Home screen of the first design. These options links to key functionality screens but could not fit on the dashboard because the dashboard was optimized for visibility. The navigation drawer

optimized navigation to key screens and increased visibility of the navigation options. Figure 5.6 illustrates how the navigation drawer was adopted in the redesign of the *My Pill Reminder* application.

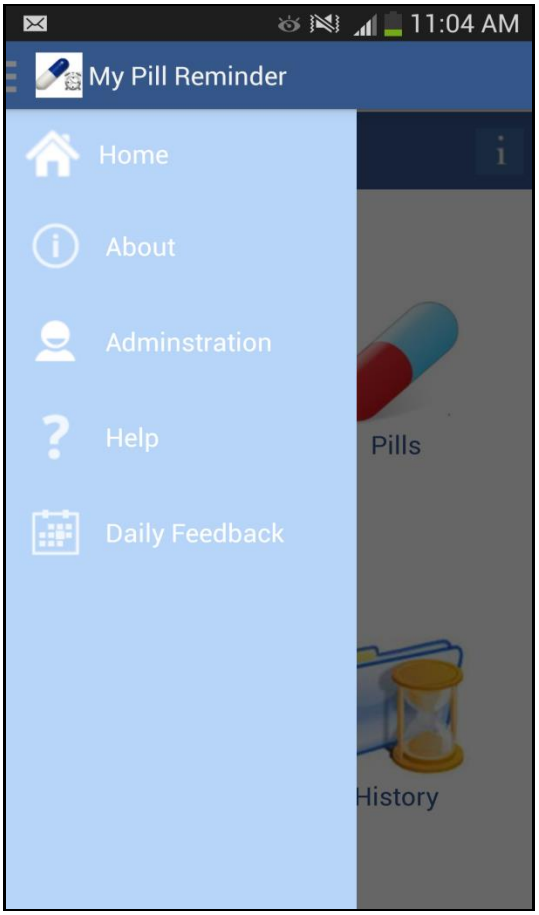

Figure 5.6: Implementation of the navigation drawer

The first design of *My Pill Reminder* was designed to always run in the background. The application's reminders were modified to have a louder sound alert which is capable of grabbing the attention of the user who might not necessarily be close to the mobile phone. The audio alert sound was made louder to draw the user's attention. The audio alert was also associated with vibration to increase the chances of the user's attention being grabbed. The way the reminder pops up was also modified to address the concerns from the pilot field study. In the first design, the reminder popped up as a notification on the Pull-down Notification area. In the second version, in addition to the notification, the reminder also popped up as a dialogue. By having the reminder as a dialogue, it minimized the number of steps required by the patient to confirm taking the pills. Figure 5.7 shows an example of a reminder which popped as a dialogue. Figure 5.7 shows the reminder which prompted the user to confirm consciousness and using the application.

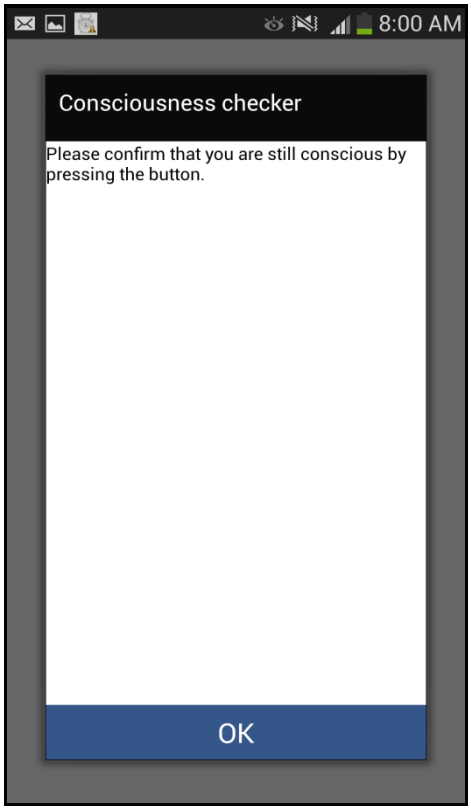

Figure 5.7: Design of the confirming consciousness and using the application

5.6.3 Flow re-design

The application's flow was also modified to make the application more context-aware. Section 5.2 highlighted the additional functional requirements based on the evaluations of the first design of the applications. One of the suggested changes from the participants was of making the application to remind the users to take their medication before leaving their homes. Incorporating location-based reminders resulted in the flow of user tasks changing. Context awareness was incorporated mainly in the dimension of time and of location. The nature of the reminder was modified to be dependent on the time that the user is getting the reminder. As shown by Figure 5.7, the user was now getting reminders and notification to check on their consciousness early in the morning.

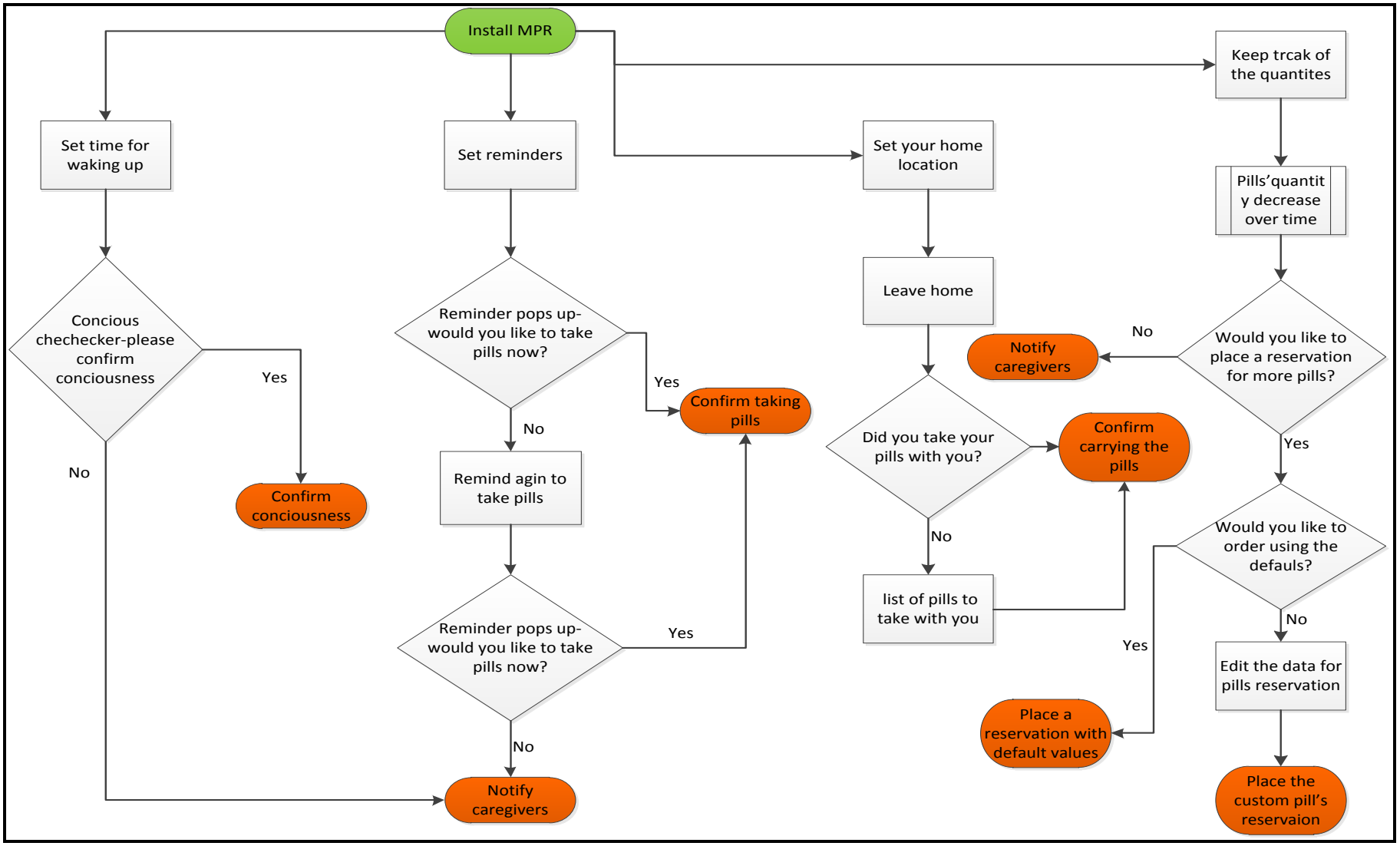

Figure 5.8: The flow of user activities of the redesign

The reminder for a particular dosage was made to be recurring depending on the time the user is meant to take the medication. The application also stored the location of the user's home and it reminded the user to carry their medication once they were about to leave their residential area. This was done so as to prevent the patient leaving home without their medication. Figure 5.8 illustrates the flow of user activities of the redesign of the application. Figure 5.8 shows the instances when the application will remind the users or contact their corresponding caregivers

5.7 Conclusion

Chapter 5 discussed the redesign of some aspects of the *My Pill Reminder* application. Chapter 4 outlined how the users felt about the first design of the application and highlighted the aspects of the application that they were not satisfied with. From the literature review, feedback from evaluations and usability issues, additional requirements were identified and implemented. The suggested changes became the basis of the redesign of the application since the DSR methodology supports iterative development and being user-driven. This chapter was used to answer research question RQ4, and supported the redesign of the application. The redesign catered for the problems identified in literature, the user study and the pilot field study. The chapter served to transform the requirements into a design that serves as a possible solution to the medication compliance problem. The redesign will be used as a tool in the second field study.

As illustrated by Section 1.8, the second version of the application also needs to be evaluated by the actual patients who are taking medication to investigate if there are more usability issues. The need to evaluate and identify the usability issues requires conducting a field study. Chapter 6 looks at the evaluation of the second version of the application.

Chapter 6 Summative Field Study

6.1 Introduction

Chapter 5 proposed the second version of the *My Pill Reminder* application to reinforce medication compliance for patients taking medication. The second version of the application will be used as a tool to investigate if it can support patients taking medication. The second version of the application addressed the concerns pointed out in the previous chapters from literature and from evaluations done. As mentioned in section 1.8.2.2, the application had to be evaluated until it gives satisfactory results before making conclusions. This chapter addressed research question RQ5 from Chapter 1, namely; "*Can the proposed redesign of the model support patients in South Africa taking medication daily to comply with their medication schedules*". Chapter 5 outlines the second field study with the second version of the application.

This chapter discusses the process of the application being evaluated by patients suffering from acute conditions. Chapter 6 looks at the selection and the user profile of the participants, the methodology of the evaluation and the post-evaluation feedback collected. The collected data was then translated into organised data and represented accordingly to draw up conclusions. During the field study, different metrics were measured and used as the basis for determining the extent to which the evaluation objectives of the field study were met.

6.2 Field Study

This section discusses the second field study carried out with the second version of the application.

6.2.1 Objectives of the field study

To examine if the second design of the application was acceptable from the users, a field study was designed. The interaction of the participants with the application and the feedback from participants was the basis of making conclusions. The success of the field study was dependent on how much the objectives of the field study were met. The main objective of this field study was to evaluate if the second version can support medication compliance. The field study also investigated if the changes made to the design had any effect on how the participants felt about the second version of the application relative to the first pilot study.

In order to determine the user experience, the field study should have ways of measuring variables can elucidate how participants feel about the application. The project focused on being easy to learn and to use. This was because the solution targets a large user base including elderly people and those users who might not be necessarily experts in mobile computing. Another important objective was to measure the usefulness of the application based on the feedback after using the application. Other objectives of the usability studies can be listed as follows:

- To determine the extent to which the participants can complete their tasks easily without any assistance;
- To determine the extent to which the application was easy to learn and to use;
- To investigate the level of user experience and utility derived from using the application;
- To identify common problems and usability issues identified by the participants whilst using the application; and
- To identify the changes that should be made based on the results of the field study.

6.2.2 Participant Selection

The participant selection process was mainly similar to the one mentioned in Section 4.3.2. There were some few changes in some of the user characteristics expected. The major change was the prerequisite of having experience with Android phones. The quality of the results of evaluating an artifact within a particular application domain is great when the participants are familiar with the problem and the tools being used in the evaluation (Ellis & Dix, 2006). To increase the quality of the field study, the participants used in the field study had to be familiar with using an Android phone. For a participant to be selected to take part in the field study, the participant had to own their personal Android mobile phone. Using participants that were already using Android eliminated the need to give tutorials of the standard Android patterns. In the pilot study, some of the participants who were not familiar with Android patterns struggled with some of the features grounded on Android design patterns. This participant selection eliminated distortion of results due to issuing an additional phone or feedback influenced inability to operate an Android phone.

Another major change from the participant selection was in the conditions the participants were suffering from. The pilot study had patients that were suffering from two specific chronic

conditions: Hypertension and high cholesterol. The second field study used participants who were suffering from acute conditions and were taking medication over a short period of time that they were prescribed to cure their disease. The participants used in the study were all in the City Of Port Elizabeth during the duration of the field study. The participants were obtained from the Campus Health Centre from Nelson Mandela Metropolitan University. The participants were prescribed to take medication every-day for at least five continuous days. The nurses from the Campus Health Centre motivated the patients to take part in the study since the patients were comfortable with the nurses. The sample size was fifteen. Some of the characteristics of the participants were as follows:

- Age- 18 year and older;
- Conditions- Acute conditions taking medication for at least five consecutive days;
- Attitude toward technology- uses Android mobile phones;
- Familiarity with the medical terminologies and exposure to medication procurement; and
- Location-Port Elizabeth

Figure 6.1 shows the demographics of the participants used during the evaluation of the application. Figure 6.1 indicates that 40% of the participants were male and 60% were female. The gender was almost evenly distributed although the number of female participants slightly outweighed the females. Figure 6.1 also shows that there were two major age groups namely the 18-25 years group and the 26-40 years group. Figure 6.1 illustrates the proportions of the participants for these two types of age groups. The majority of the participants were in the 18-25 years group since most of the participants were students. The 18-25 years group had 67% of the participants whilst the 26-40 years group had 33% of the participants. None of the participants were older than 41 years old. The mobile experience graph shows that 53% were expert mobile users. It was expected that the expert mobile users would be able to complete tasks easily. Figure 6.1 also indicates that 40% had intermediate mobile expertise whilst 7% of the participants were beginners. Figure 6.1 also shows the distribution of the participants' number of doses they took per day. 60% of the participants took medication only once per day while 33% took medication twice per day and 7% took medication three times per day. Since

the participants were suffering from acute conditions, most of their prescriptions did not require them to take a lot of medication unlike chronic diseases patients.

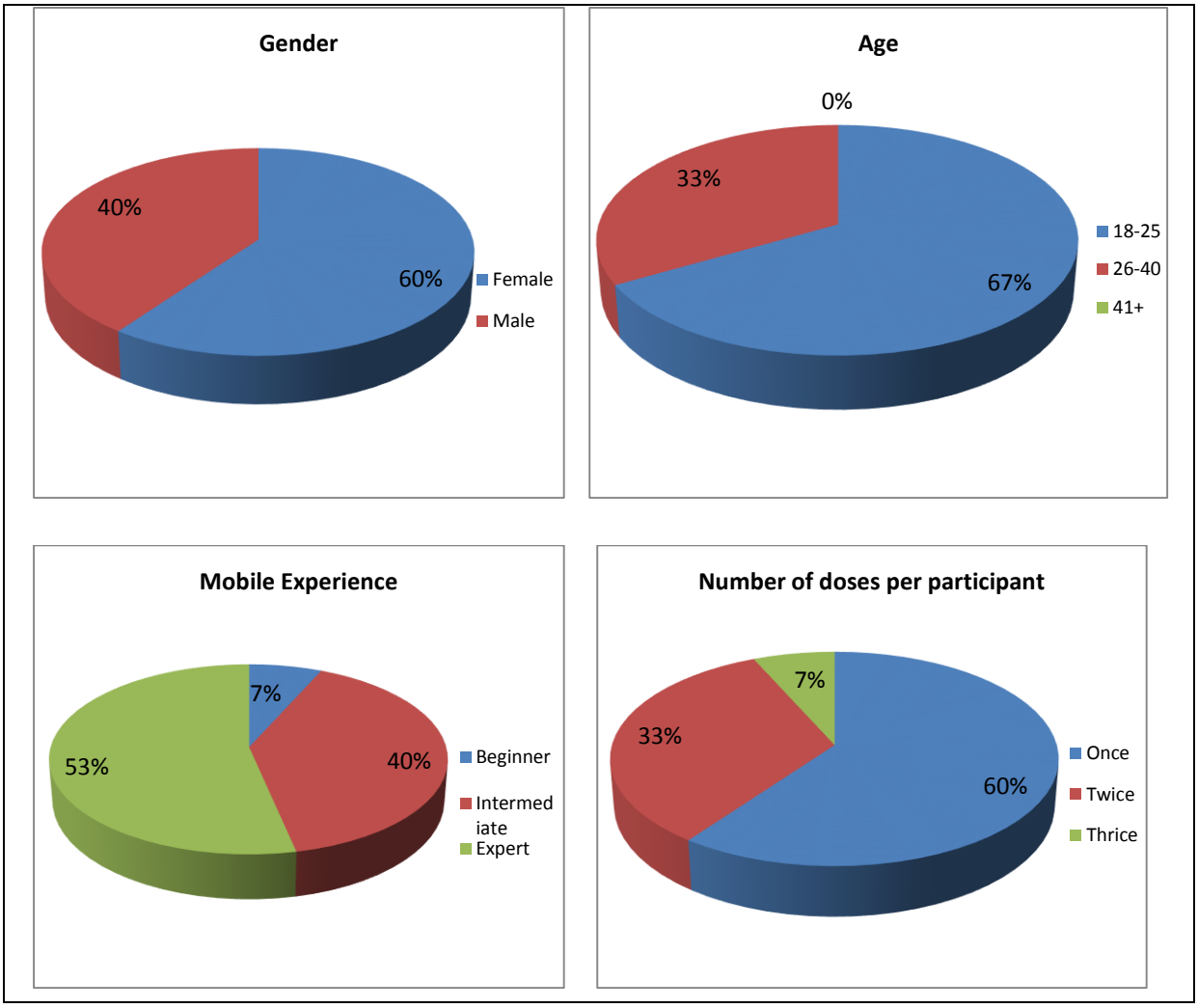

Figure 6.1: Demographics of the participants (n=15)

6.2.3 Metrics

The field study can be used to make conclusion on the performance of the application if the data collected is sufficient to meet all the objectives of the field study. To meet the objectives of the study, ways of measuring some variables that indicate participants' feelings must be measured. These metrics ought to enable drawing up conclusions which are in line with the overall goal of the study.

It was essential for participants to complete the all the tasks during the study. The effectiveness of the application was measured by ability to complete the processes required to confirm taking their medication. Some of the metrics that were measured from the field study were as follows:

- Number of pills taken correctly;
- The number of doses missed;
- The number of participants who used the location-based reminders;
- The number of times the participants confirmed conscious and using the application; and
- The number of times the participants rated the application on a daily basis whilst they were still using it and their corresponding ratings.

At the end of the field study the participants were given a post study questionnaire to complete which made use of a five point Likert scale to ask participants to rate their software on the following areas:

- Aesthetic appeal of the program's user interface;
- Ease of use;
- Ease of learning;
- Consistency of terminology; and
- Appropriateness of terminology.

6.2.4 Method

To measure task success, the author kept track of how each participant was confirming taking their medication. This information was stored on the backend server as well as on the internal phone database. The application only stored the history of how the participant was taking medication for the current week on the phone's memory and the rest on the backend server. Since the field study was carried out for only a period of five days, the participants' history for this study could be obtained from both the phone and from the backend server. The participants were also expected to confirm that they were still conscious and are still using the application every morning. There was a reminder that popped up which requested the participants to confirm that they were still using the application. The participants' confirmations of using the application were also stored at the backend server.

A post-test questionnaire was used to obtain feedback in the form of ratings which were quantified to provide some metrics. The questionnaire made use of a five point Likert scale to capture the user satisfaction ratings. The questionnaire also captured comments from the participants. The comments pointed out what the participants liked most about the application,

what they did not like as well as their general comments. The open ended questions of the questionnaire were used to gather information that was used for qualitative analysis.

In addition to the post study questionnaire (PSSUQ) daily feedback was captured which rated the application based on how the participant felt during that particular day. Getting feedback on a daily basis produced more feedback as compared to just having a single post study feedback. This is because the participants forgot some of the issues and feelings that they were experiencing during the period they were using the application (McGee, 2004). The daily feedback information adapted the After Scenario Questionnaire (ASQ). The ASQ used the ASQ standards questions as follows (Lewis, 2002):

1. *Overall, I am satisfied with the ease of completing the tasks in this scenario;*
2. *Overall, I am satisfied with the amount of time it took to complete the tasks in this scenario; and*
3. *Overall, I am satisfied with the support information (online-line help, messages, documentation) when completing the task.*

The ASQ was built within the application to reduce the amount of steps that the user had to carry out in order to give the ratings. Figure 6.2 shows the design of the daily feedback screen in which the participants gave ratings and additional comments. The participants were reminded by the application to give the feedback using the screen shown by Figure 6.2. The ASQ used a Likert scale of one up to seven and this was implemented by using Android rating stars. There were seven stars and the participants gave the number of stars corresponding to how they felt whilst doing their daily tasks on the application.

Figure 6.2: The design of ASQ for daily feedback

The second version of the application had the functionality of reminding the patient to check if they have taken their pills before they leave home. The field study also had to investigate how the participants feel about this facility. This facility was not enforced within the application and the participant could choose not to set it. The participants were asked three questions after using the application about their experience whilst using this facility during the field study. The three questions that the users were asked were as follows:

1. Did you set the location-based reminders and the corresponding information required?
2. Did you use location-based reminders to remind you to check if you did not forget to carry your medication before leaving home?
3. What is your comment on this location-based reminders facility?

6.2.5 Instruments

The instruments used in the field study were generally similar to the ones used in the pilot field study and discussed in Section 4.3. There were some few changes in the instruments to support the objectives of the field study. The application was installed on the participants' own personal phones and therefore they were not necessarily of the same type. Since the participants were using their own personal mobile phones, it was assumed that they were familiar with using Android phones and hence there was no need to give them an Android tutorial. This field study

also made use of a backend server to keep track of the how the participants were taking their medication. The backend server was also used for loading the medication details on to the phone. The server was also used for keeping track of the daily participant feedback.

Similar to the first field study, the study used the Post-Study System User Questionnaire (PSSUQ). PSSUQ was chosen as an instrument because it provides a comprehensive insight and the overall satisfaction of the users after using the proposed mobile solution (Lewis, 1995). Another reason why PSSUQ was chosen was to be consistent with the data gathered in the pilot study to enable comparing the results of this field study with those in the pilot study.

6.3 Results

Results were tabulated in Microsoft Excel and analysed. The results were analysed to investigate the task completion, compliance level, trends of their behaviour over time learnability, usefulness, satisfaction, application performance and the participants' comments of the application. The data from the server, completed questionnaires and interviews were categorized and analysed qualitatively and quantitatively. The sections that follow will present the results found during the field study.

6.3.1 Quantitative Analysis

This section outlines the analysis of the results quantitatively and illustrates the relevant descriptive statistics together with graphical representations of the results for each of the metrics. The section looks into the results from the questionnaire, ASQ daily feedback and the history stored on the server.

6.3.1.1 ASQ ratings

The results from the daily feedback per participant were gathered and analyzed. This section gives an indication of how the participants felt on a daily basis as they were actually using the application. Figure 6.3 shows the number of times that each participant gave daily feedback on the application. The participants were reminded by the application to rate the application an hour after the last time their take their medication and reminded again at the time they set to be reminded to rate on their preferred settings. Figure 6.3 shows that only one participant managed to rate the application every-day during the period of the evaluation. Also, there was only one participant who did not even rate the application at all using the daily rating facility. The average number of times that the participants gave the daily feedback was that over three days.

One of the reasons why some of the participants did not submit their daily ratings was because at times they would not have mobile data to post the ratings to the backend server. Not having mobile data inhibited internet connection and which also prevented their data from being saved at the server. Another reason was that most of the participants as mentioned in Section 6.3.2 were students, who were usually busy with their studies to rate the application. As shown by Figure 6.3, only three of the participants gave their daily feedback less than three days.

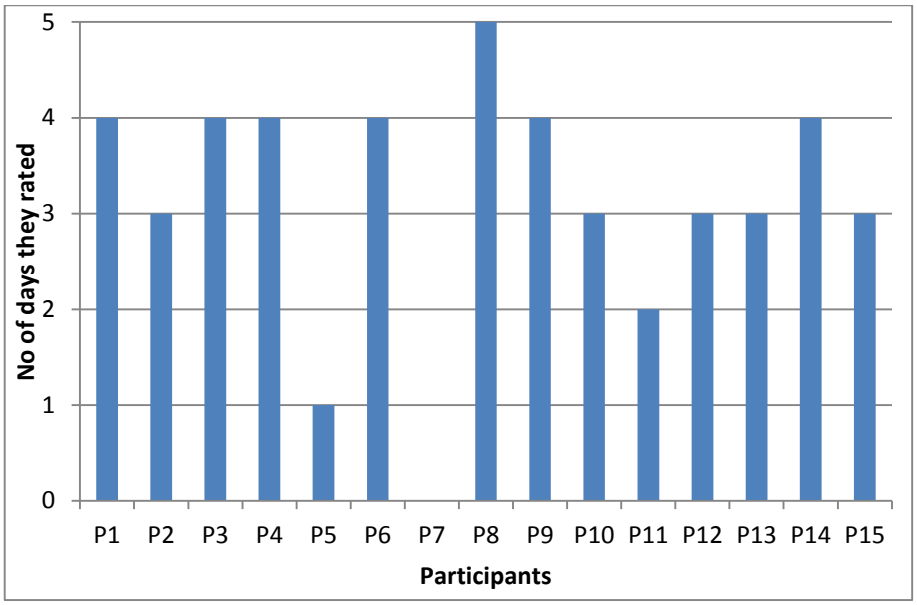

Figure 6.3: Number of days that participants gave a daily feedback (n=15)

The ratings were compiled and collectively analyzed and the results are shown by Figure 6.4. Figure 6.4 shows the descriptive statistics of the daily ASQ ratings per day from the participants whilst using the application. Figure 6.4 shows the mean, the mode and the median ratings for each of the days during the field study. The graph also indicates the error bars for the mean which gives an indication of the confidence interval per day. The confidence interval represents the region an ASQ score would be expected to fall in, if these results can be used as the basis to generalize to a different population. The confidence intervals were small because the range of the ratings per day was not very distributed. The mean ratings were high as shown by the blue bars on the figure. The mean ASQ score was lower than six only on the first day and there after increased slightly everyday as the study progressed. As the participants used the application more, they became more comfortable with using it as shown by the ratings. The mode shows the most common ratings on each of the days of the study had a score of at least six. From the graph, the median was also of a rating of at least six indicating that the rating that the participants assigned was very high. By considering the questions that the participants were

asked in the daily ratings section from Section 6.2.4, it can be deduced that the participants were able to complete their tasks easily and were generally satisfied with the application.

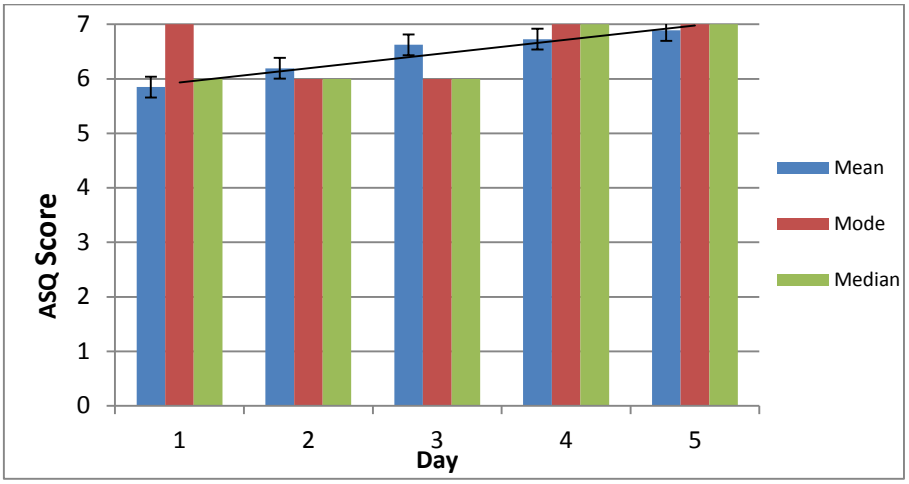

Figure 6.4: Daily ratings from the participants whilst using the application (n=15)

The linear trend-line on Figure 6.4 indicates that the change in the mean scores as the study progresses was almost linearly. However, from the figure the trend-line does not perfectly fit the results of the mean. A further representation of the results for the mean ratings was plotted on a graph to observe the relationship between the mean ratings and the time in days. Figure 6.5 was the result of the further representation and it shows the trend of the daily ratings whilst using the application. Figure 6.5 clearly shows that as the number of days increased, the ratings assigned to the application also increased. Figure 6.5 also shows a dotted linear trend-line to investigate how much the relationship between mean ratings and the number of days was linear. The graph shows the relationship was approximately 94% linear during the five days of the study. It is expected that; as the number of days increases, there would be little or no change to the mean since it would slowly approach the maximum rating. Figure 6.5 indicates that the application was easy to learn and participant managed to complete their expected tasks easily as time increased.

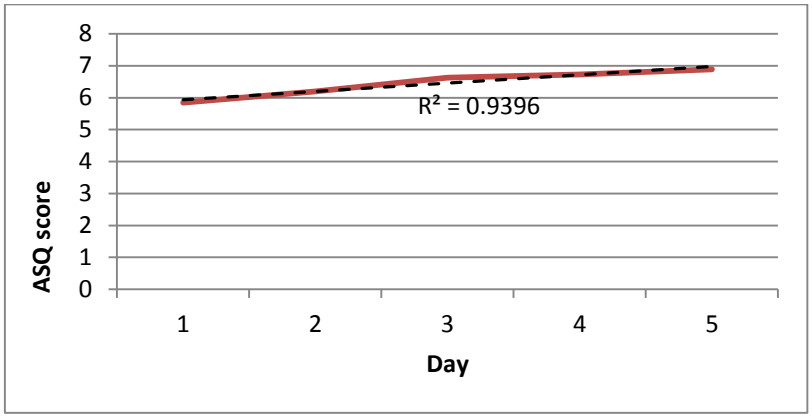

Figure 6.5: Trend of the daily ratings whilst using the application (n=15)

6.3.1.2 Task completion

Task completion was measured for the reminders that popped up on the participant's phone. The participant's response to the reminder was used as the basis for determining task success. The reminder prompted them to confirm taking medication or that they haven't fallen down but are still using the application. A participant was regarded as having completed the reminder task if the participant received a reminder and confirmed taking their medication. The reminder was regarded as not having been completed in the case when the participant does not respond to a reminder. Task completion was used to determine the extent to which the application was effective in reminding the patients to take their medication.

Figure 6.6 shows the daily average number of participants confirming being conscious and using the application. This indicates how much participants were responding to the reminder confirming consciousness and still using the application. As shown in Section 5.6.2, the process of confirming that the participant is conscious was designed to be simple and involved a single step. In the case where the participant did not respond to this reminder, a text message was sent to the caregiver. For the purpose of this field study, the text message of a participant not confirming consciousness was sent to the author. This was because the head nurse from the Campus Health Centre (where the participants were obtained) suggested not using a caregiver during the evaluations because of the type of participants. Figure 6.6 shows that on the first day, 80% of the participants confirmed that they were alert (conscious) to the application and using it. From the second day to the last day of the study, all the participants confirmed their consciousness and used the application by acknowledging receipt of the reminder. A possible reason for not having 100% of the participants confirming on the first day was that the participants might not have been alert to the new form of technology. As they used it more, the

participants got into the habit of using the application. The results from day two to day five showed that the participants used the application more.

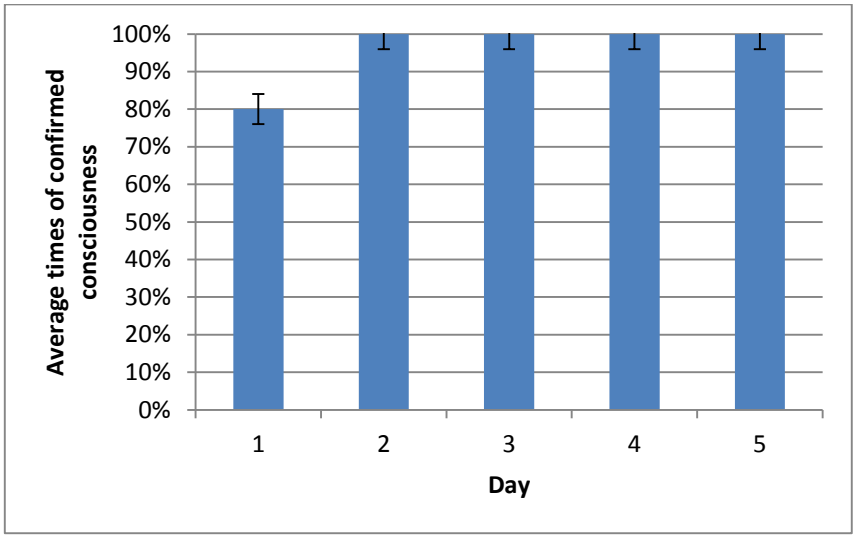

Figure 6.6: Daily average number of participants confirming using the application (n=15)

As mentioned in Chapter 1, one of the aspects which constitutes the focus of the research was being able to remind patients to take their medication at their prescribed times. In the field study, the author set reminders for the patients as prescribed for them. The field study was designed to record the patient conforming to their medication schedules. Figure 6.7 shows the total number of doses missed per participant during the field study. Figure 6.7 shows that for all the participants, the maximum number of doses missed per participant during the entire field study was two. This indicates that the application was able to remind and assist most of the participants to take their medication. Four of the participants confirmed that they did not miss any of the prescribed doses. The fact that most of the participants did not miss their doses was because of the number of times that they were taking their medication per day. Section 6.2.2 illustrated the demographics of the participants. From the demographics it was shown that 60% of the participants were taking their medication only once a day, which reduced the chances of them missing a dose. Only one participant was taking medication three times a day.

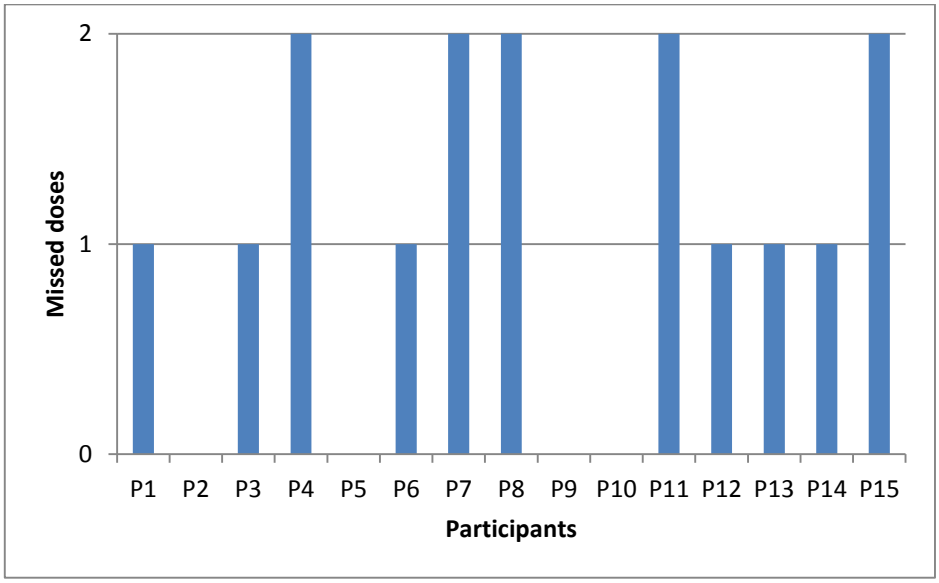

Figure 6.7: Total number of doses missed per participant (n=15)

Figure 6.8 and Figure 6.9 indicate that the participants managed to take their medication as expected and this can be shown by the high values of compliance. The compliance level was high from day two. The application managed to remind successfully most of the participants to take their medication as prescribed. Figure 6.8 shows the daily medication compliance level per dose during the filed study. Medication compliance was measured by the ability to remind and assist the participant to take their medication at the prescribed times. For a participant to be regarded as compliant, they had to confirm taking their medication when they were reminded. Figure 6.8 shows the compliance level for the three major dosage categories: morning, afternoon and evening per day. Figure 6.8 shows that the compliance level was low on the first day in all the three periods and on the last day the compliance level was 100% for all the three periods. One possible reason for a very low compliance level on the first day was that on the first day the participants were still adjusting and embracing new form of technology that they were beginning to use. By the fifth day the participants were used to the application and their compliance level was very high.

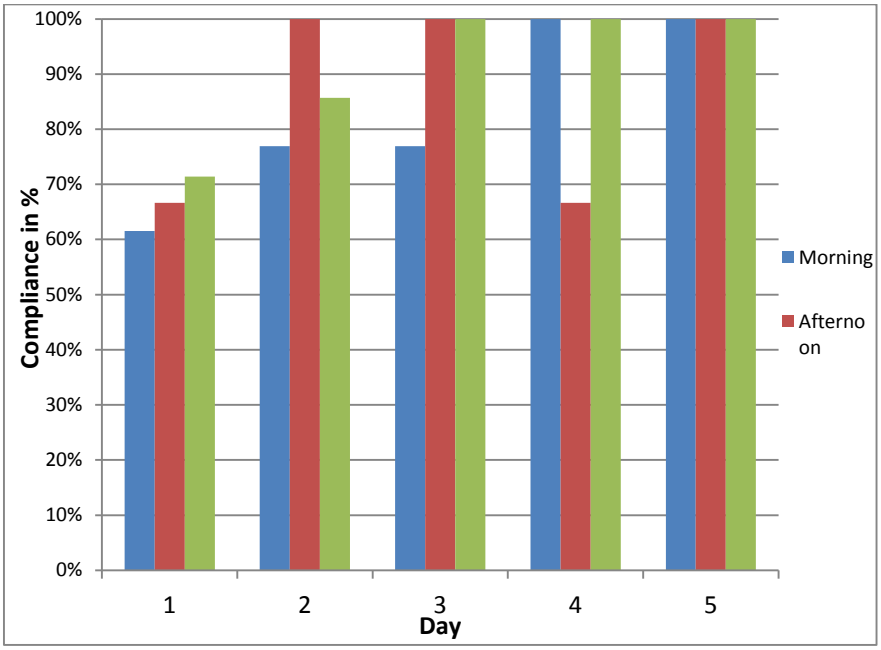

Figure 6.8: Daily medication compliance level per dosage during the filed study (n=15)

Figure 6.8 shows that the compliance level was generally increasing during the field study, on the fourth day there was a significant drop for the afternoon dosage. The huge drop was because there were only three participants who were taking their medication in the afternoon and the effect of one the participants missing their medication dosage resulted in a huge impact on the average. Figure 6.8 shows that the afternoon dosage on day four dropped by 33% because one participant did not take their medication. Compliance level in the evening was generally high because most of the participants were not as busy as in the morning or afternoon. Compliance level in the morning was generally low until the fourth day. Most of the participants were students and in the morning they were busy getting ready to go for their classes which made it relatively easy not to be compliant. As the application became part of the participants' lives, the compliance level increased as shown by Figure 6.8.

Figure 6.9 shows the daily average compliance level and their corresponding confidence interval. The daily average compliance level was the average compliance levels of the morning, afternoon and evening dosages. Just as in Figure 6.8, the average was low on the first day and high on the last day. The average was also generally increasing as the number of days increased with the exception of day four. As mentioned earlier, on day four one of the participants missed their dosage in the afternoon which had a very big and negative impact on the afternoon average.

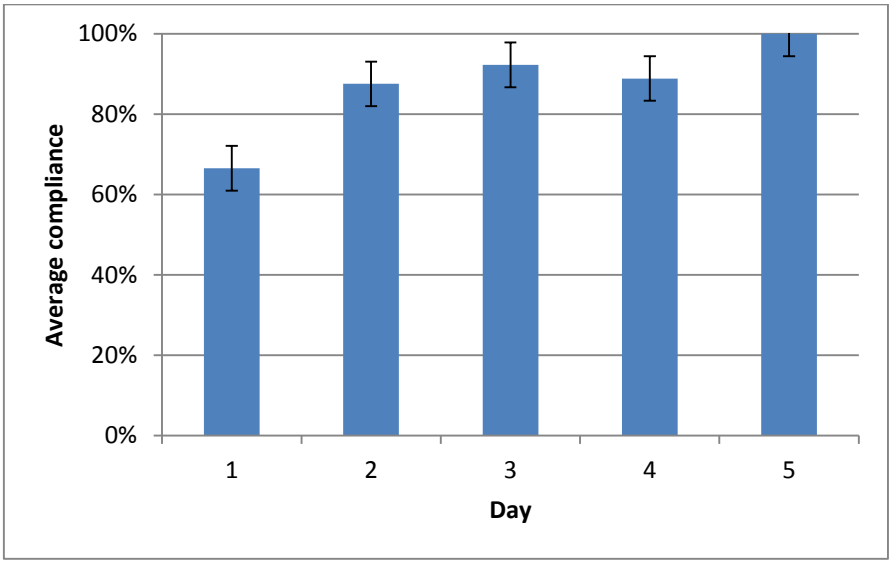

Figure 6.9: Daily average compliance level (n=15)

6.3.1.3 Trends

As the participants were taking their medication, there were some behavioral changes. These changes can be illustrated by some of the trends of their behavior over time. Figure 6.10 shows the trend of the number of missed doses as the number of days increased. Figure 6.10 shows that within the five days of the field study, the number of doses missed was decreasing. This shows that the application was able to assist the participants to comply with taking their medication on time since the number of doses missed decreased. Figure 6.10 also shows a dotted fitted linear trend-line which shows that the decrease was almost linear with linear compatibility of approximately 93%. However, since the missed doses dropped to zero by the last day, it is expected that if the period was to be increased, the graph will be generally constant on the zero mark with sporadic anomalies when participants miss a dose.

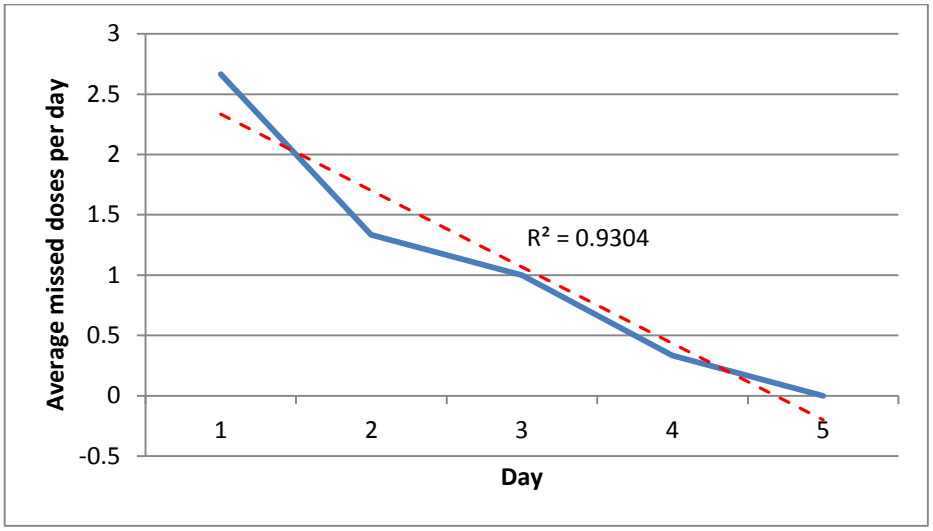

Figure 6.10: Trend of the number of missed doses with days (n=15)

Participants' behavioral change can further be illustrated through the participants' compliance levels during the field study. Figure 6.11 shows the trend of the compliance level over the five days of the field study. Morning and evening began to show increase in the compliance level from the second day. The morning period started with a relatively low compliance level and increased gradually. Evenings started with a high compliance level but by the third day, the compliance level had a maximum value. In the afternoons, the participants' compliance level increased sharply and by the second day it was already on the maximum. Afternoons had a sharp decrease on day four and on day five increased again. Generally, the curves for the morning and evening periods show that there was an increase in the compliance level as the number of days increased. This shows that the application was able to support the patients who were taking their medication to be compliant and thus a positive behavioral change. The afternoon curve shows that even if the application promotes behavioral change and increase in compliance, there is still room for a patient to miss their medication schedule.

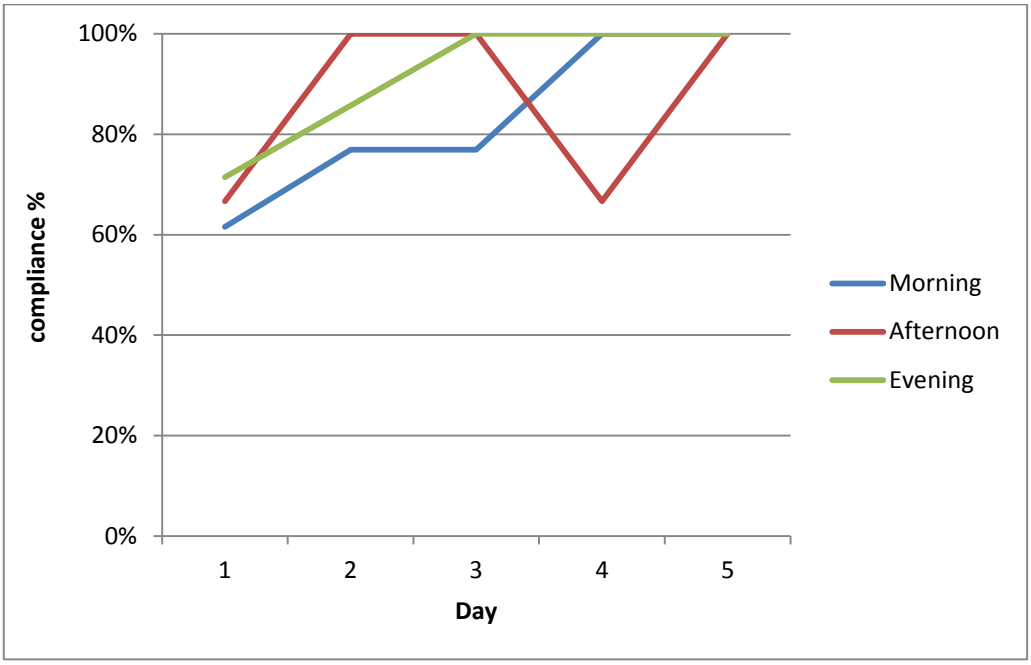

Figure 6.11: Trend of the compliance level over the five days (n=15)

6.3.1.4 PSSUQ results

The field study used the same questionnaire as the one used in the pilot field study as well as the same data collection and analysis methods. The sections that follow outline and discuss the results found during the field study. The results were categorised into learnability, usefulness, satisfaction, and the overall performance of the application. The section also discusses the comments from the open-ended questions of the questionnaire.

6.3.1.4.1 Learnability

This section outlines the results obtained from the first part of the questionnaire; Section A. This section got feedback from the participants regarding how they felt the application was easy to learn and to use. During the field study, the participants were expected to complete the tasks. The section collected the ratings from the participants which focused on how easy the participants learnt to be able to use the application. Figure 6.12 illustrates the rating from the learnability section of the questionnaire from the participants. The descriptive statistics show how the participants rated the application with regards to learnability. The mean for all of the questions had a rating greater than four, which is greater than 80%. This shows that the participants felt that the application was very easy to learn and to use. The mode and median also indicated that the most frequent rating was a rating of five. This indicates how learnable the participants felt the application was. The confidence interval was very small because the

probability of a rating that is far from the mean was low. However, **Question A3** had a lower rating relatively to other questions. Question A3 was as follows:

"I managed to navigate from one screen to another easily".

The low ratings show that participants faced some challenges with navigation. One possible reason is because the application used the navigation drawer which some participants might not have been familiar with.

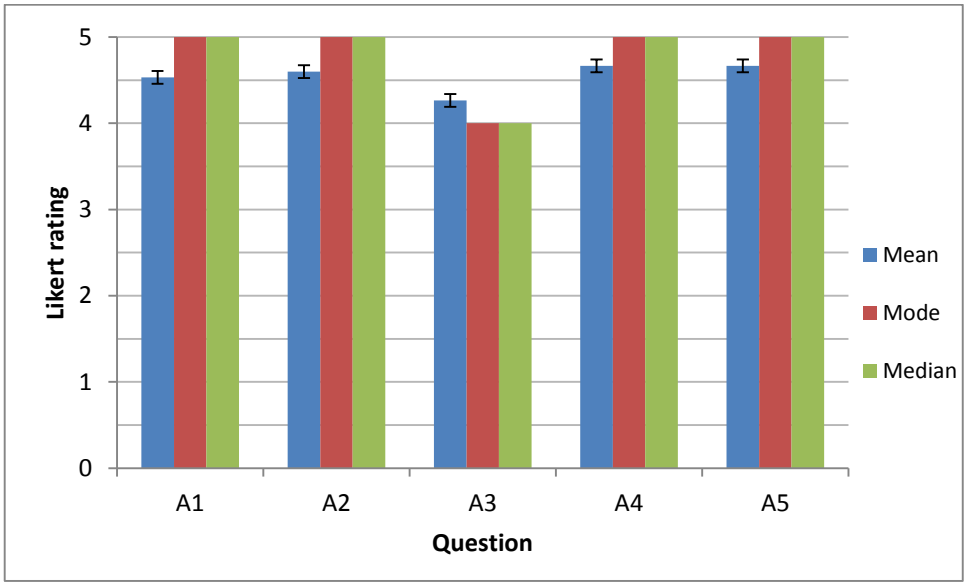

Figure 6.12: Ratings per each question from the learnability section (n=15)

Figure 6.13 shows the average learnability ratings for each participant from section A of the questionnaire. Figure 6.12 show that the participants had different perceptions about ease of use. Figure 6.12 indicates that Participant P6 had a lower rating for the section. The possible factor that might have influenced this participant can be found from the demographics of the participant. The participant was female, one of the few five people who were in the age group of 16-40years, took medication once a day and indicated being a beginner in terms of mobile experience. The participant had lower mobile expertise and this might have been the reason why the participant did not find the application easy to use. Figure 6.12 also shows that the rest of the participants felt the application was easy to learn and to use as shown by ratings greater than 80%. The section of learnability indicated that generally, the participants felt that application was easy to learn and to use.

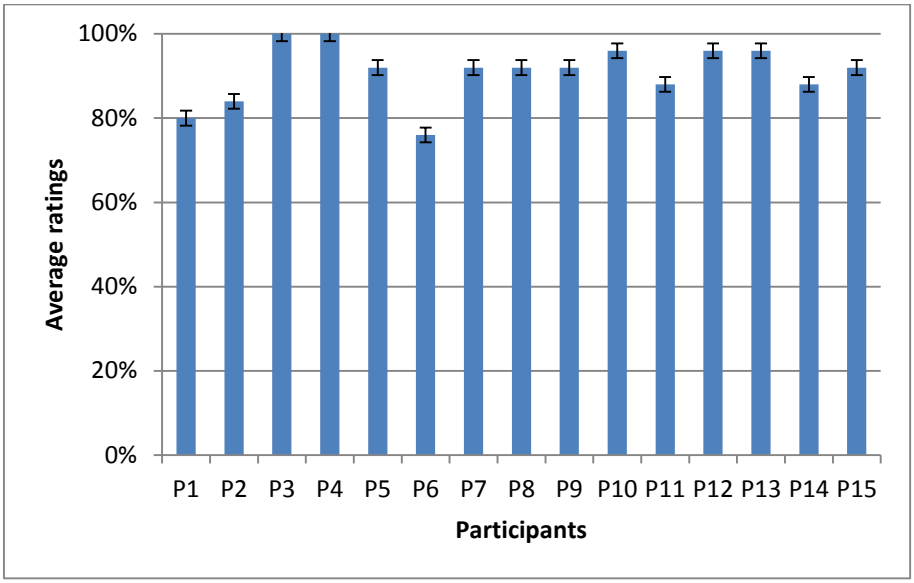

Figure 6.13: Average learnability ratings for each participant (n=15)

6.3.1.4.2 Usefulness

Section B of the questionnaire investigated the extent to which the users felt the application was useful. Usefulness was one of the most important aspects because it showed how much the participants felt the application was useful thereby addressing one of the major objectives of the field study. Figure 6.14 shows ratings per each question from the usefulness section from all the participants. The mean for all of the questions had a rating greater than four which is greater than 80%. The ratings show that the participants felt that the application was useful. The confidence interval was small because standard error was small since most of the ratings were within the same range. The mode indicated that the most probable rating was a five which shows that the participants felt the application was useful. The graph also shows that median was a four which is 80%.

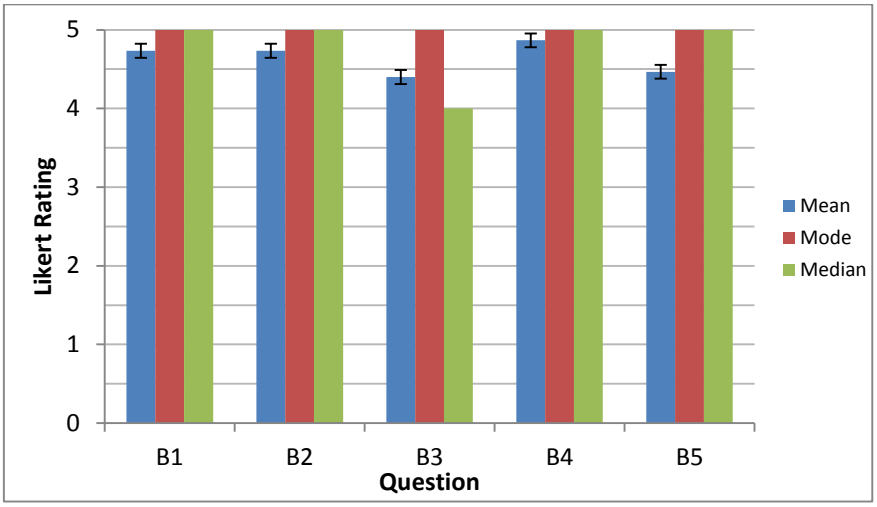

Figure 6.14: Ratings per each question from the usefulness section (n=15)

Figure 6.15 illustrates the average usefulness ratings for each participant in Section B of the questionnaire. Figure 6.15 indicates that the participants regarded the application as useful and this can be shown by the high rating values, all above a rating of 80%. The confidence intervals were small indicating that the ratings were all close to the mean. This verifies that the participants felt that the application was useful.

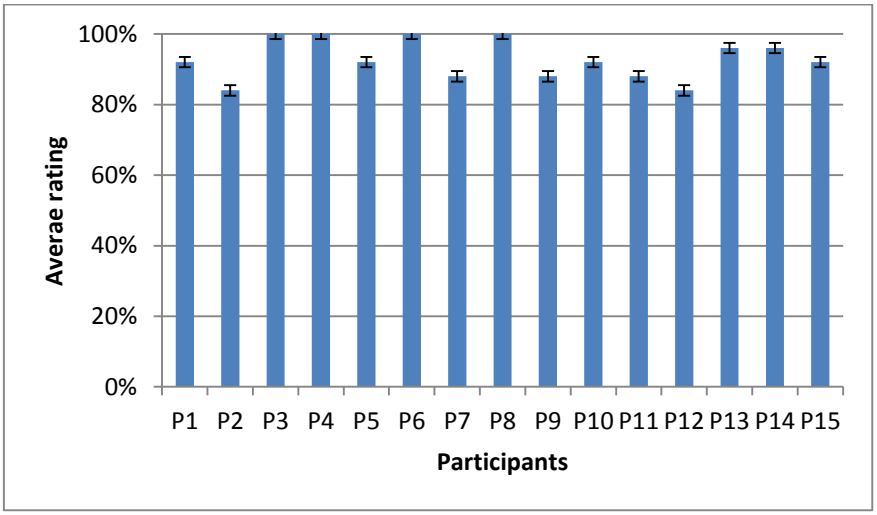

Figure 6.15: Average usefulness ratings for each participant (n=15)

6.3.1.4.3 Satisfaction

The satisfaction section obtained the feedback which shows how much the participants were satisfied by using the application and the utility derived whilst they were using it. The degree to which the participants felt their expectations were met by the application influenced the satisfaction ratings. Figure 6.16 shows the ratings per each question from the satisfaction

section from all the participants. Figure 6.16 shows the average Likert ratings per each question in Section C and shows that the participants were highly satisfied with the application. The ratings were high which shows that the participants were satisfied while using the application. Figure 6.16 also shows that the average ratings of all the questions were greater than four and half and thus at least a rating of 90%. The mean, mode and median also indicated that the most probable rating was five which shows that the participants were highly satisfied. The confidence interval was very small because the ratings that were far from the mean were low. From Figure 6.16, it can be concluded that the feedback from all the questions regarding satisfaction got a positive response.

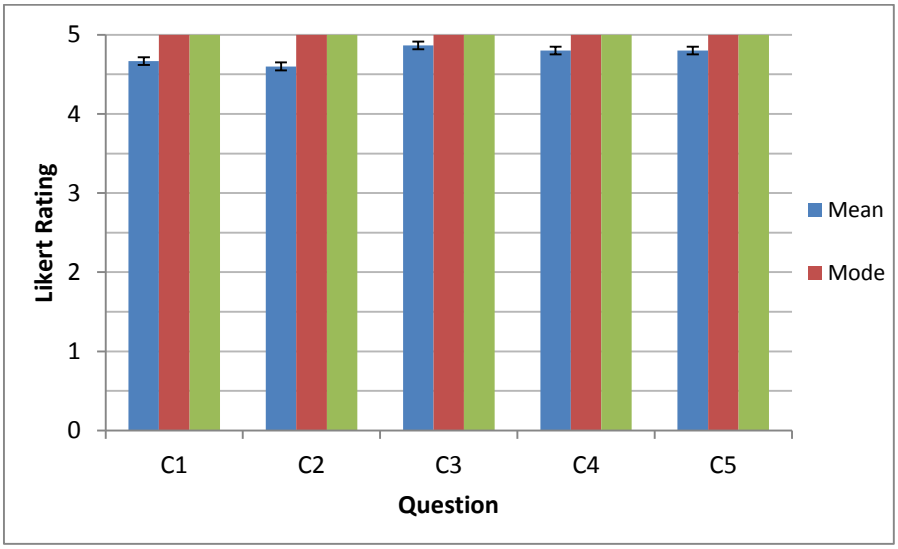

Figure 6.16: Ratings per each question from the satisfaction section (n=15)

Figure 6.17 shows the average satisfaction ratings for each participant for the Satisfaction section. Figure 6.17 shows that the participants were generally satisfied with the application. All the participants had an average rating of the section greater than 80%. Figure 6.17 indicates that there were participants who gave ratings which were closer or equal to the maximum indicating their satisfaction. The results of the section on satisfaction indicated that the participants were satisfied with the application.

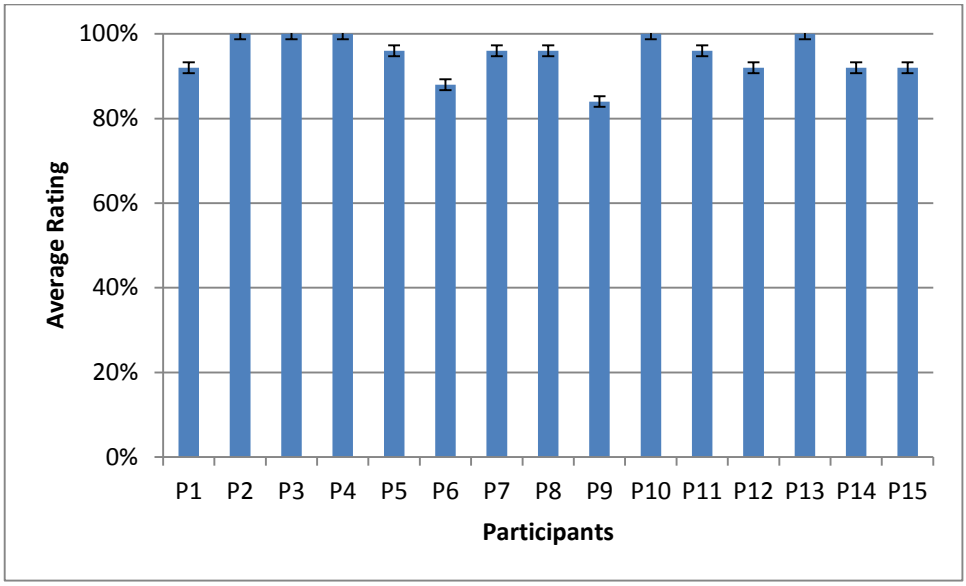

Figure 6.17: Average satisfaction ratings for each participant (n=15)

6.3.1.4.4 Application's performance

The field study also investigated the participants' perception of the performance of the application. Figure 6.18 shows that the average ratings of all the questions were greater than four. The participants gave reviews which show that they felt that the application performed well during the evaluation process. However, Question D4 had a relatively lower rating than the rest. Question D4 was as follows:

"It gave me detailed error messages with possible solutions".

A possible reason why the participants did not rate Question D4 very high is that the participants felt the application did not give possible solutions in the error messages. Some of the error messages gave assistance of what to correct clearly but others did not explicitly point out how to correct the error. From the ratings, one of the participants gave a rating of one for Question D4, which lowered the mean rating.

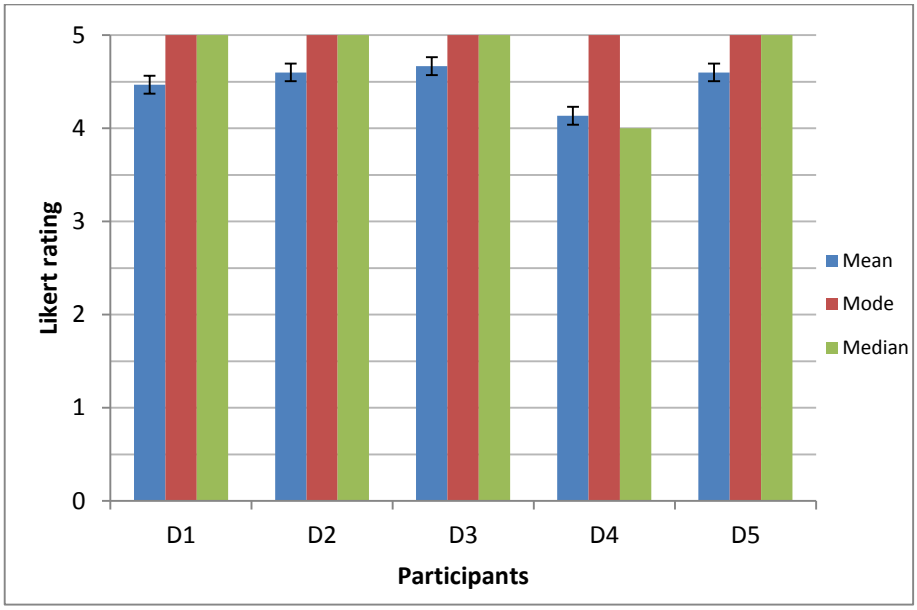

Figure 6.18: Average ratings per each question (n=15)

Figure 6.19 shows the average performance ratings for each participant in the Section D. Figure 6.19 illustrates that the participants were generally satisfied with the application. All the participants had an average rating of the section of at least 80% except for two of the participants. Figure 6.19 indicates that there were two participants who felt that the application did not perform very well. One of the participants who gave an average low rating was Participant P6. As pointed out in Section 6.3.1.4.1, the potential reason for the low rating was because of the lower mobile expertise. The other participant who gave a rating of slightly less than 80% was Participant P12 and the reason was not clear. However, the demographics of Participant P12 were: the participant was female, in the age group of 18-40 years, took medication twice a day and indicated intermediate in terms of mobile experience. Generally, the section of performance indicated that the application performed well.

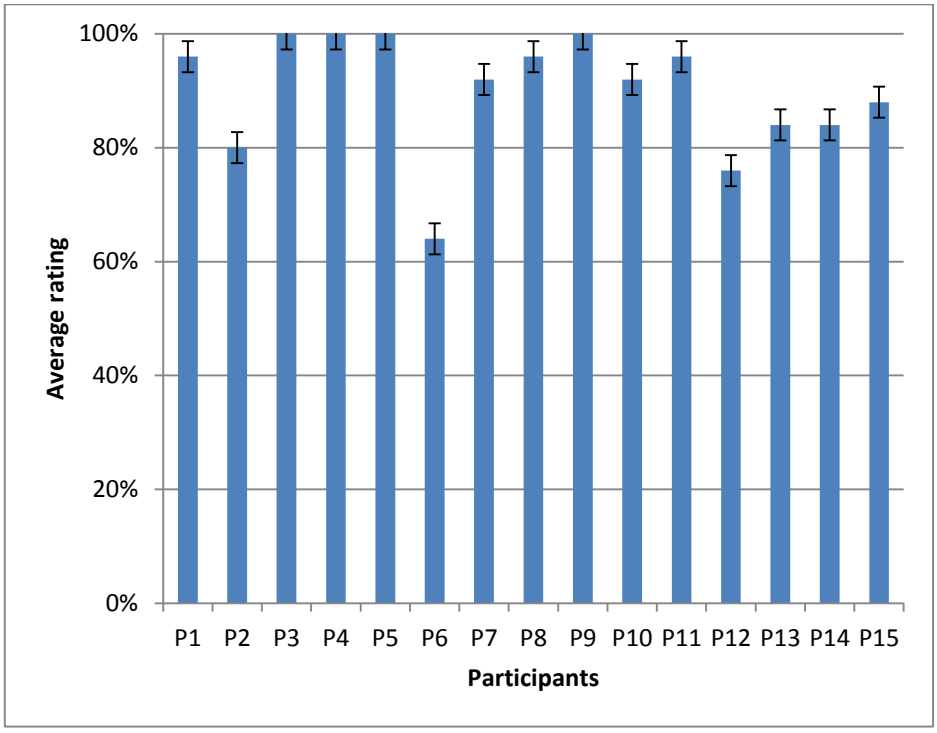

Figure 6.19: Average performance ratings for each participant (n=15)

6.3.2 Qualitative Analysis

The questionnaire comments of the participants of the field studies were recorded and were used for qualitative analysis. By carefully analyzing the comments, several themes were derived and the corresponding frequency of the comments. Just as in Section 4.4.1, a theme was regarded as a category which was chosen by having more than one comment from the participants. All the comments were categorized and assigned into applicable themes depending on the nature of the comment. Similar to the pilot study results analysis, all of the comments that had the same color fell within the same theme. Themes with the highest frequency were identified and further analyzed. The results were tabulated in Tables 6-1 and 6-2. The themes were split into two groups: positive and negative themes. Table 6-1 indicates the summary of the comments that outlined positive aspects of the application. Table 6-2 indicates the summary of the comments that outlined negative aspects of the application.

6.3.2.1 Positive Comments

From Table 6-1 four major positive themes were identified from the comments. These themes are represented in Table 6-1 by the green, yellow, blue and purple colours. These four major colour themes corresponded to ease of use, usefulness, interface quality and being helpful.

Table 6-1: Summary of positive aspects (n=15)

Participant comment	Frequency	Theme
Simple and straight forward	5	Ease of use
Easy to use and convenient	4	Ease of use
The application was user-friendly	4	Ease of use
Easy to access the information	1	Ease of use
Could remember how to use it easily	1	Ease of use
The application was very useful	5	Usefulness
A good application to help me to stay healthy	3	Usefulness
Improves health of people who have busy schedules	1	Usefulness
Increased rate of taking medication	1	Usefulness
The application is clear and reminded me very well	2	Interface quality
Interface had clear icons	1	Interface quality
Information was clear	1	Interface quality
The interface was nice	1	Interface quality
Ability to see the pills you are taking	1	Helpful
I don't have to think how many pills I have to take	1	Helpful
No errors and reliable	1	Reliable
The application gave me an overview of my medication	1	Uncategorized

1. Ease of use–

   The comments from the questionnaire show that the participants felt that the application was easy to use. The ease of use theme is denoted by the green colour in Table 6-1. The participants pointed out that carrying out the tasks on the application was simple and

straight forward which made it easy to use. The participants also pointed out that it was easy to remember how to use the application once they used it. One of the participants pointed that it was very easy to access information they wanted, which made him/her to complete the tasks easily. The comments of this theme confirm that that the application confirmed that the design was simple.

2. Usefulness–

   The comments from the questionnaire show that participants felt that the application was useful and can support them to take their medication. Table 6-1 highlights that the participants felt that mobile application could be useful in supporting them to be compliant to the medication schedules. The usefulness theme is denoted by the yellow colour in Table 6-1. The table shows that the participants felt that the application was very useful to them and assisting them to take their medication on time. One of the participants mentioned that the application can be a tool that improves the health status of people who have busy schedules. Three of the participants mentioned that they feel that by using the application, they can be assisted to stay healthy. Since the participants felt it was useful in supporting them, this theme can be regarded as a positive one.

3. Interface quality-

   The comments from the questionnaire show that participants felt that the application had a nice interface. The interface design made it easy for the participants to interact with the application and use the application effectively to be compliant to their medication schedules. Table 6-1 also highlights that the participants felt that mobile application's visual design was nice which helped them to have a good experience. The interface quality theme is denoted by the blue color in Table 6-1. One of the participants mentioned that the interface had clear icons that they could relate with. Another participant pointed out that the information was clear. Clear representation of information and icons increased the perceived quality of the interface. The comments from the participants made this theme to be categorized as a positive one.

4. Helpful-

   The helpful theme is denoted by the purple color in Table 6-1. The participants felt that the application was able to help to carry out some of the tasks they used to make an effort to remember or execute. One of the application's primary goals was to support patients with the activities they might be having difficulties in carrying out. The

participants mentioned that the application was very helpful in taking their medication making this theme was a positive one. Participants felt the application had potential impact on their medication compliance level. Some of the participants felt that they did not have to think of how many pills they had to take because the application assisted them with that.

6.3.2.2 Negative Comments

Negative comments are outlined in Table 6-2. Table 6-2 shows a summary of negative aspects or the features that the participants did not like. Two themes were identified, which are indicated by the red and black colours in the table. These colour themes corresponded to the notification sound and managing reminders.

1. Notification Sound–

Most of the negative comments were in this theme. The notification sound theme is denoted by the red colour in Table 6-1. The comments from the questionnaire showed that participants felt that the implementation of the application's notification sound did not meet their expectations. The notification sound was responsible for grabbing the participants' attention during the reminding process. Taking into consideration of the feedback from the pilot field study in Section 4.4.1, second version of the application was louder to capture the patient's attention.

Table 6-2 shows that, the participants felt that the notification sound was louder than they would have preferred. A possible reason why the participants felt like the sound was loud can be deduced from the demographics of the participants. Most of the participants were young and preferred to have the reminder to be consistent with their settings on their phone. Participants' comments points out that they could not change the sound. The sound was set to be static to make the study consistent for all the participants to determine the effect of using a loud sound. This was one of the modifications done to the application and this field wanted to investigate the effect of a loud sound. Four comments from three participants mentioned that they did not like the loud sound and the rest were comfortable with a loud sound. A possible solution might be to use a compromise design which has a loud sound but also has an option to change it to use their preferred sound. This theme show that the participants were not reminded satisfactorily and the theme was regarded as negative.

2. Manage Reminders–

Another negative theme pointed out was managing the reminders. From Table 6-2, this theme is represented by the black color. As shown by Table 6-2, there were a total of five comments which mentioned their dissatisfaction with managing the reminders. One of the participants could not cancel the reminder once they set them and another could not cancel the conscious checker. Cancelling a reminder could be done by using the contextual menu which popped up by the long press on the reminder that one needed to cancel. Two participants pointed out that they could not add a reminder. This was implemented by opening the contextual menu using a long press. This theme was regarded as negative because it consisted of comments, which identified those aspects that the participants did not like.

Table 6-2: Summary of negative aspects (n=15)

Participant comment	Frequency	Theme
Could not change the sound	2	Notification Sound
The application had too many loud reminders popping up	2	Notification Sound
Music was loud	1	Notification Sound
Could not cancel reminder	1	Manage Reminder
Could not add reminder	2	Manage Reminder
Could not cancel conscious checker	1	Manage Reminder
The application used my airtime	1	Data

6.3.2.3 Location-based reminders

This section discusses the feedback from the participants about the functionality of using location based reminders. Table 6-3 shows the participants who activated the location-based reminders and their comments.

Table 6-3: Summary of feedback of the location-based reminders (n=15)

Participant	Set	Did you use	Comment	Category
P1	No	No	Not comfortable with the service	Privacy
P2	No	No	Privacy concerns	Privacy
P3	Yes	Yes	Can be useful if I am taking pills for a long period but since I was taking pills for a short time it was easy to remember to take pills with me	
P4	No	No	Did not understand the facility	Technical
P5	No	No	Forgot to set it up	Memory
P6	Yes	No	I didn't need the facility	
P7	No	No	I couldn't not set it up	Technical
P8	Yes	Yes	It helped me but sometimes it reminded many times	
P9	No	No	Forgot to set it up	Memory
P10	No	No	I couldn't not set it up	Technical
P11	No	No	I couldn't not set it up	Technical
P12	No	No	Forgot to set it up	Memory
P13	Yes	No	I did not trust entering my address on the application	Privacy
P14	Yes	Yes	It irritated me since it asked me every time I left home	
P15	No	No	I didn't even understand what it was all about	Technical

The comments were categorized and major categories were identified. The rows highlighted with the yellow color indicate the participants who activated and used the location-based reminders. These participants were only three in total. The participants who used this facility felt that the facility was helpful. This functionality also irritated the participants because they were reminded every time they left home.

The rows marked off in green represent the participants who set the address but did not activate the location based reminders on the settings screen. The rest of the participants did not even activate the feature. Participants did not use this feature mainly due to three reasons; privacy concerns, technical difficulties and memory problems. Three of the participants were not comfortable with the functionality because they did not trust entering their address on the application. Five of the participants did not use the location-based reminders because they could not set them up. Three of the participants did not use the location-based reminders because they forgot about the facility or forgot to set it up. Generally only a few of the participants used this facility with rest of the participants not using it.

6.4 Comparison with pilot study

Section 4.4 outlines the results that were found from the pilot study. The results of the pilot study were analyzed quantitatively and qualitatively. Figure 6.20 shows the comparison of the quantitative results from the questionnaires in the metrics of: learnability, usefulness, and satisfaction and application performance. The results from the two studies could be compared because they used a similar questionnaire. Figure 6.20 shows that for all of the metrics, the second field study had average ratings greater than those of the pilot study. For all the metrics, the second field study had an average of at least 85% which shows that the participants were very happy with the second version of the application. One of the possible reasons was the difference in the nature of the participants used in the studies. The demographics of the two studies are shown in Section 4.3.2 and Section 6.2.2. The second field study had younger participants than the ones in the first field study. Younger participants were more appreciative of technology since they embrace technology more than the elderly (Grund & Westergaard-Nielsen, 2008).

Another factor that made the second field study produce higher results was the nature of the mobile phones used. The participants of the second field study used their own mobile phones and no one was given an additional phone, as was the case for the pilot field study. Participants

who were familiar with Android phones had higher user experiences than those who could not use Android phones. Another possible reason why the ratings in the second field study were higher was because the second field study used a modified version of the application. The second version of the application addressed those aspects that the participants did not like from the first field study. Elimination of the usability issues increased the usability of the application, increasing utility derived while using the application. The results from Figure 6.20 showed that the modifications made to the design of the application had a positive impac. The positive impact is shown by an increase in the ratings from the participants.

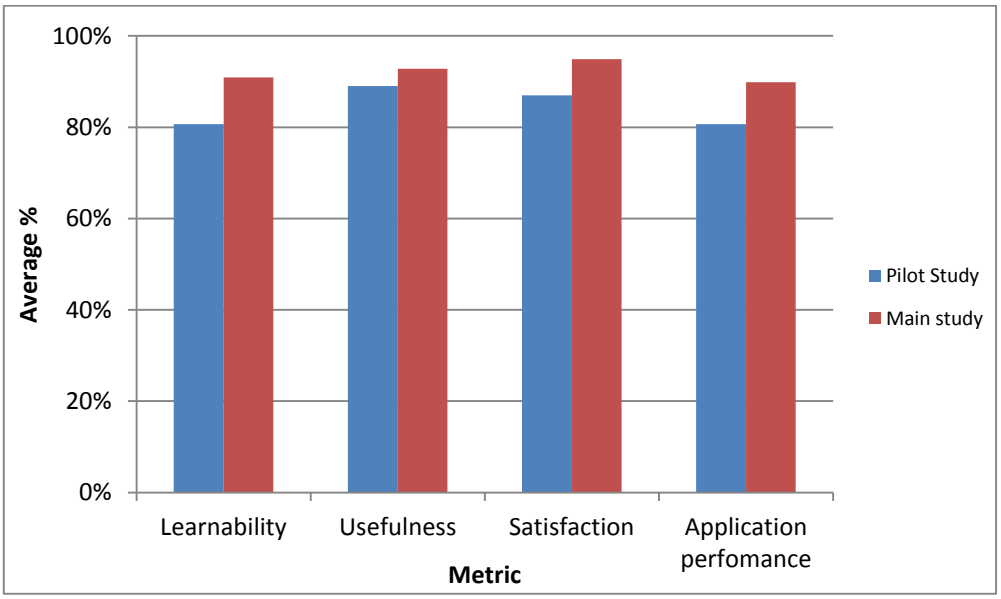

Figure 6.20: Comparison of pilot study (chronic, n=6) and main field study (acute, n=15)

6.5 Implication

The field study illustrated that the participants were satisfied by the second version of the application. The participants were satisfied by the changes that were made to the second version of the application and thus most of the features were satisfactory. As shown from the results, there were areas that the participants were not fully satisfied with. Such areas might require modifications to improve the performance of the application. An area which had a number of errors or difficulties in execution was regarded as a usability issue. The results illustrated the aspects that the participants would prefer to have improved. Some of the areas the participants highlighted that they were not fully satisfied with are discussed in the subsections that follow.

6.5.1 Notification sound-

The participants felt that the application's notification sound did not meet their expectations. The notification sound was an issue because the participants felt that the notification sound was louder than they would have preferred. Also the participants could not change the sound. These issues imply that there is room for improvement in the design of the application. One way would be to change the design to support a loud sound, (possibly as the default) but also provide a facility which permits the patients to change it to use the one of their preferred sounds.

6.5.2 Management of reminder

The participants also felt that the application's management of the reminders was not satisfactory. The field study showed that the participants were not satisfied by their inability to cancel the reminders once they set them. Other participants could not cancel the consciousness checker reminders. Participants also struggled to add a reminder using the contextual menus triggered by long presses. A possible way of improving this functionality would be to eliminate contextual menus. Long presses can be replaced by using an icon to denote additional options that can be opened by tapping on the icon. Having such icons will increase the awareness of the availability of additional options unlike use of a long press, which does not offer any affordance.

6.5.3 Location-based reminders

Section 6.3.2.3 showed that most of the participants did not use the location-based reminders. Most of the participants did not activate or use the location-based reminders due to three reasons: privacy concerns, technical difficulties and memory problems. A way that could increase the possibility of the patients using this facility would be to automate activation of this facility. This will eliminate the effort of entering the required information to set the facility. Automation can be implemented by first asking for permission from the user whilst installing the application. Granting permission will allow the application to use artificial intelligence to determine and set their home location without asking the user. This feature will eliminate technical difficulties and memory problems. Resolving privacy concerns would need further research to obtain ways of dealing with such obstacles.

6.6 Conclusion

This chapter discussed the flow of the field study of the application that was designed in Chapters 4 and 5. This chapter addressed the evaluation phase of the DSR method by using a field study. The chapter outlined how the field study was used for investigating the degree to which the *My Pill Reminder* application could support medication compliance for patients suffering from acute diseases. The results of the field study showed that the application was successful in reminding the participants to take their pills and encouraging medication compliance as shown by the higher values for the participants' compliance level. The chapter also supported that the application can be used to positively change the patient's behavior of taking their medication as the patient uses the application more frequently.

The chapter also illustrated that the design changes made to the application mainly from the feedback from the pilot field study had a positive impact on the performance and user acceptance of the application. The participants gave more positive ratings and identified very few usability issues with the application which implies that there was no need to make changes and carry out a third field study. The task success was very high, which shows that the application was usable and easy to learn and use and enabled participants to finish their tasks. The results also indicated that the participants were highly satisfied with the application. The results of this chapter are followed by Chapter 5, which focuses on concluding how much the research was able to meet its objectives.

Chapter 7 Conclusions

7.1 Introduction

Medication compliance is useful for improving or maintaining the health status of a patient. The research investigated if *My Pill Reminder* could be used as a tool to support patients taking medication. Chapter 1 to 6 discussed the activities that were involved during this research. This chapter and concludes the research project and clearly outlines the successes and failures involved during the course of this research. Chapter 7 addresses the research question RQ6; "*What are the contributions and suggestions for future work resulting from this research*?"

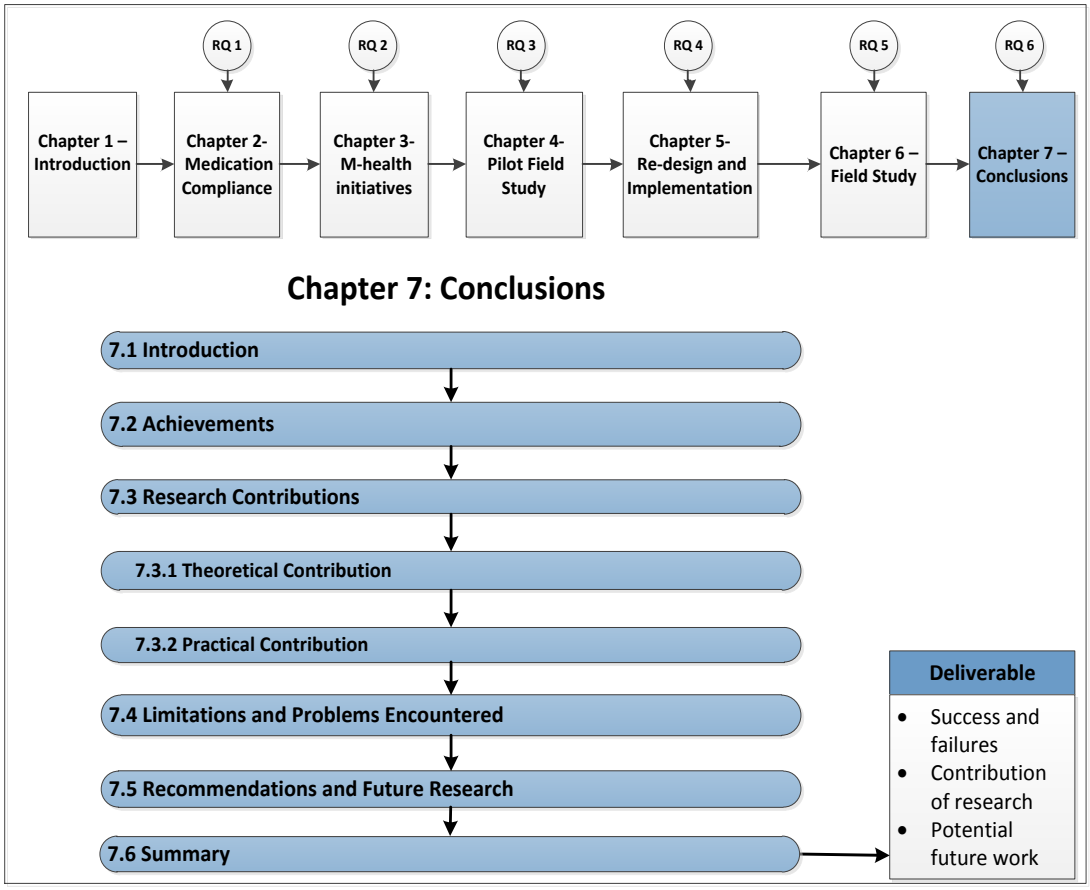

Figure 7.1: The chapter structure of the conclusions chapter

Chapter 1 outlined the problem that the research aimed to solve. The major objective was to investigate how the *My Pill Reminder* application can be redesigned to effectively support medication compliance. Chapters 1 to 6 outlined the process of solving the medication compliance problem. This chapter provides a review and conclusion of the research. Chapter 7 identifies the achievements made and challenges faced based during the research. This chapter

also outlines the problems faced and how they were dealt with. The structure of the chapter can be illustrated by Figure 7.1. Figure 7.1 shows the outline of the chapter, its deliverables and the relationships between the previous chapters and the research questions.

7.2 Achievements

The success of the project can be determined by analysing how much the project met its objectives. The main objective of the project was to investigate if a mobile health application can be used to support medication compliance for patients taking their medication. The achievements of the research were determined by the how much the research met the research objectives. The objectives of this research include the following:

RO.1. Identifying the current problems with medication compliance for patients suffering from chronic and acute diseases and how medication compliance is currently being enforced.

RO.2. Conducting literature study to review m-health approaches that have been used in disease management for medication compliance.

RO.3. Conducting a pilot field study to evaluate the first version of the *My Pill Reminder* application to find usability issues and identify additional requirements.

RO.4. Re-designing and developing a modified version of the *My Pill Reminder* application based on the user feedback and additional requirements.

RO.5. Conducting a field study to investigate the effect of using the *My Pill Reminder* application on medication compliance for patients taking daily medication.

RO.6. Analysing the results of the research to identify the contributions and suggestions for future work resulting from the research.

The first objective of the research was addressed by carrying out a literature review. The findings of the literature review done to address the first research objective were outlined in Chapter 2. Chapter 2 discussed the key concepts in chronic diseases and acute diseases, how they are currently being managed and the problems associated with them. Chapter 2 focused on medication compliance and issues surrounding medication compliance. The research was successful in outlining the problems and challenges faced by patients in sticking to their medication schedule and some of the barriers to self-care.

The second objective of the research focused on reviewing m-health approaches that have been used for medication compliance. The research used literature review to addressing the second

objective and the results of the literature review were recorded in Chapter 3. Chapter 3 reviewed the issues surrounding the field of m-health and how mobile phones can be used to provide solutions in the health domain. To address the second objective, the research summarised the strengths and weaknesses of existing approaches that have been used in the field of m-health in Section 3.5. Chapter 3 also presented an overview of the m-health initiatives that have been implemented in developing countries and their strengths and shortcomings. Chapter 3 also identified the m-health areas that are lacking sufficient research.

The third research objective focused on identifying the usability issues with the first version of the application and identifying additional requirements. The pilot field study was conducted and the results of the study were recorded in Chapter 4. Section 4.4 presented the results of the pilot field study and also outlined the usability issues and identified some additional requirements.

The research addressed the fourth objective which focused on the process of redesigning the application based on the user feedback and additional requirements. The redesigning process was discussed in Chapter 5. The application was modified to investigate how much it could support medication compliance. The deliverable of the addressing RO.4 was the second version of the application.

The research project carried out the second field study using the second design of the application to address the fifth research objective. The results of the second field study were illustrated in Chapter 6. The field study analysed the results and discussed them and made some important observations. Chapter 6 also outlined the users' perceptions towards the second version of *My Pill Reminder*. Section 6.3 shows that the research was capable of answering the fifth research objective.

7.3 Contributions

The contribution of the research can be divided into the theoretical and practical contributions. The theoretical contributions outlined ways that the research contributed to the body of knowledge through the findings of the literature review. The practical contributions point out how the artefact produced in the research was capable of supporting medication compliance.

7.3.1 Theoretical Contributions

This section outlines the research's contribution through literature study. The research was able to clearly identify that there is a problem with medication compliance which needs to be addressed. The research was able to outline the issues surrounding medication compliance and how to overcome these problems. The research pointed out the problems and challenges faced by patients in sticking to their medication schedule and some of the barriers to self-care. The barriers outlined some of the obstacles that have to be overcome for an m-health initiative to be accepted by people in South Africa.

The research contributed an analysis of some of m-health approaches that have been used for medication compliance. Section 3.4.4 gives a summary of the strengths and shortcomings of m-health initiatives that have been implemented in developing countries. The analysis is important because little research has been done in this field. Since South Africa is a developing country of the BRICS group, it can learn from other countries that are in BRICS and apply some of the tested practices. The research presented an overview of some of the initiatives in the m-health field to improve the quality of lives of the people. The research also presented the issues surrounding the field of m-health and how mobile phones have been used to present solutions in the health domain. The research project summarised the strengths and weaknesses of existing approaches that have been used in the field of m-health in Section 3.5. The strengths and weaknesses contributed a strong basis for designing solutions to the medication compliance problem.

7.3.2 Practical Contributions

The research was successful in designing a modified version of the *My Pill Reminder* application based on theory and feedback from the patients. Chapter 5 outlines how the application was designed to support medication compliance. The application managed to meet the expected requirements and perform the functionality expected of it. Thus, the research contributed a tool that can be used to support medication compliance for patients taking daily medication.

The research also contributed the results of the two field studies which discussed the participants' perception towards the artifact produced in this research. The field studies indicated how the users can behave whilst using a mobile solution to support medication compliance in South Africa. Chapter 4 and 6 the two versions of the application supported

medication compliance for patients suffering from chronic and acute diseases respectively. The results of the field study showed that such an application can be successful in supporting the participants shown by the higher values of their compliance level. The research also showed that *My Pill Reminder* can positively change the patients' medication compliance. The results of the field studies presented level of success of a mobile solution to the medication compliance problem in South Africa.

7.4 Limitations and Problems Encountered

There were a number of challenges faced during the course of the research. Some of the challenges had a negative impact on the quality of the project and slowed down the project's progress. One of the limitations of the project was obtaining suitable participants. Participants played an important role in the research project because they were the ones who gave the feedback. Finding participants was difficult for both field studies, which delayed the author in carrying out some of the activities of the research. The participants had to meet all the criteria in Section 4.3.2 and 6.2.2 which made finding participants difficult. Difficulties in getting participants resulted in having smaller sample sizes than the author would have preferred (six chronic patients and fifteen acute patients). Having few participants reduced the quality of the results.

One of the problems that the research faced was in the mobile phones used for the field studies. In the pilot field study, most of the participants did not have Android phones which resulted in the participants being issued mobile phones. Some of the participants were not familiar with operating Android phones and this resulted in low satisfaction levels. The research had limited number of mobile phones assigned to it which also resulted in a long pilot field study. The second field study used participants who owned their own mobile phones. The application had to be designed to be compatible with different types of Android phones. Running the application on mobile phones with different size and processing speed produced different user experience.

Another limitation of the research was the inability to measure if the patients actually took the medication. The research relied on the patients' honesty with regards to taking their medication. Confirming taking the medication within the application was used an indication of the patient taking the medication.

7.5 Future Research

The field of using ubiquitous computing to support medication compliance has the potential to increase in South Africa. An application like *My Pill Reminder* can be expanded to use other technologies which are typically found around the patients to monitor other aspects of the patients' welfare. The application can also be extended to provide real time information about the patient's behaviour, activities and health status. Ubiquitous computing can be extended to incorporate the concepts of ambient technology and internet of things. This creates the potential of designing more efficient solutions which can be instrumental in improving the quality of life in South Africa by supporting Ambient Assisted Living (AAL). AAL services provide intelligent and context aware assistance for people in their home environment. Through AAL, there is potential for even allowing the user to use their natural actions to execute tasks like having speech interaction and facial recognition.

Another potential area for future research would be to carry out field studies over a longer period of time. These studies will give an indication of how usable the application would be in the lives of the patients over a longer period of time. This research carried out field studies over a period of a maximum of five days. Within the five days, some of the participants behaved based on their excitement of using new technology. However, to get better feedback, the field studies should have a longer duration. Having longer field studies can determine if the patients will be irritated or not by using the application over a long time.

Even though the application investigated the effect of using the application to remind the patient to take their medication, there was no way to actually measure if the patients took the medication. There is potential of researching cost-effective ways of eliminating relying on the patients' honesty regarding taking pills. This can be achieved by using equipment which can use Bluetooth to connect to the application and measure if the user actually takes the pills or not. Having such an extension will make the application rely on the equipment rather than on the user. Therefore, there is potential to research this field to use other forms of technology to improve *My Pill Reminder*.

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List of Appendices

Appendix 1: DSR

Design Science Research Guidelines (Esearch, Hevner, March, Park, & Ram, 2004)

Table 1. Design-Science Research Guidelines

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

APPENDIX 2: PSSUQ

***My Pill Reminder* Questionnaire**

1. Biographical Information

Gender: Male ☐ Female ☐

Age: 18-25 years ☐ 26-40 years ☐ 41-65 years ☐ +65years ☐

Marital Status: Single ☐ Married ☐ Other ☐

Mobile Experience: None ☐ Beginner ☐ Intermediate ☐ Expert ☐

2. Satisfaction Feedback

Instructions:

- Please mark (**X**) the number which indicates the extent to which you agree with the statement based on your experience with the application.
- **Scale:** **STRONGLY DISAGREE** 1 2 3 4 5 **STRONGLY AGREE**

	Scale					
A. LEARNABILITY	**1**	**2**	**3**	**4**	**5**	**N/A**
1. The application was easy to learn.						
2. Preforming the tasks was easy and straight forward						
3. I managed to navigate from one screen to another easily.						
4. I can easily remember how to use the application.						
5. The application was easy to use.						
B. USEFULNESS	**1**	**2**	**3**	**4**	**5**	**N/A**
6. I think the application is useful.						
7. It gives me more control over taking my pills						
8. It makes me contact my caregivers easily						

9. It helps me be more effective in managing my medication						
10. The application does everything I would expect it to do.						
C. SATISFACTION	**1**	**2**	**3**	**4**	**5**	**N/A**
11. I felt comfortable using this application.						
12. The interface of this application was pleasant.						
13. I would like to have this application on my phone						
14. Overall, I am satisfied with this application.						
15. I will recommend my friends to use this application.						
D. OVERALL PERFORMANCE	**1**	**2**	**3**	**4**	**5**	**N/A**
16. The information provided for the application was easy to understand.						
17. The organization of information on the application screens was clear.						
18. It was easy to navigate from one screen to another						
19. It gave me detailed error messages with possible solutions						
20. The information was clearly visible on the screen						

General

1. **Please list the aspects you liked most about this application**

_____

_____

_____

2. Please list the aspects you liked least about this application

3. General Comments

APPENDIX 3: Informed Consent Form

NELSON MANDELA METROPOLITAN UNIVERSITY

INFORMATION AND INFORMED CONSENT FORM

RESEARCHER'S DETAILS	
Title of the research project	**Using a Mobile Pill Reminder to support Chronic Disease Management in South Africa**
Reference number	
Principal investigator	**Cainos Mukandatsama**
Contact telephone number (private numbers not advisable)	**041 504 2323**

A. DECLARATION BY OR ON BEHALF OF THE PARTICIPANT		Initial
I, the participant and the undersigned	**(full names)**	

A.1. HEREBY CONFIRM AS FOLLOW		Initial
I, the participant was invited to participate in the above-mentioned research project		
that is being undertaken by	**Cainos Mukandatsama**	
from	**Department of Computing Sciences**	
Of the nelson Mandela Metropolitan University		

A.2 THE FOLLOWING ASPECTS HAVE BEEN EXPLAINED TO ME, THE PARTICIPANT			Initial
	Aim	The investigators are studying the impact of using a mobile health application to help chronic disease management in South Africa The information will be used to/for research purposes	
	Procedures	I understand that I am required to use a mobile application to remind me to take my prescribed medication at the prescribed times. In addition, there may be an interview at the end of the study.	
	Risks	I understand that I should not only rely on the application to be reminded, but use it a secondary reminding mechanism	
	Confidentiality	My identity will not be revealed in any discussion, description or scientific publications by the investigators	

	Access to findings	Any new information or benefit that develops during the course of the study will be shared as follows:			
	Voluntary participation / refusal / discontinuation	My participation is voluntary	YES	NO	
		My decision whether or not to participate will in no way affect my present or future career/employment/lifestyle	TRUE	FALSE	

	No pressure was exerted on me to consent to participate and I understand that I may withdraw at any stage without penalisation	

	Participation in this study will not result in any additional cost to myself	

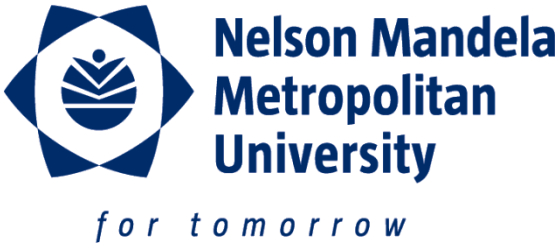
I HEREBY VOLUNTARILY CONSENT TO PARTICIPATE IN THE ABOVE-MENTIONED PROJECT:	
Signed/confirmed at on 20	
Signature	Signature of the witness:
	Full name of witness:

B. STATEMENT BY OR ON BEHALF OF INVESTIGATOR (S)

	I, (name of interviewer)			declare that:					
1.	I have explained the information given in this document to			(name of patient/participant)					
	And / or his / her representative			(name of representative)					
2	He / She was encouraged and given ample time to ask me any questions;								
3	This conversation was conducted in	**Afrikaans**		**English**		**Xhosa**		**Other**	
	and no translator was used OR this conversation was translated into								
	(language)		by	(name of translator)					
4.	I have detached section D and handed it to the participant			Yes		No			

Signed /confirmed at	on	20
Signature of the interviewer	Signature of witness:	
	Full name of witness:	

APPENDIX 4:



Faculty RTI Committee (**Faculty of Science)**
Tel: +27 (0) 41 5042268
E-mail: lynette.roodt@nmmu.ac.za

Ref: H2013-SCI-CSS-019

Contact person: Mrs L Roodt

Date: 18 June 2013

Mr C Mukandatsama
c/o Prof J Wesson
Computing Science
North Campus
NMMU
Port Elizabeth
6001

Dear Mr C Mukandatsama

TITLE OF PROJECT: USING A MOBILE PILL REMINDER TO SUPPORT CHRONIC DISEASES MANAGEMENT IN SOUTH AFRICA

Your above-entitled application was considered and approved by the Sub-Committee for Ethics in the Faculty of Science on 8 May 2013.

The Ethics clearance reference number is **H2013-SCI-CSS-019** and is valid for three years. Please inform the Committee, via your faculty officer, if any changes (particularly in the methodology) occur during this time.

An annual affirmation to the effect that the protocols in use are still those, for which approval was granted, will be required from you. You will be reminded timeously of this responsibility, and will receive the necessary documentation well in advance of any deadline.

We wish you well with the project. Please inform your co-investigators of the outcome, and convey our best wishes.

Yours sincerely

Lynette Roodt
Manager: Faculty Administrator
Faculty of Science