Medication Adherence Reminder (MAR): A Comparison of Persuasive Techniques to Promote Medication Adherence

by

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DEDICATION PAGE

I dedicate my dissertation work to my Family.

To my country, Saudi Arabia, who believed in me and sponsored my studies.

To Dalhousie University and my supervisors, classmates, and every person wishes me success.

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ABSTRACT

This thesis investigates the effectiveness of three versions of a mobile persuasive application called Medication Adherence Reminder (MAR) in promoting medication adherence level among patients. MAR-1 offers a reminder feature, similar to most mobile applications on the market today, and a medications history, intended to promote self-awareness of medication adherence behavior. MAR-2 adds a points system to reward adherence, while MAR-3 adds a demerit system to punish non-adherence. An experimental comparative approach was employed to evaluate and compare the effectiveness of the three versions of MAR. The sample consisted of 30 participants over 18 years of age and on long-term medication regimens. A four-week field study with 10 participants for each MAR version was conducted. The majority of the participants found the app useful in helping them stick to their prescriptions. Most importantly, both the reward and penalty features were found to promote medication adherence behavior above the MAR-1 baseline level. While participants favored rewards over penalty, no statistically significant difference in medication adherence was found between the two approaches.

LIST OF ABBREVIATIONS AND SYMBOLS USED

GEM	Graphics and Experiential Media
HCI	Human Computer Interaction
MACS	Master Applied Computer Science
MAR	Medication Adherence Reminder
MAR-1	Medication Adherence Reminder app - Version One
MAR-2	Medication Adherence Reminder app - Version Two
MAR-3	Medication Adherence Reminder app - Version Three
UI	User Interface
App	Application
Meds	Medications

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CHAPTER 1 INTRODUCTION

Medication adherence is defined as the level to which patients take medications as prescribed by their physicians [1]. Research has shown that medication adherence is central to patient's safety and wellbeing, the literature described a rate of 20 % to 50% of poor medication adherence [2]. Poor medication adherence is problematic because of the associated impact on patients' health and healthcare cost [3][4]. Poor medication adherence is associated with 33% to 69% of medication-related hospitalizations [4] and could lead to multiple diseases [3]. The cost associated with poor adherence was estimated to be $100 billion annually in the United States [4] only. Of significance is the fact that poor adherence to medication has been described as common among patients with chronic diseases [5]. For example, over 80% of patients suffering of chronic psychiatric disorders failed to adhere to their prescribed medication regimen incurring an associated cost of $100 to $300 billion each year [6][7].

Acknowledging the importance of improving medication adherence, technology has been introduced as a solution in the form of mobile phone applications [8]. Research has shown that mobile phones are effective medium for reminding patients to take their medications considering their high penetration, adoption, and availability [9] along with ease of access and connection [10]. Furthermore, a systematic review conducted in 2015 by Chio et al. [1] showed that several mobile applications are beneficial for facilitating patients' adherence to their medications. The effectiveness of mobile health applications in improving medication adherence has been associated with positive health outcomes. Patel et al. [11] studied the health outcomes associated with the use of a mobile automated medication reminder app (Pill Phone) of 48 high-risk patients with hypertension. Use of the application resulted in improving medication adherence and a measurable decrease in average blood pressure level among the 48 users.

Most of the mobile applications introduced in the last decade to enhance medication adherence are based mainly on automated reminder messages, or alert [5][7] as the only technique for motivating adherence. However, Oliviera et al. [12] argued that alerting patients to take their medications daily does not actively engage or motivate them to comply with their medication regimen. A such the concept of persuasive technology was introduced. Persuasive technologies are designed for the explicit purpose of changing human attitudes or behaviors [13] using various persuasive techniques. Some examples of persuasive techniques that have been developed for motivating and maintaining desirable behavior include: competition, simulation, self-monitoring and feedback, goal setting and suggestion, customization, reward, social comparison, cooperation, punishment and personalization [14]. In relation to medication adherence reminders, the literature described the use of some persuasive techniques including competition, self-monitoring, goal setting and rewards [12][31]. The evidence shows that when these persuasive techniques are introduced into medication reminder apps, patients' conscious behavior of adhering to the medication regimen improved [31]. Although initial research on the utilization and effectiveness of persuasive techniques in the area of medication adherence is promising, it is still limited [15].

1.1 Research Problem

In relation to medication adherence reminders, the literature on the utilization and effectiveness of persuasive techniques is not conclusive. For example, the two features of self-monitoring and goal-setting have been described as incorporated in most medication adherence reminder applications and as being effective [16][17][18]. The addition of a reward feature to medication adherence reminder applications is not uncommon [12][31], yet the evidence supporting its effectiveness is not consistent [12]. Moreover, when it comes to the use of penalty as a persuasive technique in medication adherence reminder applications, no evidence on the utilization or

effectiveness of this feature could be identified. Thus, this thesis focuses on exploring and comparing the effectiveness of reward and penalty for medication adherence. Three versions of a mobile application called Medication Adherence Reminder (MAR) were tested: MAR-1 served as a baseline and had reminders only; MAR-2 added rewards; and MAR-3 added penalties.

1.2 Research Objective

Research questions:

How does introduction of persuasive technology in medication adherence reminders affect the medication adherence level of patients?

Which persuasive feature (reward or penalty) is more effective in improving patients' medication adherence level?

Two hypotheses:

1) The medication adherence level of patients will improve significantly when persuasive techniques either rewards or penalty are that introduced in reminder apps.
2) Rewards will be more favored and more effective in improving medication adherence level than penalties.

1.3 Contribution

Research studies in the field of Human Computer Interaction (HCI) have focused on how mobile applications could improve adherence to medications using persuasive techniques [12] [31]. This study contributes by providing a description and comparison of the effectiveness of persuasive techniques in improving medication adherence. As such, this research investigates the effectiveness of the persuasive techniques of reward and penalty.

The findings of this research showed that medication adherence level improved with both persuasive techniques rewards and penalty. Moreover, when compared to rewards, penalty emerged as a more effective persuasive strategy.

The results can inform further investigations of persuasive features in medication adherence reminders. The results are also useful for the collaborations between health care providers (including physicians, nurses and pharmacies) and health application designers in the design of effective medication adherence reminder applications.

This thesis builds on previous work that lead to MAR-1 and MAR-2, done by Tearo, Mohammed, and Reilly at the Graphics and Experiential Media (GEM) lab in the Faculty of Computer Science at Dalhousie University, as detailed in Section 3.1. The work conducted by this author leading to the thesis involved refining research questions and modifying an existing study design to focus on the impact of reward vs. penalty for medication adherence, adding a version of MAR with a penalty feature (MAR-3), executing a comparative field experiment using the three MAR versions and conducting analysis of the data.

1.4 Overview of the Thesis

This study is divided into 7 chapters as following:

Chapter 2: **LITERATURE REVIEW** provides a discussion of research that has been conducted on the effect of poor adherence to medication on patients and healthcare and role of mobile technologies to address this issue. It then discusses persuasive technologies for promoting better health practices. In addition, it identifies research gaps in this field.

Chapter 3: **MAR PROTOTYPE** describes previous work on MAR. In addition, it provides detailed information about MAR app. It explains versions of MAR and describes the features of each version.

Chapter 4: **METHODOLOGY** describes the research questions. It then discusses the recruitment, study procedure, pilot study, data collection and data analysis.

Chapter 5: **FINDINGS** provides detailed information of the results that were acquired from the log data that captured our participants' daily MAR usage, participants' post hoc interviews and their weekly online survey responses.

Chapter 6: **DISCUSSION**, limitations and future work discusses findings of this study in detail. It then describes the limitations of the study and the future work that could be carried out on basis of this study.

Chapter 7: **CONCLUSION** gives a brief conclusion about the research.

CHAPTER 2 LITERATURE REVIEW

The following section includes a review and synthesis of the relevant literature and empirical evidence on medication adherence as a health issue, and the employment of technology, in specific persuasive technology to address this issue and to improve medication adherence. This literature review is presented under five themes: (Section 2.1) issues associated with medication adherence, (Section 2.2) practices for improving medication adherence, (Section 2.3), factors associated with poor medication adherence, (Section 2.4) use of mobile technology to improve medication adherence, (Section 2.5) persuasive technology, and (Section 2.6) the research gap.

2.1 Medication Adherence: Issues

Poor medication adherence or non-adherence continues to be an enormous challenge facing patients and the health care system [5]. When patients fail to adhere to their prescribed medications regimen, it is a major barrier to their treatment and recovery [3]. Poor medication adherence may lead to multiple diseases, and decrease quality of life for patients [3]. About 125,000 people in the United States die each year because of medication non-adherence [5], and the literature describes high rates of non-adherence in the range of 20-50% depending on medication regimen [2]. Of significance are patients suffering from chronic diseases since these diseases are identified to cause 60% of deaths worldwide [3]. Many of these patients are expected to maintain a chronic medications regimen, and while life-threatening conditions tend to be associated with higher levels of adherence. A number of studies have shown that many patients with chronic diseases do not take their medication as prescribed. When a chronic condition is not classed as life-threatening, non-adherence can rise significantly. For example, a study by Trujillo showed that over 80% of individual patients suffering chronic psychiatric disorders failed to adhere to their prescribed medication regimen [6].

In addition to its impact on patient health, poor adherence contributes to raising the consumption ratio of health care resources [5]. Non-adherence to medication is linked with rise of rates of hospitalization, deaths and healthcare costs [9]. Poor adherence causes approximately 33% to 69% of medication-related hospitalizations and accounts for $100 billion in annual health care costs [19].

2.2 Factors Associated with Poor Medication Adherence

The literature presents several factors that have been associated with poor medication adherence, including complexity of the medication regimen, forgetfulness, changes in daily routines, and challenges in the logistics of taking medications [10][20][21].

- *Complexity of medication regimen* refers to regimens that include taking multiple medications at different times of the day [19][22]. Additional criteria that renders a medication regimen complex include a medication prescribed more than a simple once-a-day; medications to be taken in the middle of the day, every other day, or weekly; medications that should be taken with meals or on an empty stomach; and medications that shouldn't be taken at the same time with other medications [10].
- *Forgetfulness* is another factor that contributes to poor medication adherence. Forgetfulness increases with aging, and thus medication adherence gets more challenging with complex medication regimens [22]. Other reasons that lead to forgetfulness include fatigue, distractions at the time of medication, and being busy [10].
- *Changes in medications and in daily routines* have also been associated with poor medication adherence. Changes in medications involve a new prescription, a change in dose, or even a change on pills' shape or color as these changes take time to become part of the routine [10]

People may change their routines over weekends and holidays as they may sleep longer than usual, change their meal times, or travel [10].

- *Challenges in the logistics of taking medications* include refilling prescriptions, carrying the medication along when leaving home for work or while on vacation [10].

2.3 Practices for Improving Medication Adherence

The literature describes several strategies to improve medication adherence, and these include strategies developed by patients, strategies delivered by the health care system, and strategies embedded in mobile applications.

Lee et al. [10] described various techniques developed and employed by their participants that helped in improving their medication adherence. These techniques included: 1) associating medications within daily routines, 2) relying on family/friends for reminders, 3) associating specific body signs or symptoms with missing a medication, 4) exerting control over one's medication regimen, and 5) autonomy in medication management. We consider each in turn here:

- Associating medication with daily routines includes keeping the medication at a spot people access as part of their daily routines, such as at the bedside or by their morning coffee equipment. Moreover, taking medications regularly at specific times of the day such as mornings or at bed time has been identified as helpful. For instance, mornings were described as stable times, where no changes in life events are expected, in comparison to other times of the day, where the patient may not be home, or something unanticipated might come up. Taking medications at bed time has been described as helpful as one associates the medication with bedtime rituals [10].
- Relying on family/friends for reminders in the form of text messages, or asking family to bring medications along when leaving home [10].

- Associating specific body symptoms with missing a medication dose. This occurs when patients miss their dose and start experiencing bodily signs and symptoms which alert them and serve as reminders to take medications [10].
- Exerting control over medication regimens occurs when patients alter the regimen with medications that are hard to remember or that disrupt daily routines. For instance, anticipating that they will forget their medications at noon, patients might take an extra medication (as a double dose) in the morning. Other forms of exerting control include adjusting the dose; for example, patients experiencing side effects of a medication will decrease the dose until they reach a dose they tolerate with minimal side effects [10].
- Autonomy in medication management occurs when patients seek knowledge of medication, dosage instructions, and purpose of medication and abide by this knowledge [10].

The literature also identifies strategies the health care system can adopt to improve medication adherence. These strategies include: counseling, simplified regimen plans, and compliance aids.

- Counseling involves educating patients about their illness, the benefits and side effects of therapy, how to take prescribed medications, and the risks associated with non-adherence. The evidence supporting this strategy is contradictory, Russell et al. [15] found that 21 out of 42 studies involving counseling did not identify any difference, whereas the other 21 did.
- Simplified regimen plans include dosage boxes, drug reminder charts, calendar packaging. The evidence shows that this strategy alone is unlikely to be associated with improvement in adherence [23][24].
- Compliance aids, such as phone follow up by pharmacist, have proven to be effective, but are hard to implement in large populations [2][25]. Diaz et al.[26] described smart packages

are another compliance aid where these packages record the time and date they were opened, but the effectiveness of these packages was hard to determine because of methodological challenges.

2.4 Use of Mobile Technology to Improve Medication Adherence

Mobile phones including smartphones are widely owned and operated worldwide. Among other uses of smartphones, people report using them to access health information, deliver health messages, and provide support for health behaviors [27]. As study in 2011 by the Pew Internet Research Center showed that more than half of the US adults own a smartphone (53%), 31% of them have used their phone to search medical information, and 19% smartphone users have downloaded a mobile application to help them manage their health including medication applications[28]. Mobile medication applications are intended to support medication self-management [29][30] by reminding patients what medication to take, along with the dose and the time it should be taken [31].

A study by Baily et al. [31] in 2014 intended to provide an understanding of the availability, functionality, and quality of existing medication mobile applications. Studying a total of 424 mobile applications, Bailey et al. showed that the quality and content of applications varied widely. In analysis of the features, all applications provided a medication reminder or alert; and only half enabled the user to design a medication history or log. Other features in fewer applications included ability to email medication information to a health care provider (like a pharmacy or physician); allowing other users (such as family members) to manage their medications; providing a refill prescription reminder, and the ability to order refills. Other features were even less common, including visual aids such as photos of pills, or checking for drug interactions. The app store user evaluations of the applications in Bailey's et al study showed a total of 260 applications out of the

424 having customer ratings, with a mean number of reviews of 107.4 (SD 1118.2), and a mean rating of 2.8 (SD of 1.7). This means that some applications were considered of high quality, yet more than half were evaluated as suboptimal and needing improvement. It is important to mention that the number of downloads of the 424 applications varied widely (as did the number of reviews, as shown above) with most of the applications exhibiting a number of downloads in the range of 100-1000 (49 apps (32%),) and 1000-10 0000 (47 (30.9%)). To gain a deeper understanding of the quality and functionality of these apps, Bailey et al reviewed a subset of applications. The subset selected were among to the top 10 results retrieved during searches for mobile apps. From this subset, the top 75 consumer reviews per application were examined. In the subset analysis, 26 applications were identified and a total of 1091 reviews examined. Half of the reviews were positive, but the common challenges identified included: 1) technical difficulties describing the application crashes or freezes (195 reviews); 2) absence of desired features (164 reviews) including additional notification/sound features for alarms, improved/expanded visual images of medications, ability to a create historic log of medications, being able to export the log to providers or family, improving the screen color, being able to note expiration dates and future refills, need for an area to add notes or describe irregularities, ability to document laboratory results, and being able to add the user profile of family members; and 3) poor compatibility with some medications was a third challenge (53 apps) including contraceptive pills, tapered medications and over the counter medications. It is interesting to note that "game-like" features, or "persuasive techniques" are not requested in the vast majority of these reviews.

Research findings regarding the effectiveness of applications employing reminders alone on improving medication adherence are encouraging but not conclusive [32]. Some app user reviews in Bailey et al.'s study [31] described the medication reminder feature as tremendously

helpful and life-saving. Also, a systematic review by Cole-Lewis and Kershaw [29] reviewing 7 articles related to disease management and medication reminders supported the effectiveness of text messaging reminders on medication self-management. Another systematic review by Free et al. [30] identified six studies that support the effectiveness of simple medication mobile reminders in the form of SMS in improving medication adherence in patients taking multiple medications to treat HIV, malaria, vaccines, antidiabetic, and antibiotics.

On the other hand, Linn et al. [20] conducted a systematic review of 13 studies that used reminders. Out of the 13 studies, five showed a large effect on adherence, while six showed a moderate effect, and two showed no effect of adherence. In addition to reporting this variation in effects on adherence, Linn et al. [20] communicated concerns regarding the use of self-reported measures of adherence used in the studies, which Linn et al. argue should be considered low quality evidence.

Other researchers argue that alerting patients to take their medications daily does not in and of itself motivate patients to comply with their medication regimen [12][32]. These researchers explore the application of persuasive technology to this domain, as discussed in the next section.

2.5 Persuasive Techniques

Persuasion is an attempt to influence behaviors, attitudes, feelings, or thoughts [17]. Persuasive technology is the class of technology that has the explicit purpose of changing human attitudes or behaviors [13]. Researchers look at persuasive technologies not only to improve health, but to create better habits when it comes to taking medications or performing a medical routine [13].

With persuasive technology, technological mobile reminder applications aim to increase the patient's interest in adhering to their regimen and consequently patients become motivated

and maintain the new behavior—medication adherence [12]. As such, Oliviera el at. proposed introducing persuasive activities that patients are good at and enjoy such as social competition in the form of games, social media, and competition in reaching goals with rewards [12].

The literature shows that a number of persuasive techniques or strategies have been developed over time and applied to many domains. In 2002 Fogg described seven persuasive strategies [17], and in 2008 Oinas, Kukkonen and Harjummaa [18] expanded Fogg's seven strategies to present 28 persuasive strategies. According to Orji et al. [14], the ten most commonly used persuasive strategies in technology are: *competition, simulation, self-monitoring* and *feedback, goal setting* and *suggestion, customization, reward, comparison, cooperation, personalization,* and *punishment*, each summarized here:

- Through *competition* users compete with each other to achieve the desired behavior [14].
- By *simulation*, users access the means through which they observe the cause and effect relation of their own behavior [14].
- *Self-monitoring and feedback* occurs when patients can view their progress through accessing a screen that shows their progress towards a goal [33]. Providing access to medication logs and identifying what has been missed vs taken could permit self-monitoring in medication adherence [31]. Through self-monitoring, people can also track their behavior and access both past and current positions [14].
- *Goal setting and suggestion* necessitates that users set a clear goal and then make recommendations that eventually lead to favorable outcomes [14].
- Through *customization* users get the opportunity to adapt the content and functionality of the system to their needs and choices [14].

- Through *rewards*, when individual perform the intended behavior, they are offered virtual rewards, as "trophy case" [33] and point reward system [10][14].
- Through *comparison* individuals can view their own performance and compare their performance to that of others [14].
- Through *cooperation* individuals are expected to work together, set a common goal, and work together to achieve the goal. The group are rewarded when they achieve the goals together [14].
- Through *personalization*, the users access a content and service tailored to their own needs which is typically based on the users' characteristics [14].
- With *punishment*, the users are penalized for not performing the desired task or not reaching the intended goal. Forms of punishment include removing acquired rewards or specific possessions from the user [14].

Another promising persuasive strategy used with medication adherence reminders is *sharing*. Sharing occurs when patients post their progress towards the goal and share this information with friends and family members through an app or through a link to social media [7][31]. Sharing differs from competition, comparison, or cooperation because the information is not necessarily shared among all patients taking medications but with people of the patient's own choice [7][31]. For example, an elderly sharing his medication taking information with an individual, a child, or a caregiver who monitors his/her medication adherence. It is argued that sharing details about medications are often a private matter for an individual and perhaps their closest family. As social media may still be acknowledged for the role it plays in medication adherence, Oliveira et al. [12] demonstrated that social sharing can be a powerful motivator among a peer group undergoing similar regimens, and in this case aligns well with either competition, comparison or cooperation.

Even though, sharing along with the above mentioned persuasive strategies have shown to be frequently used and effective, the impact of these strategies in medication adherence reminders is limited. Moreover, I acknowledge the importance of studying the impact of the different persuasive technologies as well as a blend of these technologies. However, I focused in this study on only two persuasive technologies: rewards and punishment, as a build-up on prior work in the department and to meet the timeframes expectations of the Master program thesis.

According to Wächter et al. "reward and punishment are potent modulators of human and animal behavior" [34]. Reward and punishment as persuasive techniques have been implemented in different health contexts such as smoking cessation, weight loss [33][35][36], and also in medication adherence [12].

Reward has been identified as one of the mostly used persuasive strategies [37]. Rewarding is motivational and can be either extrinsic or intrinsic. Extrinsic rewards include offering points, badges, or money upon completion of the desired tasks. Extrinsic rewards are further categorized as tangible or intangible. Intangible rewards such as virtual rewards include virtual achievement, trophy case [36], points and badges [10]. Tangible rewards include physical rewards as money or gift cards. Intrinsic rewards associated with medication adherence include feeling good or more energetic, and improving confidence in one's ability to maintain healthy behavior. The literature describes a relation between intangible extrinsic and intrinsic reward [38]; for instance, the extrinsic rewards of badges, points, and scores induce intrinsic rewards of feeling good and sense of accomplishment.

The literature shows a gap when it comes to the number of studies that evaluate the effectiveness of reward use in medication adherence. Nevertheless, the available evidence in medication adherence with reward systems is promising. For example, Oliveira et al. [12]

conducted a six-week study that involved 18 elderly users who needed to take prescribed medication at multiple given time frames. The application, called MoviPill, reminded users to take their medication at the prescribed times and provided rewards in the form of a point system within social competition with the other users. Thus, patients were reminded to take their medication, and in doing so they gained points, after which their points score was shared among the group of users [12]. Findings from Oliveira et al. revealed an increase in interest and improvement in adherence among users. The authors also noted that sharing the rewards in the form of point score created a friendly environment and enhanced participants' acceptance of the app [12].

As for punishment and penalty as a behavior change persuasive technique, up to the knowledge of this author, no study specific to medication adherence has been conducted. As such, evidence form other contexts is presented. Luft [39]and Hannan et al. [40] presented a study and comparison of effect of penalty and rewards in the context of employee contracts which tend to consistently adopt rewards. Luft [39] and Hannan et al. [40] found that penalty is effective and attribute this to the concept of loss aversion. Loss aversion implies that employees experience a greater disutility with the loss associated with penalty than not gaining a reward [39][40]. Because of this aversion loss, employees tend to exert more effort to avoid the loss and hence the employer set outcomes are achieved. In comparison to rewards in employee contracts context by Hannan et al. [40] the authors described what they called the "reciprocity effect", pointing to the impact of rewards in having employees exert more effort and achieve better outcomes. In elaboration, Hannan et al. [40] participants preferred the reward feature first because of the loss aversion associated with penalty, and second because participants considered rewards as a fairer contract option. When employees consider a contract to be fair, they tend to exert higher level of effort and hence employers get the outcomes they need.

Applying Hannan et al's. [40] concept of reward and punishment in medication adherence reminders, one would speculate that when punishments are introduced, users would avoid the negative feelings associated with loss and hence abide by medication timings. In this aspect, punishments are expected to be effective. Hannan et al's concept of avoidance of loss aversion would indicate that participants would psychologically favor rewards to punishments, and that would comply with medication adherence when rewards are provided so that punishment is not introduced.

Wächtera et al. [34] conducted a behavioral study to compare the effect of reward and punishment on procedural learning on a total of 91 participants divided into three groups: one receiving reward, another receiving punishment and a third control. In this study, participants were rewarded or penalized in a monetary value that was posted on a screen. The results showed that only the reward impacted the process of learning, suggesting that rewards are more effective in behavioral change than penalty, at least for learning [34].

A personalized approach in introducing persuasive strategy is a rather recent concept. Orji et al. [14] argues against a "one-size- fits- all" approach to designing and introducing persuasive techniques. Orji et al. [14] clarifies that the effectiveness of persuasive techniques is a factor of personality traits as different types of people are motivated by different persuasive strategies. Orji et al. [14] argued that the effectiveness of punishment is dependent on the personality of the individual and showed punishment as a significant motivator for individuals whose personality style tends toward agreeableness and extraversion while being less open to experience. Studies have shown that one strategy that may prove motivational with one group may prove demotivational with another [41][42]. In a study of 660 individuals employing different persuasive techniques including reward and punishment in motivating health behaviors, Orji et al. [14]

revealed how these two persuasive techniques had different effects on different groups. For example, when analyzing the effect of reward as a motivator in her study a group of the 660 participants were motivated and considered the reward as fun, appealing and providing incentives. On the other hand, another group (out of the 660 individuals) did not think of reward as a high motivator and described rewards as childish, and as trivializing the benefits of the behavior. In looking at personality types, the first group who considered rewards motivational were highly agreeable, extroverted, and less open to experience. Whereas the others who did not like the reward were described as neurotic and conscientious.

In relation to punishment, Orji et al. [14] presented the same argument; agreeable and extrovert participants were motivated by punishment, and described penalty as fun, challenging, engaging, encouraging. On the other hand, neurotic and conscientious participants were not motivated, and described punishment as awful, silly, childish, discouraging, depressing, boring, harsh and demoralizing.

As implications of the individualized approach presented by Orji et al. [14] participants of this study may respond differently to each of the persuasive features rewards or penalty depending on their personality type. Even though this study did not aim to study the association between personality type and medication adherence reminders, the evidence by Orji et al. might justify individual differences in participants' favoring of each persuasive method.

2.6 Research Gap

As discussed earlier in this chapter, a limited research in the health persuasion area has focused on effect of reward motivation to improve adherence to prescriptions, but that has not evaluated the impact of penalty on motivation. Therefore, this research employs a comparative study using the MAR mobile application in three variants: reminders only, reminders with reward, and

reminders with penalty, to address this research gap. MAR features were designed to motivate users and give them incentives to maintain their level of taking medications as prescribed. In this study, we used baseline assessment MAQ, an "experience sampling" weekly questionnaire, log data, and post hoc interviews to explore how reward, penalty, and other features in mobile health applications can encourage people to adhere to their prescribed medication regimens. The findings from this research can help designers to develop reminder applications that will best contribute to enhancing users' medication adherence.

CHAPTER 3 MAR PROTOTYPE

This chapter presents a description of the MAR prototype. Section 3.1 describes previous work on MAR, and Section 3.2 provides a detailed description of the MAR app and the three MAR versions.

3.1 Previous Work

This thesis employs the Medication Adherence Reminder app (MAR) developed in the Graphics and Experiential Media (GEM) lab, and it builds on existing study design work. In this section I outline this work, including the contributions of other lab members up to and including the start of my involvement.

The MAR app prototype is an Android mobile application that was programmed by Aaqib Mohammed, a former MACS student, and designed by Khalid Tearo (PhD student), Dr. Derek Reilly, and Aaqib Mohammed in collaboration with industry partners HealthQR. Out of this work came the first and second versions of the medication adherence reminder app used in this research, which are smart reminder (MAR-1) and smart reminder with rewards (MAR-2) [48]. The design of MAR is the culmination of several design brainstorming and prototyping sessions conducted by Mohammed, Reilly, and Tearo, with input from HealthQR. A series of "smart" or context-aware notifications rules were explored during this period, including a range of location-specific triggers (e.g., when I leave the house, when I arrive at home, blocking notifications from occurring in specific locations), activity-specific triggers (e.g. trigger an alarm if it seems the user is going to sleep without having taking meds), and adaptive triggers (e.g., update the next reminder based on when the user has taken their medication). After a series of development iterations by Mohammed, including feature refinement after feedback from a mock 2-week trial with several GEM lab

members using candies instead of pills, the versions of MAR-1 and MAR-2 used in this study were created.

Features of MAR are as follows: the first version (MAR-1) provides a user profile feature, a smart reminder in the form of notification, and a track location. The user profile feature allows users to enter their medications and the expected regimen including 1) the time of the day and 2) the days the users should take their medication. Through the smart reminder, and when it is time for the user to take their medication (as entered in the user profile), users receive a notification reminder. Track location reminds users to carry along their medications with them before going out from their homes. The second version (MAR-2) is a smart reminder with positive rewards (bonus points). It contains all the features of MAR-1 in addition to a rewards system through which users collect points when they take their medications on time. A third version (MAR-3) that inverted the rewards feature of MAR-2 to apply demerit points when medications were missed was later built using the MAR application base by this author and Hossein Salimian (GEM lab PhD student).

The study design employed in this thesis also builds in large part on the work of Tearo, who wrote the initial study design and completed significant revisions required by the health research ethics board for approval. The original study employed a 2x2 factorial design (MAR version - 1 and 2, and mobile device - phone or watch). Tearo conducted a pilot study to validate the study design and uncover outstanding bugs or design issues with MAR prior to running the full study. He recruited two Android users who used the app for four weeks, each using a different MAR version. After the four weeks, the researchers interviewed the two users. The interview focused on understanding the experiences of the users with MAR, and to find out how MAR was accepted by them; feedback was generally positive for both versions, and pilot participants reported different

impacts on adherence, suggesting that our line of inquiry would yield useful findings. Through consultation with our industry partner HealthQR, patients with specific medication regimens were identified as appropriate for our study population, and a significant recruitment effort was undertaken, involving advertisements and direct mailings associated with a chain of pharmacies in the Halifax Regional Municipality. Unfortunately, recruitment was slow, made difficult due not only to the specialized target demographic but also to device requirements for the MAR app (specifically, Android vs. iOS[1]).

After the issues encountered with recruitment for the initial study, the project was temporarily suspended. The work presented in this thesis encompasses the project's resumption, for which I was principal investigator. Several brainstorming and study revision sessions were held among myself, Dr. Reilly, Dr. Hawkey, and Tearo, culminating in the refocussed study design, most importantly the comparison of reward vs. punishment as persuasive techniques for medication adherence. In addition to the use of the MAR application, a number of key elements from the original study design remain (to be described in detail later in this thesis), including the study's overall procedure, and the data collection methods including the diary, software logging, and post hoc interview. Tearo assisted in creating the revised study design and in facilitating the study.

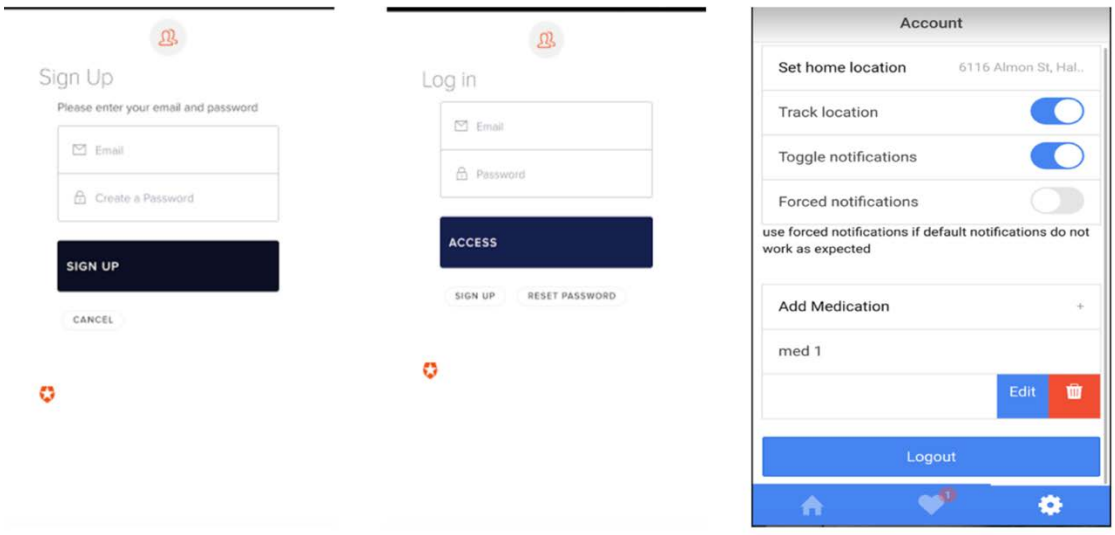
3.2 MAR App

Medication Adherence Reminder (MAR) is an Android medication adherence reminder application developed for this study. Three versions of MAR were created with the objective of comparing the effectiveness of reminders alone (MAR-1) to reminders with reward (MAR-2), and

[1] An iOS version of the application was made that would function on Apple Watch and iPhone devices, however the framework used did not offer access to the iOS notifications API when the app was minimized, and gaining access would require a significant rewrite. In the end, it was decided to require Android devices for the study.

to reminders with penalty (MAR-3) in promoting medication adherence. All the three versions have a main dashboard screen including a log screen and settings screen. There is also an "updates" screen that links to a weekly questionnaire and displays reward and penalty scores in the MAR-2 and MAR-3 variants, respectively (in MAR-2 users collected bonus points for adherence while in MAR-3 they accumulated demerit points for non-adherence). The three versions are explained in detail below.

When the users initiate the application, they will be greeted by two pages: 1) sign-up and 2) log-in pages, through which users can sign up and/or log in (see Figure 1:(a) and (b)). After logging in, the app displays the setting screen (see Figure 1:(c)), that allows users to enter their medications name, and schedule and provides the users with the option of enabling or disabling the notification and location features – each of these features is described below.



a **b** **c**

Figure 1.(a) the sign-up screen, (b) log-in screen, (c) settings screen.

3.2.1 MAR-1

MAR-1 provides a daily log and reminders to help users adhere to their medication regimen. The user interface (UI) consists of three screens: a main dashboard including a log screen, a settings screen, and an “updates” screen (see Figure 2 & 3).

The dashboard screen shows the schedule of the medications set by users. The schedule includes the name of the medication, the dose, the due date, and due time. This feature is helpful especially with users on complex medication regimens, who take more than one medication and at different times of the day. These users can easily access their medication schedule, identify the day and time each medication should be taken, and the medications with the timing of those due on that specific day.

Historical logs can be accessed from the dashboard as well to promote self-monitoring. We used traffic signal colors so that each color indicates to specific status (see Figure 3): the green color indicates that the user has taken the medication, the red color indicates that the user recorded that s/he did not take the medication 'it was missed', and the yellow color indicates that no entry was recorded for that medication. The historical logs page shows the history of previous medications including the time the medication was taken, the number of pills taken, and the status of each medication. Users can update that they have taken the medication at any time before the second upcoming notification for the same medication, after which they cannot update their logs. This feature is also helpful with users on complex medication regimens or who face the challenge of forgetfulness as to whether they took the medication or not to avoid taking double medications which is causes side effects.

The settings screen allows users to schedule their medications by entering the times and dates the medication should be taken. Users have the option of choosing to be reminded by a specific time of the day or by hourly intervals (e.g., every 48 hours). Moreover, it provides toggle controls for the time and location-based notifications. Notifications are out-of-app modal popup windows that appear on the user's phone when the related event occurs, and user must be interacted with or dismissed. In case the notification is ignored or not noted by the user, the popup widow remains visible on the users' screen until the user interacts with or dismisses. Upon receiving a notification, the user also has the option of choosing to be reminded later within a specific time frame. Location-based notifications occur when the user leaves a specific location set by the user and generally expected to be their home. Location-based notifications include a popup window that appears on the users' screen and includes a reminder of the pending medications for that day, and the text stating "going out do not forget your medication". As mentioned in the literature review, the changes in daily routine (traveling) and the logistics of taking medications when leaving home are challenges to medication adherence. Location-based notification is a helpful feature to address these challenges; moreover, this feature has become a common one in mobile reminders. It reminds users to take their medications with them as they leave home, and also those who want to travel long distance and still having pending medications for that day.

Time and location-based notifications are the main way that the user interacts with MAR. Clicking on a notification brings the user to data entry screen, where they can indicate that the medication has been taken (see Figure 4). The user can also indicate that medications have been taken without being prompted by a notification; in these cases, they can indicate whether the medication was taken on time, and if not, when. In such cases, the notification associated with that medication will not be triggered by MAR for that occurrence.

Finally, the “updates” screen simply contains a weekly questionnaire to capture ongoing experience using the application (the screen has additional functionality in the reward and penalty variants of the app, described below).

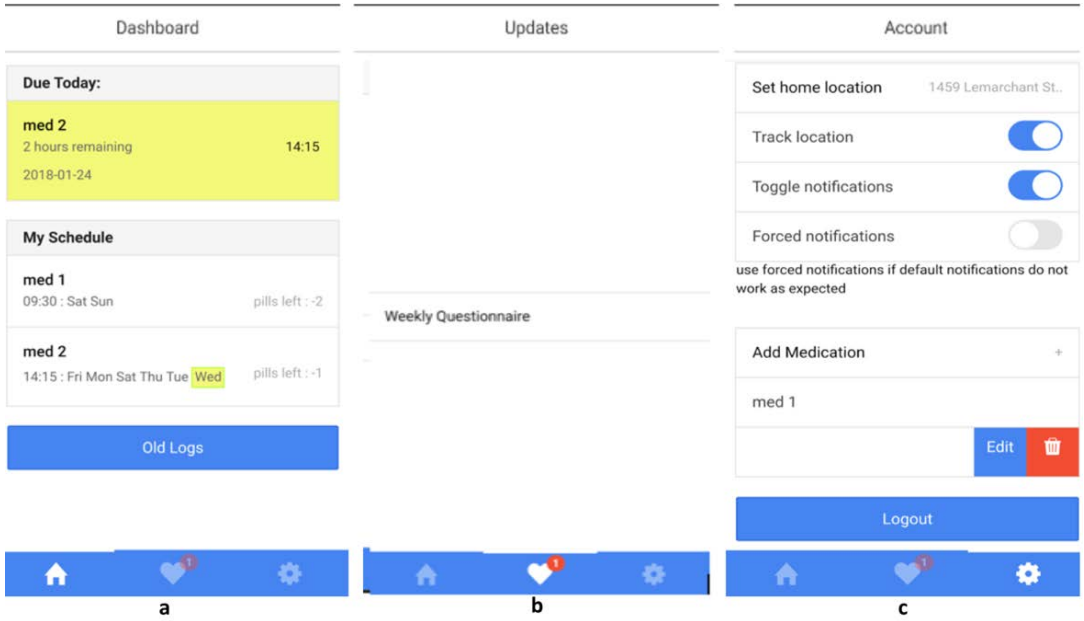


Figure 2.(a) dashboard screen, (b) “updates” screen for entering the weekly questionnaire and (c) settings screen.

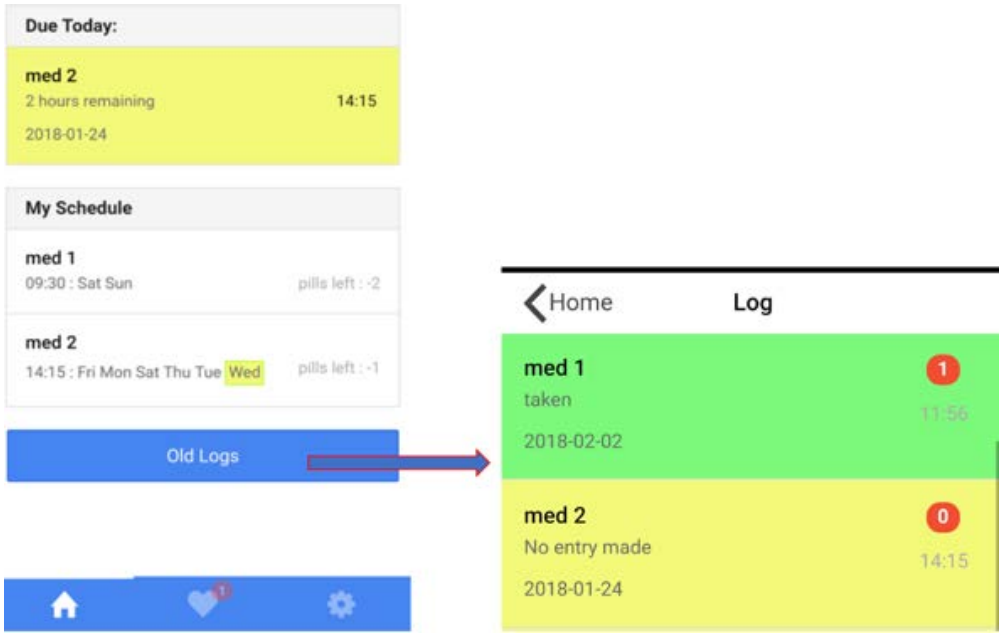


Figure 3.Dashboard screen and log screen.

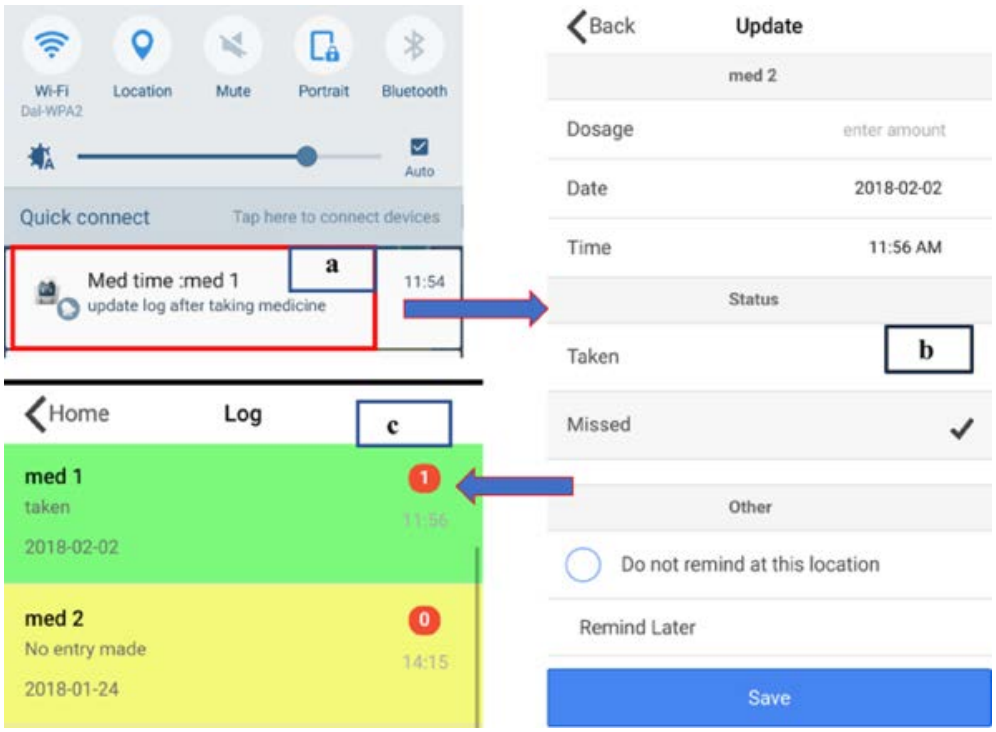


Figure 4.Notification, data entry and logs screens.

3.2.2 MAR-2

MAR-2 has the same functionality and interface as MAR-1 described above in addition to a rewards feature. In this version, the users collected points every time they took their medication on time, as shown in the "updates screen" (see Figure 5). The points earned corresponded to the punctuality of taking the medication on time. For example, when users took their medications within one hour of the specified time, they received ten points rewards. With any delay in medication taking by more than one hour, they received five points. In case they missed taking the medication totally, then they did not receive any point (zero points). Participants' score was updated with every due medication and corresponded to the average points collected up till that time. The average of the points was computed by dividing the total number of points collected by the total number of times the medication was due.

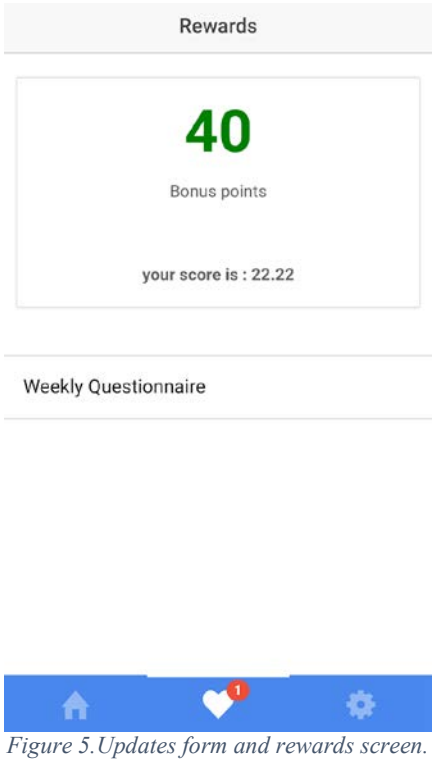


Figure 5.Updates form and rewards screen.

3.2.3 MAR-3

MAR-3 also has the same functionality and interface as MAR-1 described above in addition to a penalty feature. To allow controlled comparison, the penalty feature closely mimics the reward feature of MAR-2 in both function and visual presentation. In this version, the users began with a set score of zero, and accrued 5 demerit points for each missed medication that showed as red colored in the "updates screen" (see Figure 6). Accrued demerit points were never taken away. Demerit points were accrued only for missing medications completely and not for taking medications earlier or later than prescribed.

The point system in relation to the time of taking medications was incremental with the reward feature, but it was fixed with the penalty. We deliberately chose to implement penalty in a different way to rewards, as described here. Rewards as a behaviour changing strategy is described to be motivational [33], thus an increment in the point system aligns with the motivation strategy to keep users interested and engaged towards their goal (taking medication on time). On the other hand, penalty as a behaviour changing strategy is known to be associated with loss aversion, a feeling that individuals generally dislike as it renders them tense and tend to exert effort to avoid it. So, making the penalty incremental would be more stressful to the participants and this might initiate a discussion on maleficence specifically in cases of mental health medications. Moreover, giving an incremental penalty for a delay in taking medications might not seem fair, and may lead users to stop using the app.

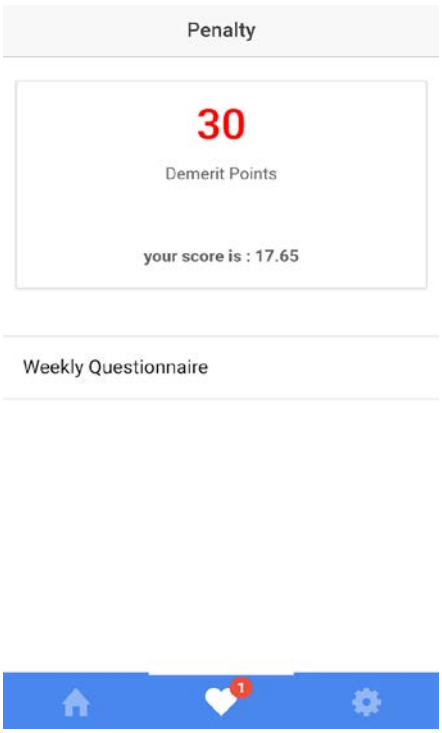


Figure 6.Updates form and penalty screen.

CHAPTER 4 METHODOLOGY

In this chapter, I will discuss the research questions (Section 4.1), population and recruitment (Section 4.2), pilot study (Section 4.3), study procedure (Section 4.4), data collection (Section 4.5) and data analysis (Section 4.6).

4.1 Research Questions

This study answers the following questions:

How does the introduction of two persuasive technology features (rewards and penalty) in medication adherence reminders affect the medication adherence behavior of users?

Which persuasive feature (reward or penalty) is more effective in improving users' medication adherence behavior?

4.2 Population and Recruitment

4.2.1 Inclusion Criteria

- Patients on long-term medication regimens. These patients were targeted for several reasons:

  1) They will be taking the medication for the duration of the study which is almost four weeks.

  2) They typically have tried various adherence methods over time and can provide a valid evaluation of our app [48].

- Patients with any medical condition and on any type of medication (complex or simple, critical or non-critical). Complex medication regimen refers to taking one or more medication at several times of the day [19][22]. Simple medication regimen refers to taking one mediation once per day [43]. Critical medications refer to medications whose early or delayed

administration may cause harm or suboptimal therapy to the patient, non-critical medications are those where early or delayed administration within a one to two hours does not typically cause harm or result in substantial sub-optimal therapy or pharmacological effect [44]. It is expected that patients with critical medications want to take their medication on time. Thus, recruiting them might be easy if they feel they need the app to improve their adherence, or might be challenging if they were already satisfied with the reminder methods they use and might be cautious about using different reminder methods. On the other hand, patients using normal type of medications might not consider taking medication on time as important and hence might not be interested in trying a medication reminder app. We did not limit our inclusion criteria to either as we wanted to increase the pool of participants to ensure recruitment of the required number.

- Patients taking medications in a pill form because pills are the most commonly used adult home medications. We also aimed to unify the form of the medication taken to control the variables considered in this study, for example, antidiabetic subcutaneous injections (Insulin) or liquid form medications (once opened) typically should be kept in a fridge. Thus, participants may find it difficult to carry their medications with them when leaving home or should attend to specific arrangement. These challenges might impact the adherence behavior and thus the effectiveness of the MAR application.
- Have an Android device with a data plan. This was dictated as the app is only compatible with Android, and it requires the use of the internet in order to receive a notification because MAR have to be running in the background. This selection criteria eventually shaped the characteristics of the sample we have recruited. According to a study conducted by three universities in the United Kingdom comparing iPhone users and Android Users, Android

phone users were found to be older, less interested in wealth and social status, showing more honesty and agreeability, and are less likely to break the rules for personal gain [45]. Furthermore, and for implications of personality type and character, a study of Orji et al [14], described users who exhibit agreeableness as a personality character as motivated by rewards and punishments as persuasive techniques. Moreover, the condition of having a data plan individual limits our population. Because of this criteria people who are economically disadvantaged or the elderly who do not have smart phones and/or data plans could not participate in this study, and thus we could not assess the medication adherence behavior among them.

- Participant to be 18 years old or above.

4.2.2 Recruitment

We recruited 30 participants, with 10 participants for each MAR version. Participants were recruited through a recruitment notice emailed to the Computer Science Faculty list of emails (csgrads@cs.dal.ca and csugrads@cs.dal.ca), this resulted in recruitment of 10 students from the Computer Science Faculty. We also distributed posters across Dalhousie campus, through that we recruited 8 participants (see Appendix E).

We were not successful in recruiting the required number of participants through these methods, so we requested ethics amendment to incorporate Kijiji and Facebook announcement as a recruitment method. I initially posted the announcement on my personal FB page, publicly accessed, and shared the post also on Facebook group pages Halifax Buy, Sale, Trade and Give away; Dartmouth buy Sale and Trade group page. Through Kijiji we recruited only 2 participants, and through Facebook we got the required number of participants (10 participants). As for participants assigned to MAR-1, three were recruited through Facebook, four from the Computer

Science department, two through Kijiji and one through distributed posters. Participants of MAR-2, three were recruited from Computer Science department, two through Facebook, and five through distributed posters. As for MAR-3 participants, three were recruited from Computer Science department, five through Facebook, and two through distributed posters. Once I received email from potential participants, I replied with description of the study with a call for a meeting. Meetings were conducted in our lab at Mona Campbell building, 4th floor "meeting room" and participants were provided with more details about the study, they signed the consent form (see Appendix A), and I installed the application on their phones. Information about compensation was also communicated verbally and in the consent form. Compensation was $50 for MAR-1 participants, $40 plus rewards up to a maximum of $50 for MAR- 2 participants, and $50 minus demerits to a minimum of $40 for MAR-3 participants.

As to assigning participants to a specific MAR application, at the beginning I faced challenges recruiting participants and was far from recruiting the 30 participants needed. So, I started on the basis of "First Come First Served", assigning the first five participants to MAR- 2, the second five participants to MAR-1, and the third five members to MAR-3. This distribution up to five in each MAR was conducted to ensure having equal number participants if I could not recruit the targeted number. After having five members in each MAR, I started assigning each new participant to a different MAR application, while at the same time ensuring that no one MAR application includes a maximum of 2 participants more than the other MAR application(s).

4.3 Pilot Study

This study was piloted with three GEM lab members. The aim of this pilot stage was to assess the functionality of our app, including existence of technical bugs (particularly for MAR 3, which

had not yet been evaluated), and to validate our study design and data collection instruments, including whether our study procedure is easily comprehended and followed by participants.

Volunteers were recruited through an email, inviting GEM lab members to participate in this pilot study. It was communicated that lab members who own Android devices with a cell phone data plan and were taking medications were eligible to join our study.

Once I received responses from three volunteers, I arranged an initial meeting with each in the GEM Lab at Mona Campbell Building, Dalhousie University. During this meeting, I explained the study, after which the three lab members signed the informed consent forms. I installed the application on their Android phones and showed them how to use MAR app. The members used the app for one week. The results of the pilot study showed that the app was working well with two of the users who found it helpful. The third user encountered a bug with the notifications feature where he did not receive notification sometimes.

With the weekly Questionnaire, after analyzing the responses, I added some questions: Did you take your medication today? Did you take your medication yesterday? and Did you have any comment? These questions helped us to capture the ongoing experience of using the application, and to know if the users encountered any bug with the MAR app.

4.4 Study Procedure

I conducted a four-week between-subjects field experiment to explore the impact of Medication Adherence Reminder (MAR) prototype on patients' adherence level, and to compare the effect of the three MAR versions (MAR-1: reminders only, MAR-2: reminders and reward, and MAR-3: reminders and penalty). Participants were randomly assigned into one of the three MAR application versions.

After receiving approval from Dalhousie's Research Ethics Board REB (see Appendix H), I started the recruitment process. I arranged an initial meeting with each participant individually in the GEM lab. During this meeting, I informed the participants that the purpose of this study was to enhance patients' compliance with their medication regimen by introducing two different persuasive strategies: rewards and penalty. As for the persuasive techniques adopted, I explained that one different persuasive feature was introduced in two MAR applications: no persuasive feature with MAR-1, rewards with MAR-2, and penalty with MAR-3. I also clarified that the compensation for participants in these two apps correspond to the points they gather as such.

- Participants in MAR-1 (baseline condition) were informed that MAR-1 provides a reminder for taking medications on time, and that they are expected to log in when their medication taken. Regardless of whether they took their medication or their punctuality in taking their medication, they will get a $50 compensation for participating in this study at the interview.
- As for MAR-2, participants were informed that they will get a reminder and reward points which is a function of their punctuality in adhering to their medication regimen. For example, when participants take their medications within one hour of the due time, they would be rewarded 10 bonus points. When they take their medications with a delay of more than one hour, they would only get five bonus points. When they miss taking the medication, they don't get any points. They were informed that to encourage them to adhere to medication, their compensation for participation of this study will be a function of the reward points collected. So, for MAR-2, all participants would receive a $40 gift card and an extra $10 corresponding to the rewards points they collected.
- With MAR-3, participants were informed that they would receive a reminder but also would collect demerit point for not taking their medications. For instance, each time participants don't

take their medications, they would be penalized by five demerit points which will be accrued. The accrued demerit points will be displayed on their updates screen. So, participants in MAR-3 would be compensated by a $50 gift card if they take all their medications, and would be penalized by a deduction in a certain amount of dollars up to maximum of $10 corresponding to the accrued penalty points.

Participants were also informed that each MAR application is connected to a data base which allows the researcher to monitor and track users' daily updates as to whether users took their medications and the times taken, and the points accumulated.

Participants then signed the informed consent form (see Appendix A). After this, participants completed a brief questionnaire which includes basic demographic questions (age range, gender), an outline of their medication regimen by day, and the 8-question Medication Adherence Questionnaire (MAQ) often used in medication adherence research [46] (see Appendix B). I also installed the application on the participant's phone, and trained participants on using the application version assigned to them.

Participants then used the application on their own for four weeks. After each week, participants received a pop-up notification asking them to complete a short questionnaire built into the app (see Appendix C). The questionnaire asked participants about their adherence level over the previous week, and their experience using specific app features. Both application logs and the weekly questionnaire responses were stored locally on the device and sent via network to a secure server for data collection purposes. Participants contacted the facilitator through the weekly questionnaire comments section or through email if they encountered problems with the application. In general, this contact was more frequent during week one.

After four weeks of using the app, I contacted each participant to arrange for an audio-recorded semi-structured interview (see Appendix D). In the interviews, I asked the participants to elaborate on their experience using the app, to reflect on specific features, and to share how using MAR impacted their level of medication adherence. Interviews lasted between 15 to 20 minutes. I then guided the participant in uninstalling MAR from their device and provided them their compensation.

4.5 Data Collection

In this thesis, I used multiple sources to collect qualitative and quantitative data, including application logs, audio recordings of semi-structured interviews, and responses from the demographic and weekly questionnaires.

4.5.1 Log Data

I used firebase cloud database service to create a database that contains all data as logged in by each user about their medication adherence including the name of medication, the scheduled regimen, and the number of pills missed, number of points collected (bonus or demerit points), as well as events of users' logging in to MAR and the corresponding interaction with each log. This data was used to track participants' daily updates, and to monitor the performance of participants during the study (see Figure 7).

Figure 7.Log data.

4.5.2 Audio Recording

I audio-recorded the semi-structured interviews to ensure that I captured all the information provided by participants. I transcribed the audio recordings after each interview using VLC and Microsoft Word.

4.5.3 Weekly Questionnaire.

Once a week during the experiment, I asked participants to complete an "experience sampling" online survey to capture their ongoing experience using the application, and to know if there is any problem that participants encountered during using MAR. This helped us to understand adherence level of participants through these weeks and if there was any improvement in adherence or not.

4.6 Data Analysis

Because participants were learning how to use MAR during week one, I only considered weeks 2-4 in the analysis. I used various data collection methods, the form "*Baseline assessment MAQ: Medication Adherence Questionnaire (MAQ)"* was designed to understand each participant's' adherence level before starting the study (see Appendix B). MAQ includes the *8-items Morisky's Medication Adherence Scale (MMAS*), in addition to other demographic information such as age and gender, as well as a table to collect names medications and their due time. MMAS is an 8-items scale with each item scored on a scale from 0 to 1, so the lowest score would be 0 (strong adherence), and the highest would be 8 (weak adherence). It is imperative to mention that MAQ was not used for a "before- after" study MAQ comparison. MAR's application logs recorded details about medication adherence in the app, including when medications were taken on time, when they were taken late, and when they were missed. I determined % of medication taken on time with each version during the study period, and I used a one-way ANOVA test to compare the effectiveness of the three versions on medication adherence level of the participants. The weekly questionnaire responses were cross-checked against application logs during analysis to build a representation of adherence behavior and participants' experience using MAR. The weekly questionnaire included a 5-point Likert scale question "MAR helped me with my medication" that I use as a rough self-reported evaluation (see Appendix C). The post hoc semi-structured interviews were transcribed and used to uncover participants' impressions of specific application features. I coded the interview transcripts and generated themes from these codes. Pre-set codes embedded in the interview questions were the codes used in the analysis. Recurrent themes identified through these codes included type of medication (critical vs noncritical, and complex vs non-complex), prior reminder techniques used, perceived adherence level with

utilization of MAR, their experience using MAR, impact of persuasive feature, personal preference of reward vs penalty, and suggestions and recommendations. Comments were grouped to uncover trends in participant responses, while interesting outlier comments were kept for reflection (see Appendix D).

CHAPTER 5 FINDINGS

This section presents the main results that address our research questions. I collected both quantitative and qualitative data; quantitative data was collected through log data, and some questions in the baseline and weekly questionnaires; whereas qualitative data was collected through interviews and to a lesser extent questionnaire questions. The primary aim of this study was to compare the impact of the three versions of MAR (reminders only, rewards and penalty) on users' adherence level. Before considering the study results, I first summarize the relevant demographic information about our population sample.

5.1 Participant Demographics

This section presents the age, gender distribution, and novelty in medication adherence reminders of our sample. Moreover, this section provides data on the baseline medication adherence levels of participants, the medication reminders they used prior to MAR, the complexity of their medication regimen, and the criticality of their medications.

Participants showed comparable characteristics in relation to gender and age. Gender distribution was balanced (see Table 1) in the three MAR versions. As for age group distribution, it was balanced for MAR-2 (reward) and MAR-3 (penalty) but skewed toward the upper and lower age groups for MAR-1 (notifications only) (see Table 2). The potential limitation of having age groups skewed towards upper and lower limits in MAR-1 is addressed below in figure 8 that shows the correlation of age groups with Morisky's Medication Adherence Scale.

Table 1. Gender distribution of participants of each MAR version.

	MAR-1	MAR-2	MAR-3
Female	7	7	7
Males	3	3	3

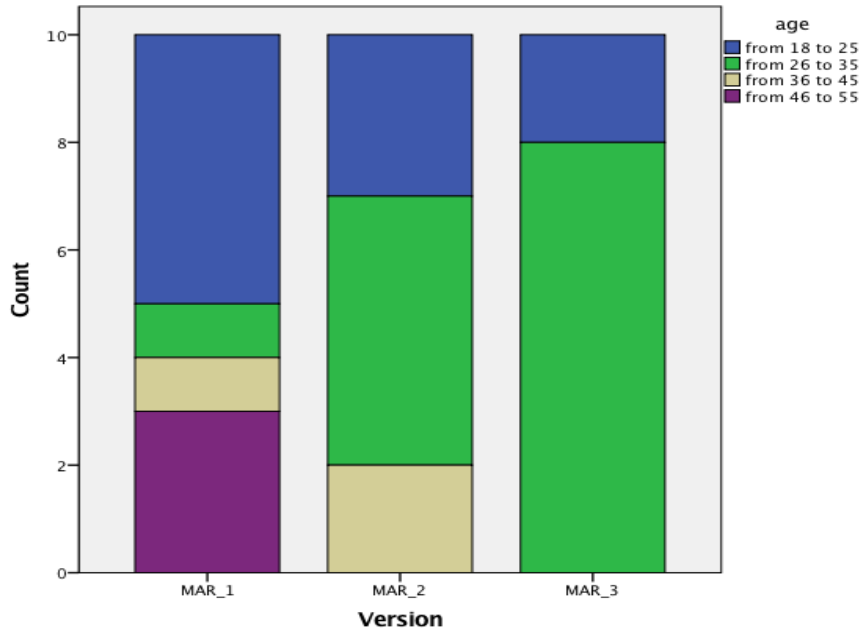


Figure 8. Age group distribution of participants of the three MAR versions.

Table 2. Age group distribution of participants of each MAR version.

	MAR-1	MAR-2	MAR-3
18-25 years	5	3	2
26-35 years	1	5	8
36-45 years	1	2	0
46-55 years	3	0	0

As to participants' novelty with medication adherence reminders apps, 29 participants out of the 30 declared that they had no prior exposure or experience with medication and adherence

apps. Only one participant who joined MAR-1 group used and kept using another medication adherence App along with our App.

5.1.1 Baseline Medication Adherence Behavior

The baseline medication adherence behavior of participants was assessed using Morisky's Medication Adherence Questionnaire (see Appendix B). The Morisky's Medication Adherence Scale (MMAS) is an 8-item self-reported scale for measuring medication-taking behavior. Participants answer each item as (Yes/No), where Yes is allocated a score of 1 and No allocated a score of zero. The sum of the scores of each item indicate the medication adherence behavior of the individual as follows:

- a score of >2 indicates low adherence behavior,
- a score of 1 or 2 indicates medium adherence,
- a score of 0 indicates high adherence.

The findings from our participants showed that almost all of our participants exhibited a *low baseline adherence level*, with two participants falling into the "medium" adherence classification. When compared between participants of the three MAR versions, MAQ score distribution showed a good balance of medication adherence scores between the three groups (see Table 3).

Table 3. Descriptive statistics of MAQ scores across MAR versions.

	MAR-1	**MAR-2**	**MAR-3**
Mean	4.5	5.8	6
Median	5	6	6
Mode	5	6	6
Standard deviation	1.26	1.47	1.63
Minimum	2	3	2
Maximum	6	8	8
Count	10	10	10

Noting that the age group distribution was skewed to the upper and lower age groups in MAR- 1, I studied the baseline medication adherence level as a factor of age groups. Most of the participants (28 out of 30) exhibited a low medication adherence level. The only two participants that showed medium adherence level belonged to MAR-1 and MAR-3 and both belonged to the lower age group (Figure 8), but I note that our sample included only 6 participants over the age of 35. Thus, our participants across all age groups exhibit comparable MAQ scores, so I do not consider age as a covariate when comparing MAR conditions.

A Pearson Correlation test was conducted, and it did not show a significant relationship between MAQ score and MAR adherence ($p > .092$).

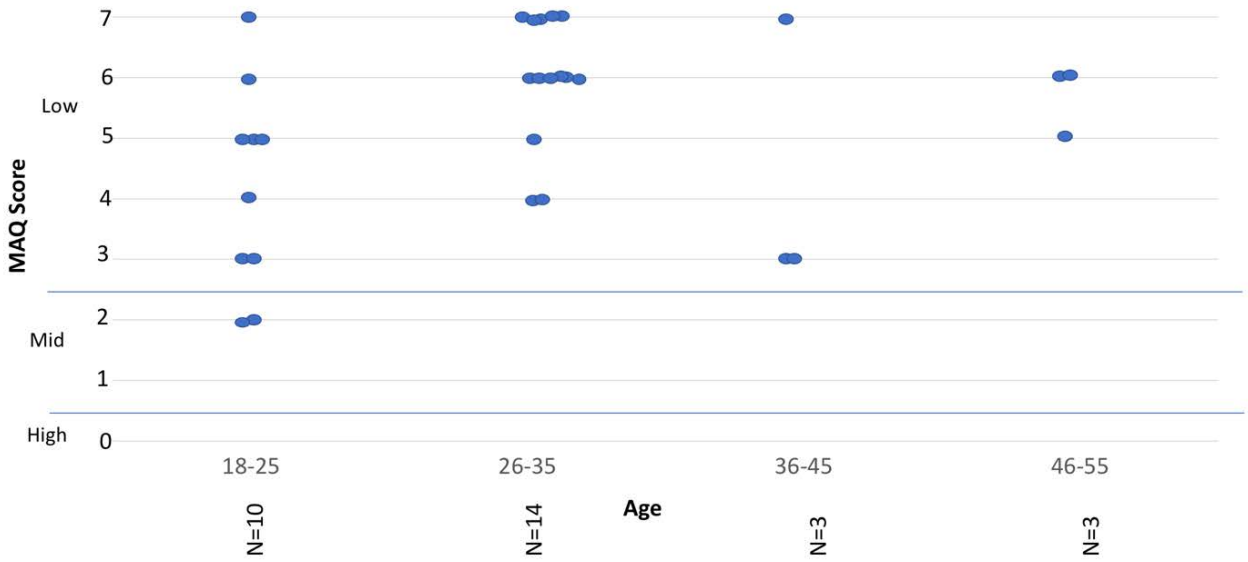


Figure 9. MAQ scores across MAR versions.

5.1.2 Medication Reminders Used Prior to MAR

During interviews, participants were asked about the medication reminder techniques that they used prior to MAR (see Figure 9). Out of the 30 participants:

- Only one was found to use a medication reminder application.
- Nine used alarm reminders on their phones, watches, or clocks.
- Seven participants used non-digital strategies like putting reminders in a printed calendar or placing their meds in a meaningful location such as bedside table or coffee maker.
- The remaining thirteen participants indicated that they don't use any reminder (MAR-1 six participants, MAR-2 three participants, MAR-3 four participants. Eight users from the thirteen said they place medications in a visually accessible spot, but that they do this out of habit and not as medication reminders. The other five usually keep medications in closed high cupboards out of reach of children.

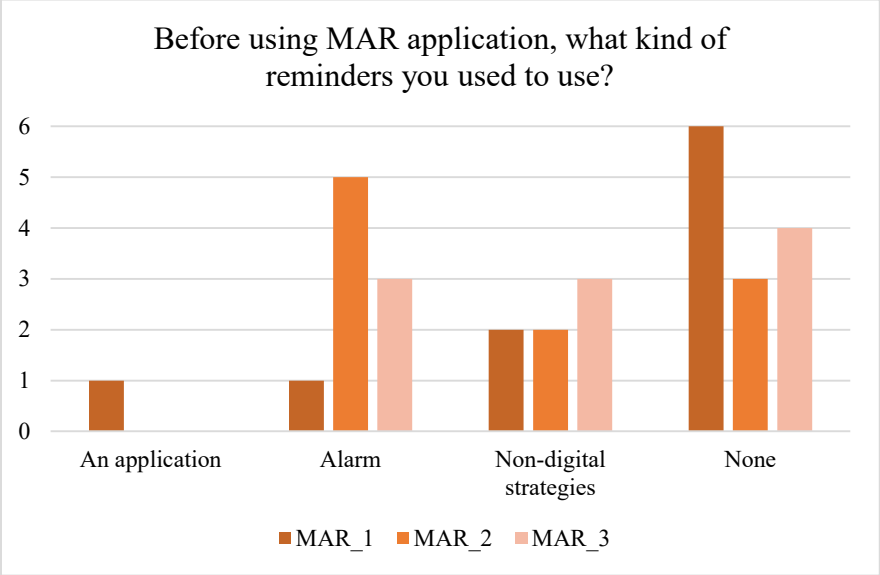


Figure 10. Medication reminder technique used prior to MAR.

5.1.3 Complexity and Criticality of Medication Regimens

I also considered the complexity of the medication regimen across our sample, corresponding to the number of medications they take. Participants were given definitions and asked whether their medications were critical or non-critical. As mentioned previously critical medications are supposed to be taken exactly on time otherwise any delay might highly be associated with harm or suboptimal therapy [44]. The sample was evenly distributed across MAR versions in terms of the number of medications taken daily and whether those medications were deemed critical to their health or not (see Figure 10). This data was collected through post hoc interviews where the participants were asked about the number of medications they were taking daily. The results showed that 15 participants were taking one medication daily, while the other 15 participants were taking two or more medications daily.

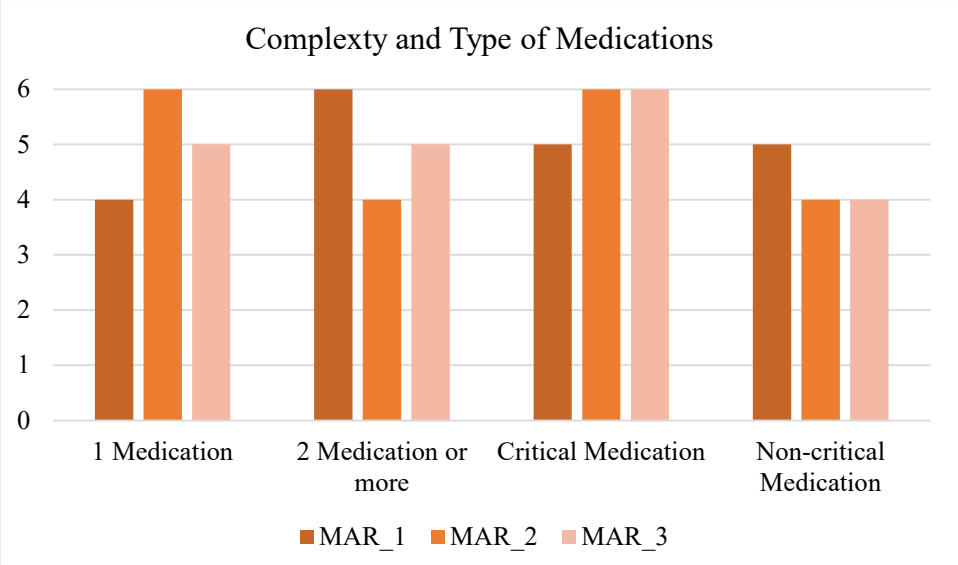


Figure 11. Sample distribution by condition of number of medications taken.

5.2 Adherence Level Variations Between MAR Versions

The medication adherence behavior of participants was assessed in several ways: as a medication adherence score determined using data collected from log data, from participant feedback in the weekly questionnaire, and by analyzing the post-hoc interviews of participants.

Using log data from weeks 2-4, I determined the adherence level of the participants for each version by computing a score or percentage of medications taken. The score was computed by dividing the total number of times medications were taken on time by the total number of times medications should have been taken. Results showed that MAR-1 (reminder only) users exhibited an adherence level of 67%, in comparison to an 82% for MAR-2 (reward) users and 88% for MAR-3 (penalty) users.

I used a one-way ANOVA to analyze log data. The level of significance was taken as $p < .05$. The dependent variable was the score of medications taken, and the independent variable was the MAR version feature: reminder only, reward, or penalty [47]. Before conducting a one-way ANOVA test, I conducted Levene's test for equality of variances on the data, there was no significant difference ($p < .338$). Then, a one-way ANOVA test was conducted, and it showed a significant difference in adherence behaviour between the three versions with $F = 5.037$ ($p < .014$) (see Figure 11). Therefore, I followed the ANOVA with Fisher's Least Significant Difference post-hoc test to find means that are significantly different from each other. Post hoc analysis indicated that there was a significant difference between MAR-1 (reminder only) and MAR-2 (reward) ($p < .037$), and between MAR-1 (reminder only) and MAR-3 (penalty) ($p < .005$), but there was no significant difference between MAR-2 (reward) and MAR-3 (penalty) ($p < .384$).

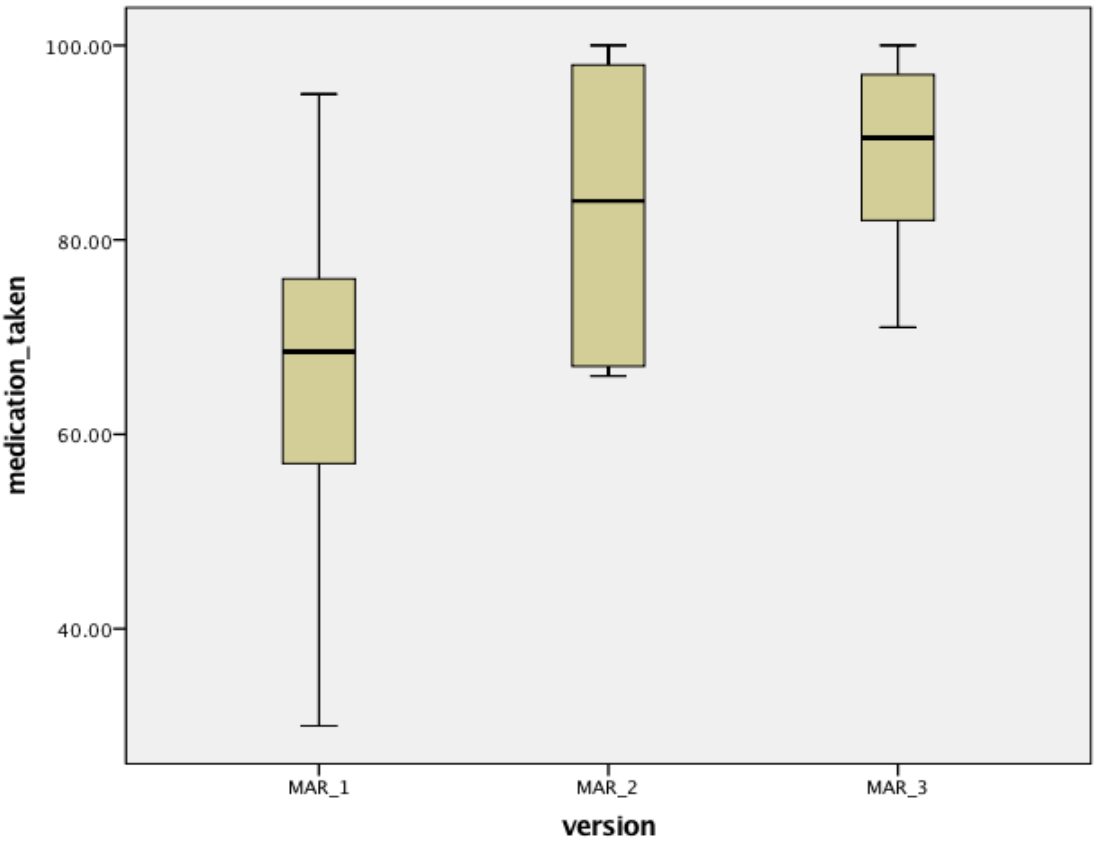


Figure 12. Adherence levels by MAR versions.

Table 4 shows the mean and standard deviation (SD) of scores for each version. As suggested by the box-plots in figure 15, the MAR-1 scores show the highest variance, followed by MAR-2 and then MAR3.

Table 4. The mean total medication taken for each version.

	N	Mean	Std. Deviation
MAR_1	10	67.5000	19.88439
MAR_2	10	82.4000	14.04121
MAR_3	10	88.4000	9.85675
Total	30	79.4333	17.14378

5.2.1 Comparison Between MAR Versions Weekly Questionnaire Data

In the weekly questionnaire, I asked participants if MAR helped them in managing their medication adherence (on a Likert scale). A one-way ANOVA test was conducted, and it showed no significant difference in Likert scores between the three versions for any of weeks 2-4, week 2 ($p < .657$), week 3 ($p < .578$), and week 4 ($p < .571$), but rather report trends here. I found that MAR-3 (penalty) had highest agreement, however with two participants becoming less appreciative of the penalty system over time. Participants were split in their evaluation of MAR-1, with participants who were trending negative at the start of the study becoming more so by the end of the study. MAR-2 (rewards) had the fewest number of highly positive evaluations, but fewer highly negative evaluations as the weeks progressed (see Figures 12, 13, 14 & 15).

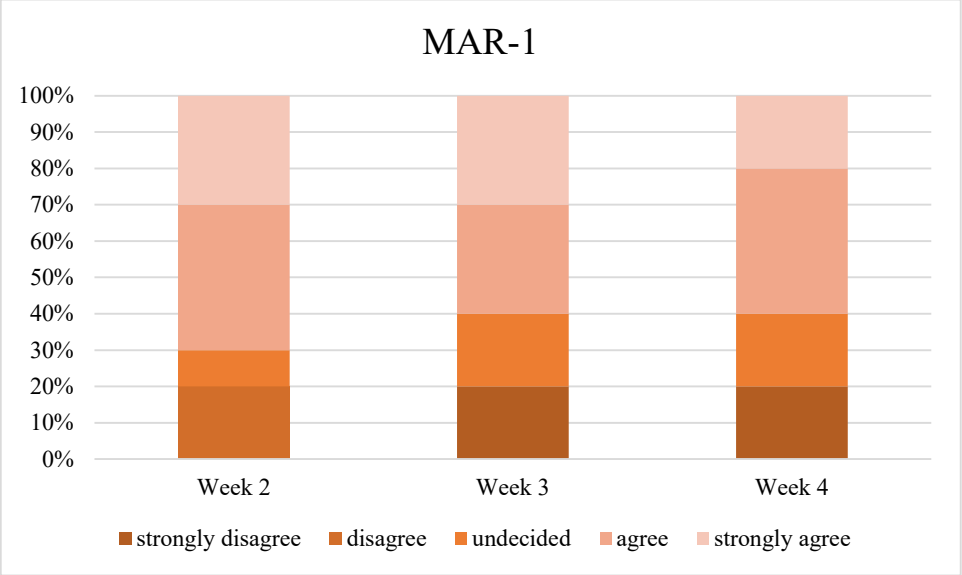


Figure 13. Effectiveness of MAR-1 of medication adherence through weekly self-report.

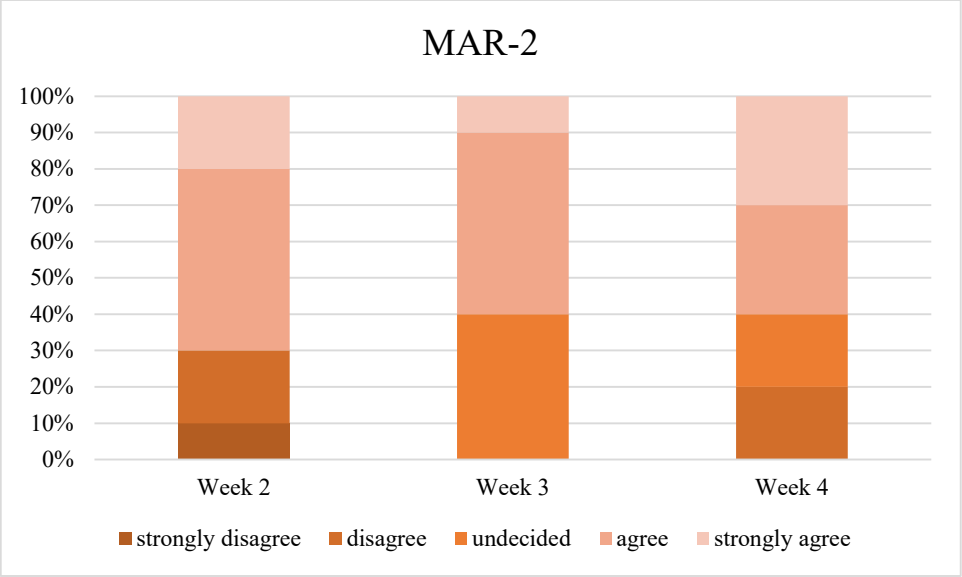


Figure 14. Effectiveness of MAR-2 on medication adherence through weekly self-report.

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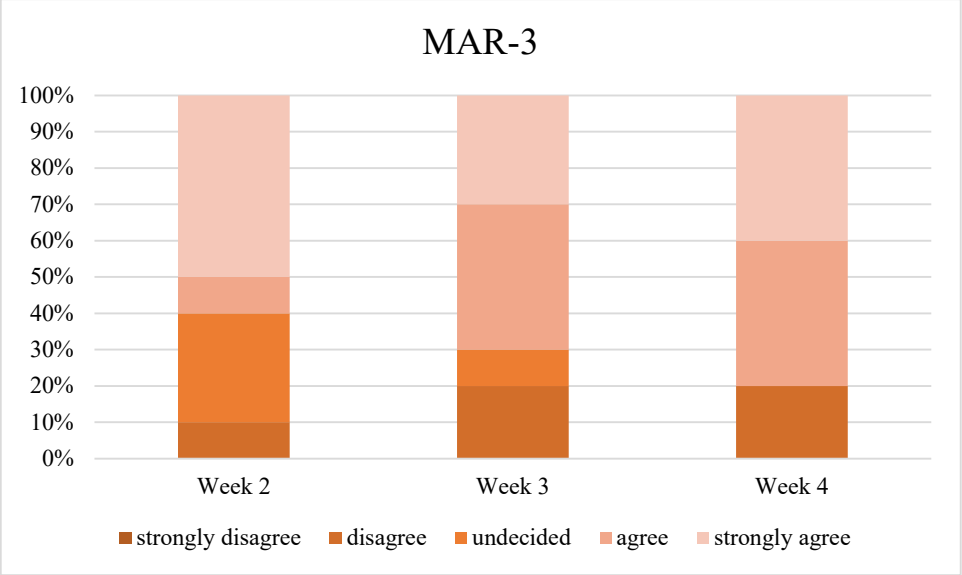

Figure 15. Effectiveness of MAR-3 on medication adherence through weekly self-report.

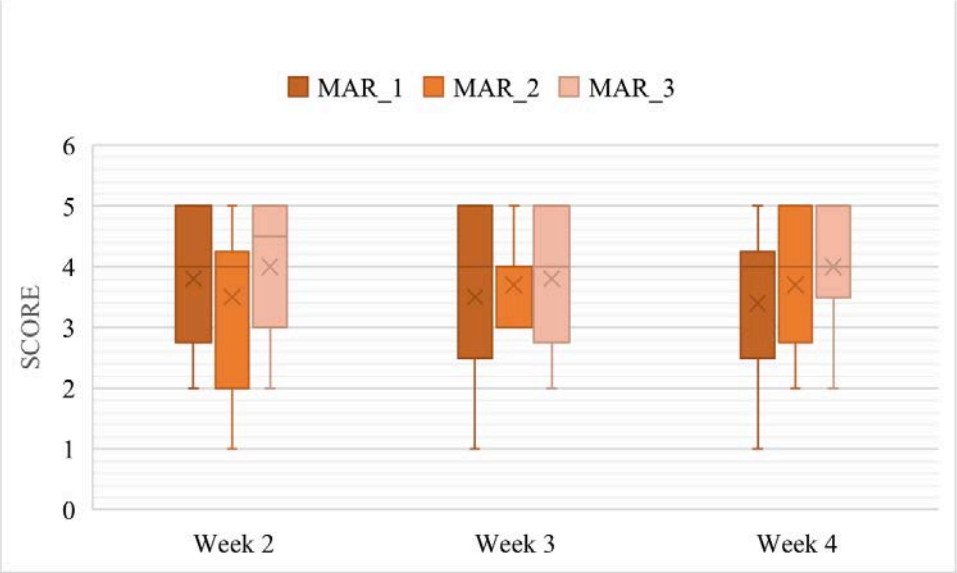

Figure 16. Weekly questionnaire results regarding the impact of MAR on participants' medication adherence, by MAR version.

5.2.2 Weekly Comparison of Log Data Between MAR Versions

A one-way ANOVA test was conducted, and it showed no significant difference in log data scores per week for the three conditions MAR-1 ($p < .192$), MAR-2 ($p < .930$), and MAR-3 ($p < .479$) (see Figure 16, 17 and 18). Log data showed that the medication adherence level of individual users varied between MAR versions. Out of the ten participants MAR-1, six showed same adherence level in week 2 and 3, but this level was not sustained and dropped in week 4. With MAR-2, the reward was effective with seven participants in improving medication adherence in week 3 which was sustained to week 4. And with MAR-3, the medication adherence with three participants declined in week 3 in comparison to week 2, which then increased again in week 4.

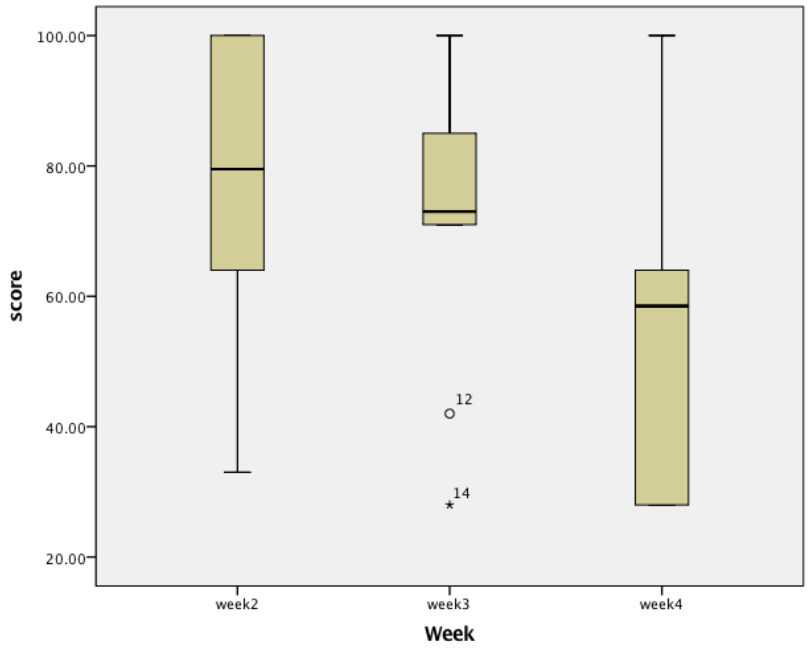

Figure 17. Log data results of impact of MAR-1 on participants' medication adherence level.

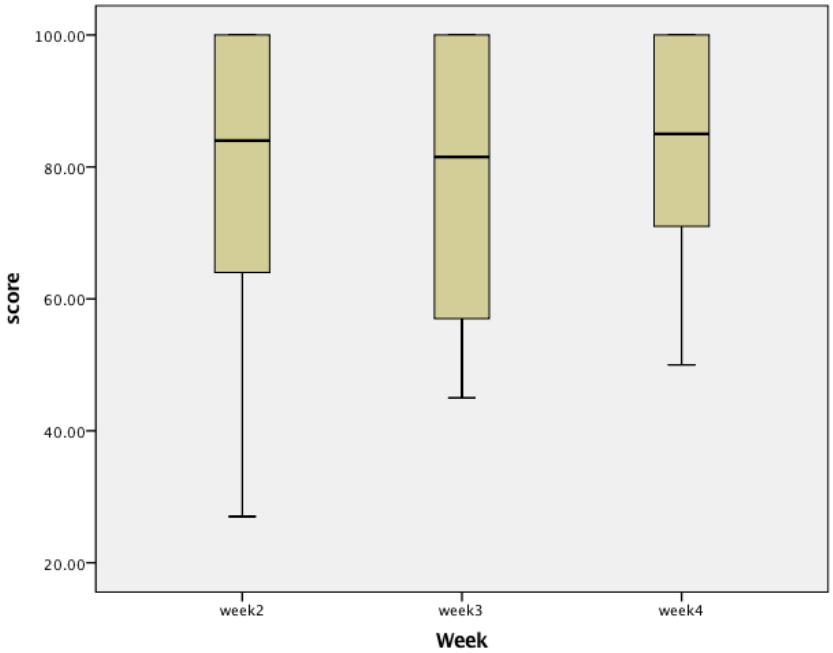

Figure 18. Log data results of impact of MAR-2 on participants' medication adherence level.

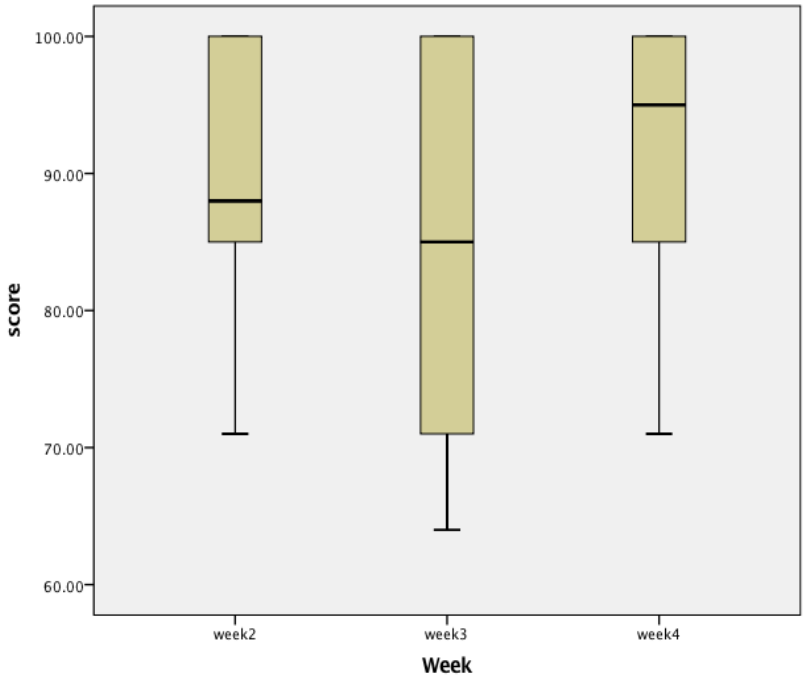

Figure 19. Log data results of impact of MAR-3 on participants' medication.

In comparison to bonus and demerit points, graphs show a comparative trend to that of ratings for MAR-2 and MAR-3 (see Figure 19 & 20).

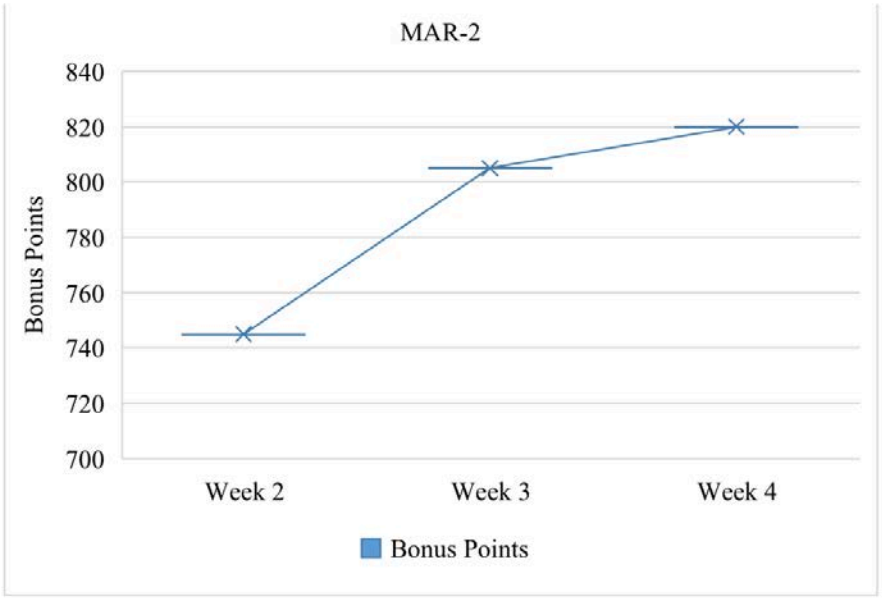

Figure 20. The new weekly bonus points collected by users of MAR-2.

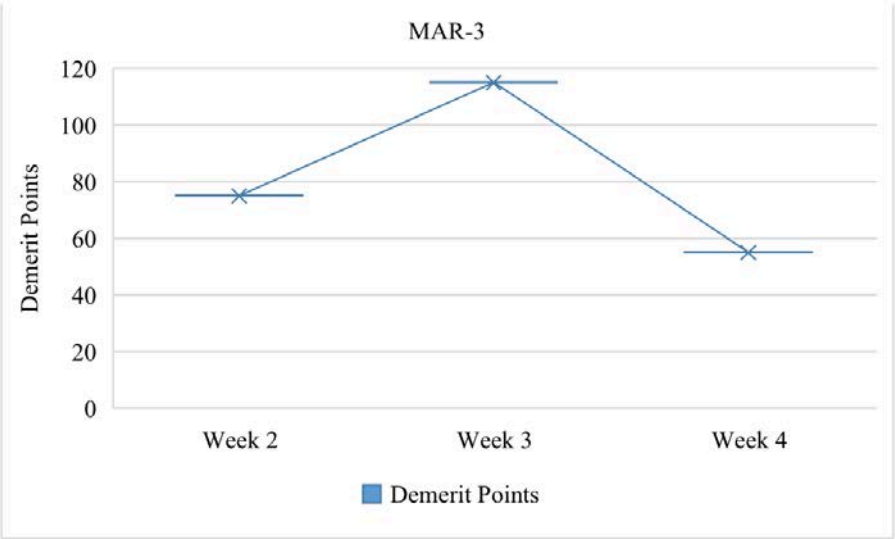

Figure 21. The new weekly demerit points collected by users of MAR-3.

5.2.3 Comparison of Compliance with Medication Timing Between the Three MAR Versions

I did a comparison between the three MAR versions to explore in which version participants were more likely to take their medication on time. To compute this, I allocated a score of 2 for each time a medication was taken on time, and a score of 1 for each time a medication was taken late. As described, with the rewards feature (MAR-2), when users took their medications within one hour of the specified time, they received ten points rewards. With any delay in medication taking by more than one hour, they received five points. Before conducting a one-way ANOVA test, I conducted Levene's test for equality of variances on the data, which showed no significant difference ($p < .092$). Then, a one-way ANOVA test was conducted and showed no significant difference in adherence with medication timing between the three MAR versions $F = 2.297$ ($p < .120$). However, findings showed that with five participants in MAR-2, the increase in the rewards points did not have high impact and was not associated with an increase in frequency of taking medications on time. On the other hand, with the penalty feature (MAR-3) no increment in penalty was given as a function of delay in taking medication, and results showed that most of

participants were more compliant in taking medication on time. So, these participants in MAR-3 were probably circumspect to taking medication on time and avoided missing medications (see Figure 21, 22 & 23).

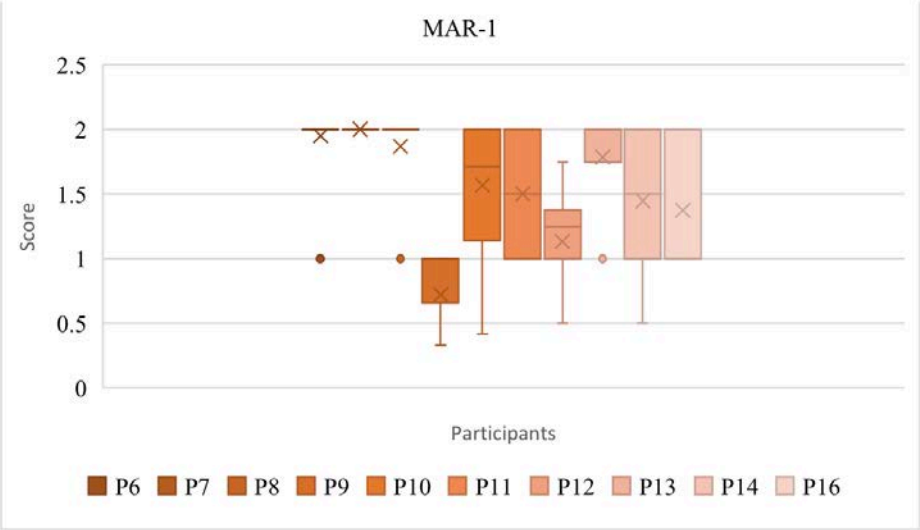

Figure 22. The scores of taking medications on time and late in MAR-1.

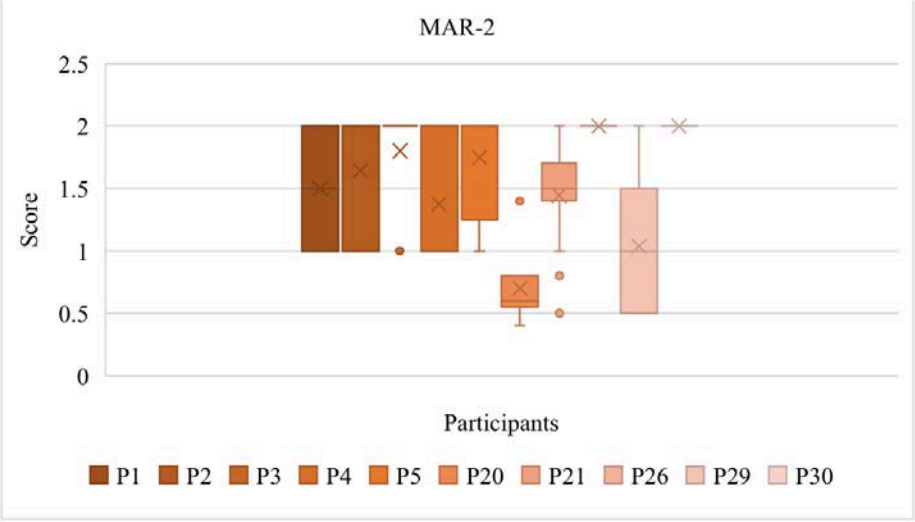

Figure 23. The scores of taking medications on time and late in MAR-2.

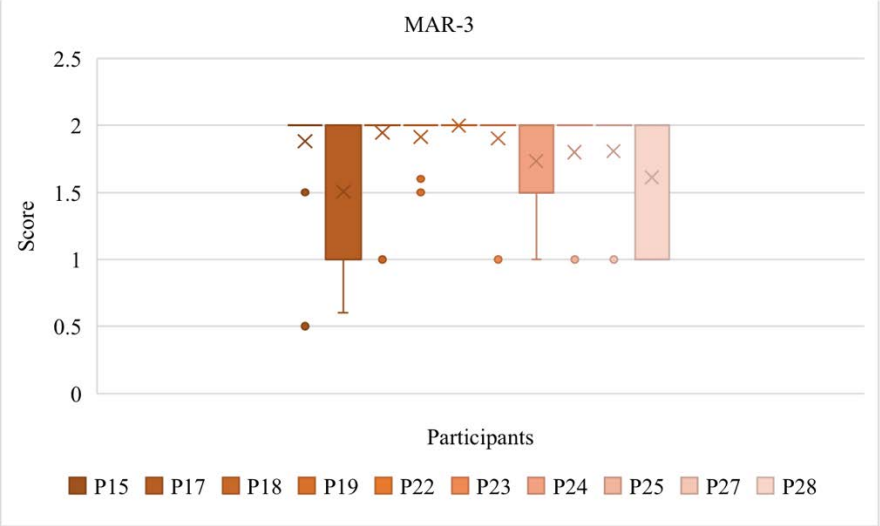

Figure 24. The scores of taking medications on time and late in MAR-3.

5.3 Participant Response to Reward and Penalty Features

Upon examining the findings in light of my proposed hypothesis, the findings only support one part of the hypothesis. The hypothesis stated that rewards would more effective in improving medication adherence and more favored by participants when compared to penalty. However, findings showed that rewards were less effective than penalty in improving medication adherence. Interestingly, whereas the adherence levels were good and evaluation scores for MAR-3 (penalty) were largely positive across participants, post hoc interviews suggested that while penalties were effective, most participants preferred to use rewards as a persuasive technique. During interviews, the majority of MAR-2 participants (8) expressed that the reward feature was an incentive to keep on track them with their medications. I also asked MAR-1 and MAR-3 participants what they thought of a reward feature. Out the 10 MAR-3 participants, seven expressed that rewards would have more impact in improving medication adherence than penalties. Also, out of the 10 MAR-1 participants, nine liked the idea of collecting reward points, "*now the reward system is known to improve compliance, that is human nature*" (P6).

5.3.1 Rewards

Rewards as a persuasive technology in medication adherence apps has shown to be an appealing feature that participants like, capable of changing behaviors by motivating people, and is effective in improving medication adherence [12].

Most of the feedback from our interviews in the MAR-2 condition (8 out of 10) considered the reward feature as appealing and interesting, while the remaining two participants were more apathetic about the feature. Participants who had liked the rewards described it as interesting and an incentive to taking medications on time. One of the participants said, "*I am a big fan of point structures*" (P20), another participant reported "*it is something new, encouraging, and it is like a game*" (P27). On the other hand, the other two participants did not consider rewards as interesting P4 said "*the rewards would not make a difference for me personally" and* "*my adherence level did not change because I am fairly good with my medications*" P2.

The introduction of persuasive technology is intended to induce behavior change in users by motivating them to take the medication on time [12]. Upon examining the effectiveness of the reward feature, seven of the eight participants who verbalized a positive experience with the rewards feature, including the four participants who were on complex medication regimen such as P29, initially scored low on Morisky's Adherence Scale, and their adherence level showed improvement in week 3 compared to week2 and was either sustained or improved into week 4, Their quotes reflect that they were conscious of the change in their adherence level and were motivated to pursue it, "*it made a difference*" P29, "I was more aware of taking my medication on time" (P3), and were motivated to take their medication in time *"it is great to encourage people to keep on going taking their medications*" P5. P21 expressed that she likes the rewards feature but did not really need a motivation *"I am actually fairly good with my adherence level…it did add an*

extra reminder for me". P21 was on a complex medication regimen and exhibited high adherence level in weeks 2, 3 & 4. Two participants expressed indifference for the existence of a rewards feature, as P2 said "*I am fairly good with my medications*", she did not need reminders. P2 was on critical medication and with an initial low adherence, she exhibited high adherence level throughout the 3 weeks. P4 also expressed indifference for the rewards features and that rewards would not motivate him to take medications stated" "*the rewards would not make a difference for me personally*". P4 started with low MAQ level, and was on simple, non-critical regimen, and his adherence improved on week 2 but declined in week 3 and further in week 4.

The individual differences of responding to persuasive techniques was addressed by Orji et al.[14], providing evidence that personality type is instrumental in determining individuals' acceptance of the reward feature. While we do not assess our participants' personality type, this may be a factor affecting the impact of rewards and penalty in medication adherence applications.

5.3.2 Penalty

Penalty has also been identified as a behaviour changing approach, and it has been explored in various domains but not in medication adherence apps. Generally, our results showed that users exhibited better adherence rate with penalty compared to reward. The literature does not provide information about users' agreeability of the penalty feature and whether they were active and conscious about the associated change in their medication adherence. Out of the ten participants, only four described penalty as an agreeable feature, P22 said "*I like this idea because it is something forcing me to do it*".

Upon examining individual users' adherence level with MAR, the medication adherence behavior improved in eight users, four of which indicated that they liked the penalty feature and the other four stating that they would prefer the reward feature. Participant (P19) who liked the

penalty feature was on a complex medication regimen, and their adherence showed a slight decrease in week 3 and then increased significantly in week 4. P19 was conscious about this change saying, "*it gave me better routine*". Participant (P18) who verbalized that they preferred reward feature was on simple medication regimen, started with low medication adherence scale. P18 consciously exhibited a high adherence level throughout weeks 2 to 4, "*I did start to take my medication more regularly, I was not taking it regularly before*". Even though P15 expressed a distaste to the penalty feature, their adherence level improved throughout the 3 weeks. P15 started with low adherence, on a critical medication regimen and exhibited high adherence score all through the 3 weeks, yet he stated, "*I found the demerit part a little annoying, nobody likes to know that they are making a mistake".* Also*,* P25 was on a complex medication regimen, but exhibited consistently a medium adherence level over the three weeks. Upon describing the penalty feature, P25 said "*it causes a little more stress than it should*".

Participants also articulated their thoughts on why penalty feature was effective. P24 had an initial low adherence scale, complex medication regimen, and who exhibited an overall high adherence level, with a slight decrease in week 3 followed by improvement in week 4. P24 said that he liked that idea of the penalty feature more than the reward feature; he said "*when patients forget to take their medications, they will lose points…. but in the reward version, they will not lose anything… so the reward version will not be that effective"*. P28 started with low adherence scale with a simple medication, and she exhibited high adherence level throughout the three weeks. P 28 said *"If I skip my medication, I will not lose any point, while in the penalty feature I will lose points, so I will be more careful not to lose any points"*.

5.4 Participant Impressions of Other MAR Features

The three versions of MAR share time-based reminder, location-based reminders, and a medication history as features. Among these features and in alignment with persuasive technology the focus of this study, the literature identifies monitoring medication history as a persuasive technology. Through self-monitoring of medication adherence by logging into the medication history, people can also track their behavior and access both past and current medications [14]. In this section, I present our participants' evaluation of the three features: time-based reminder, location-based reminder, and medication history.

5.4.1 Time-based Reminder

Most participants of the three versions found the time-based reminder helpful, and very few expressed inconveniences. Most users who had a positive experience described the time-based reminder as simple and helpful "*it was handy, practical*" (P6); "*I felt very mindful of [my medication] … I found that I did not miss my medications at all during the 4-weeks*" (P8). None of the participants disabled the notification feature. Participants felt good when they were reminded of their medications, "*I felt much more secure in knowing that I was going to remember to take it*" (P13). These reminders made users more aware about their prescriptions, as one participant stated, "*I like the notifications, it is really helpful, so having that feature at night time was good for me*" (P29). P7 he used an application beside MAR app "*it was pretty good*".

There were some complaints about details of the reminder's operation and suggestions for improvements. P12 described it as "*good*" but encountered a problem with the reminder's sound which at times was not audible "*it just notifies in the notification bar*". A few participants wanted to be able to change notification type and how the app notifies, for example if the medication was

not accessible or when the user did not notice the reminder, they requested that the reminder could repeat after several minutes, if they could have "*a second prompt*" with "*better flashing*" (P13).

5.4.2 Location-based Reminder

Participants' impressions of the location-based reminder feature were mixed. Most of the participants found this feature helpful, some reported it would be a great idea to help people especially in case of travel, "*it was a very nice feature to have in the app*" (P18). One of the participants mentioned it was great to have a feature to remind people before traveling, saying, "*I went on a trip and forgot to bring my medicines*" and the trip was not that far "*luckily it was just one hour away, and I could come back*" (P15). Another said, "*I am definitely a person who forgets things all the time, and actually when I was on vacation, it reminded me to take the medicine that I left behind, so it actually saved me*" (P19). Also, one user stated that this feature helped him, so two or three times he had to get back to his house to get his medications (P10). However, seven participants did not find the feature particularly useful. One of them said "*I did not care about that*", and she mentioned it would be better if this feature had more options; for example, if she could schedule her vacation times and times that she needs to be notified, not every time when she leaves home, "*Having it every day, when I was coming out of my house and into my house was just too frequent*" (P14). Three participants reported they did not receive location notifications every time when they left home. Three users discussed privacy concerns "*I did not use the notification feature myself just because I never keep my location on*" (P11).

5.4.3 Medication History

Most participants expressed that the 'medication history' feature helped them to stay on track with their medications, and some mentioned that the record's use of colors to identify taken vs. missed medications affected their behaviour. Also, they found that the colors increased their

awareness of medication adherence. Some participants felt comfortable with this feature because they can check if they took their medications and avoid taking double medication which might cause side effects. This was especially useful for patients with busy schedules or were suffering from a psychiatric disorder. P16 mentioned that sometimes she becomes so busy, and then she completely forgets if she took her medication or not, so she found that this feature helped her to avoid taking this medication again. Another participant expressed "*it kept me on track of taking my medications*", and because she takes her medication depending on her health status "*my dose depends on my symptom*", and she mentioned sometimes she increased her dose to 2 tabs "*I have been trying to figure out which part of the month I have these symptoms, as they go with my hormonal cycle, so MAR, it got me to the point where I figured that out*" (P6). Another participant mentioned that a "*couple of times I had deleted the notification, either purposely or accidentally, and I was waiting, did I take it, especially the night one, so it was definitely helpful*" (P19). Some found it easy to check what was going on "*it is like a month calendar*" (P17). Several participants expressed that the colors of the records had an impact on their behaviours "*using a stop light system is good way to influence people*" (P20). P30 cited she felt good about herself when she saw a lot of greens, P22 pointed *"it was encouraging to me"* she said when she was seeing some red records she felt upset. She was trying her best so as not to see red records any more "*I do not want to see it again, colors affect my behaviour*".

5.5 Challenges and Suggestions

5.5.1 Challenges

Keeping the app running in the background in order to receive notifications was challenging for some participants. P4 stated that he closed all apps at night, so when he woke up in the morning he would forget to reopen the app, so that became an additional task for him.

Another user said, "*I do close all apps because my phone gets slow if I do not, and having to get back and open it is difficult*" (P7). In addition, a few participants found it a bit difficult to remember recording their medications when they received a notification to take a medication, and they preferred to just check out the notification "*it might have been more useful if there was less work to fill it out"* (P10). Another participant found it hard to open the app to update his medication's data after receiving a notification *"I want to see it in the notification bar. I want to select this missed or accept without opening the app"* (P24). In addition, three participants mentioned the ability to change the notification type to be more visible (e.g., flashing). Moreover, change in the user's daily routine may make adherence difficult even with the application without modifications (e.g., travelling, vacations and incompatible routines). One participant was travelling "*it was a long weekend*", so she encountered a problem with the time *"my hours were not typical"* and she did not have her phone turned up loud enough to hear the notifications (P15).

5.5.2 Participants Suggestions

I provide a summary of participants' suggestions that may be useful for mobile application designers.

Interestingly, many of the suggestions involved connecting the application to the user's broader context of care. Some participants would like to add family doctor and pharmacy information to the app because "*it would be easier if I can renew my prescription through the app*" and that will "*save more time*" (P27). Another user cited that it would be good if MAR had a page that held family doctor information "*so that you can call them easily*" (P4). In addition, some users would prefer to add their friends, families and people who are taking the same kind of medications "*adding friends would definitely be a nice feature*" (P18). Another participant pointed out that adding her family will be helpful: "*my children take medications as well, so it would be very nice*

to have all of them, to be able to monitor everything" (P19). P28 mentioned she likes to add her friends who are taking medications, so they can see each other's points, and "*based on our points we can get emoji and then like competitive game*". P17 pointed that it would be good to have some third-party monitoring capacity "*a senior living alone and their children who live in a different house can check that they are taking their medications*". In addition, P17 said if MAR could send her a message when her mom took her medication "*I am her primary caregiver*" that would be helpful, so "*I do not have to worry about that*".

5.5.3 Rewards Suggestions

As most of participants found the reward feature an incentive, I asked participants about what kind of reward system they believed would improve medication adherence and be attractive to patients when MAR is connected with pharmacies. The majority expressed that the reward system would motivate them to continue using MAR *"I would care more about my medications"* (P2). Most participants cited cash-back and discount the best two types of rewards *"a discount is more effective"*(P25). In addition, another user was happy to check the app to see how much reward she got, and she mentioned "discount would be more rewarding" (P26). P18 stated *"I prefer a cash-back because that you can use towards anything….and, I will definitely download it in the future".* A few participants prefer other kinds of rewards, for example; *"free session with my physician"* (P3). Two participants suggested using both reward and penalty together "*mix them together, it will be amazing*" (P23).

CHAPTER 6 DISCUSSION

This section discusses the results obtained during our four-week field study. The purpose of the study was to study the impact of introducing persuasive technology, rewards and penalty into a Medication Reminder App and investigate which persuasive technology is more effective and more accepted by users. In this section, I will present a discussion of the results of introduction of rewards vs penalty feature, and the MAR features that proved most impactful.

6.1 Mobile Reminders and Persuasive Techniques Promoting Medication Adherence

The findings of this study support the first hypothesis is this research that mobile reminder techniques enhance participants' medication adherence level. Out of the 30 participants in this study, 28 exhibited low initial MAQ scores and only one participant used a mobile reminder app prior to introducing MAR. This indicates that the need for using technology as reminders hold a potential for effectiveness which was supported by the results our study. Moreover, introducing persuasive technology, mainly rewards, was found to be novel, interesting and agreeable for participants, as P27 articulated: "*it is something new, encouraging, and it is like a game*". These factors were central for effectiveness of the mobile.

This study contributes to the available literature by investigating whether adding rewards and penalty features to a medication reminder system improves medication adherence. This study is unique since, to the best of our knowledge, it is the first study to test the effect of penalty and compare it to the reward feature on medication adherence. The results revealed that using persuasive behavior change techniques in the form of reward and penalty was associated with better medication adherence when compared to the reminder only version. In general, this finding

aligns with the theoretical and empirical literature on the effectiveness of persuasive behavior change technique in improving health behaviors including medication adherence [12][14][34][36]. This study showed that medication adherence score was significantly higher with the use of persuasive techniques (rewards or penalty feature) than with the baseline version.

As mentioned, this is the first research that studies the effectiveness of penalty on improving medication adherence. The results showed that even though medication adherence score was highest with the penalty feature compared to the reward, most of the participants (6 out of 10) in the penalty feature favored reward feature to penalty. This finding aligns with the findings of Hannan et al [40], who referred the dislike to penalty to "aversion loss", which is the feeling of harm associated with loosing something, as P25 said "*It causes a little more stress than it should*" and P15 said: "*I found the demerit part a little annoying, nobody likes to know that they are making a mistake".* Hannan et al. [40] also referred the effectiveness of penalty (demonstrated by highest adherence scores in this study) to "Aversion Loss". Participants don't like the feeling of losing and hence exert more effort to meet the goal which was taking medication on time, as P22 said "*When I see demerit points…. I feel upset …. I don't want to lose any more point*". P28 said *"If I skip my medication, I will not lose any point, while in the penalty feature I will lose points, so I will be more careful not to lose any points".*

6.2 Individual Variations in Accepting Different Persuasive Features

The findings also showed individual variations among participants in their acceptance of the persuasive features introduced: penalty or reward. Among participants of the reward feature, two out of the 10 participants said that they were indifferent towards rewards. Among the 10 penalty feature participants, four said that they liked penalty and six expressed that they favored reward to penalty. This finding of variation in individuals' responses to persuasive features was

also addressed by Orji et al. [14]. Orji et al. revealed that people's personality traits have a determining role in how they perceive and interact with persuasive technologies. Orji et al. [14] showed that people who are agreeable, extroverted and more open to experience are more acceptable of persuasive technology including reward and penalty feature. Whereas individuals who are neurotic are less acceptable of rewards and penalty feature. On another note and as mentioned in the recruitment section, participants of this study were Android mobile phone owners. The evidence showed that owners of android tend to be agreeable, and as Orji et al's agreeable individuals are more accepting of reward or penalty. This might explain why the majority of our participants in both MAR-2 and MAR-3 (18 out of 20) verbalized acceptance and agreeability to either of the persuasive features (reward or penalty). Whereas the literature and Orji et al. did not study why some participants prefer a specific persuasive feature (for example reward over penalty or penalty over reward), the findings of this study showed that our participants favored one persuasive feature over another (generally rewards were more favored). It might seem logical that the personality type and features might explain users' preference of persuasive techniques, but this is beyond the question and the data collected for of this study. As such, this research implications specifically for research studying personality-driven persuasive technology.

6.3 Persuasive Technology and Sustainability of Medication Adherence Behaviour

As mentioned in the literature review section, persuasive technologies are introduced and studied not only to improve health, but to create better habits or performing and sustaining a medical routine [13]. When it comes to comparing the habit of medication adherence over time (weeks) between the three MAR versions, our data did not show a statistically significant difference. However, individual participants in each version exhibited different pattern of

adherence level changes when it comes to improvement and sustainability of improvement. Our findings showed that six participants in the reminder only exhibited same levels of adherence in week 3 which then decreased in week 4. Seven participants in the rewards feature exhibited an increase in adherence level in the third week that was also sustained to the fourth week. While participants in the penalty feature exhibited highest adherence levels, three participants showed a decrease in the adherence level in the third week, followed by increase in the fourth week. So, improvement was achieved initially in the three versions, but was only sustained with the rewards feature. Imperative to mention the literature supporting the role of persuasive technology in sustaining behavior and medication adherences is mainly theoretical [13], and not empirical. The findings of this study are not conclusive as they were not statistically significant and also the duration of studying the sustainability of behavior is limited to two weeks. The implications of our findings hold research one for studying the impact of persuasive technology: reward or penalty or both on improving and sustaining health behaviors in general and medication adherence in specific and over longer periods of time. The importance of longitudinal studies to determine the impact of persuasive strategies in sustaining behaviors was emphasized by Klasnja, Cocsolvo, & Pratt [49], who suggested at least 24 months longitudinal study with frequent follow ups.

Considering the fact that this is the first study that studies the effect of penalty feature, these findings hold implications for conducting more studies on the effect of penalty and how it can be strategically implemented to stop unwanted behavior and promote a wanted behavior. It also necessary to investigate who penalty works as for different personality traits for and in what context. Moreover, if the penalty proved effective in improving medication adherence at one point but could not achieve sustainability along with being psychologically rejected as a concept, then investigating the effect of combining both ‘reward and penalty features’ is worth studying. As

mentioned in the literature review, penalty is associated with loss aversion which induces individuals to exert more effort so as not to live the feeling associated with loss. Also mentioned the reciprocity effect of reward, where by individuals consider reward as a fairer option, and hence expert effort to meet fairness, which can parallel the work they do prompted by loss aversion. So, theoretically idea of combining rewards and penalty features might result in: 1) because of penalty and the need to avoid the loss aversion, participants will do an effort to take the medication, 2) because of the reward, participants will be more conscious and motivated to take the medication on time. This theoretical analysis holds both practical and research implications. The practical implications include designing a medication adherence reminder that incorporates both features where users lose five points if they miss a medication, and they gain five points if they take a medication on time. The research implications are investigating the adherence level and also exploring how each feature psychological motivates participants to avoid penalty and seek rewards.

6.4 Monitoring: An Effective Persuasive Feature

Monitoring as a persuasive strategy in this study was provided when the users accessed their medication log and visualized through colors when they took their medication (green color) and when they missed them (red color). Monitoring which was color coded was described by most participants as very helpful "*it was encouraging me*" (P5). The literature recognized the existence of monitoring through a medication log in some applications but not all, and most existing applications did not specifically evaluate the effect of the medication log by itself. Our participants expressed that this tool helped them in keeping track of their medication history "*it kept me on track of taking my medications*" (P6). Another participant mentioned "*couple of times I had deleted the notification, either purposely or accidentally, and I was waiting, did I take it, especially the*

night one, so it was definitely helpful" (P17). Another tracking feature in our app is the monitoring of the number of pills taken. One participant elaborated that this feature is specifically helpful in cases where doses change with the condition of the patient such as with diabetes where the dose of the medication change with sugar level. She commented that having a log serves as a tool for communicating with physicians and this will be helpful in adjusting the whole dosage regimen (P6). This stresses the need to incorporate the medication log in every app and on the need for evaluating its effectiveness. Of specific practice and research implications is the significance of logging the number of pills taken in medical cases where patients don't follow a fixed dose (such as with diabetes) or even fixed schedule (such as with pain medications). Keeping this log of doses is instrumental for improving communication between patients and their physicians or adjusting their medication doses.

6.5 Technical Issues

The literature also identifies some technical errors associated with mobile reminder applications including frequent application crashing. The challenges associated with the application in our study were mostly user related and being a newly designed application and tested for the first time, were mainly dictated by the design of application. By design, for the application to operate, it should be kept running on the background with the icon showing on the screen at all times. The findings showed that users in this study did not like having the application running at all times, and they expressed inconvenience when needed to manually open the application if for any reason it was closed. Some forgot to restart the application, and some neglected to reopen it.

Another finding related to users was the decision of a few participants to disable the location tracking feature, which was identified as a privacy issue or as not wanting to be bothered by reminders when out of home. The implications these user related findings hold is that it is

necessary to identify the preferences and expectations of users from technology. Also, how far they would permit health-related technology and, apps into their personal space such as showing on the screen of their personal phone and when they choose to change physical locations. These parameters are important to take into consideration when designing apps and incorporating specific features because they are their effect are so powerful that some participants in our study decided to completely stop the feature or the application.

6.6 Methodological Reflection

In this thesis, I employed different and various data collection methods; at different times of the study: pre-, during, and post the study; and employed both quantitative and qualitative data types and analysis. As this is essential for the validity and rigor of my study, it was associated with a level of complexity that was challenging and interesting for me as a researcher. I faced several challenges but also became more interested and curious as the findings started to show.

- Recruitment was challenging as it was hard to recruit the number of participants needed, and employing different recruitment methods was necessary of which the most effective being face book. Compensation for participants was already set from the beginning and was instrumental.
- Testing a previous application designed by another previous student had its pros and cons. It was very helpful as it was the main tool of the study, but the limitations were included that I could only recruit Android users. As suggestion for future students work, it would be helpful to identify the typical inclusion criteria of participants and design or re-design the application to capture the intended participants.
- The employment of different types of data collection and at different points of time rendered the data very complex to analyze. It was complex and stressful for me as a student to figure out which analytical methods to use and which types of data to compare. This was a section

that I received support and guidance from my supervisor, which was very helpful. Nevertheless, it was a very stressful phase, and I would suggest for future students to discuss and agree on data collection and analysis methods that would serve to support the hypothesis with their supervisor and committee prior to initiating data collection.

- It was also quite helpful to present my methodology and work at the GEM lab, as this provided lots of ideas from my supervisor, other professors and students. This was very helpful for the analysis and also for the discussion chapter.

6.7 Limitations

This research explored how basic motivational/persuasive strategies (reward and penalty) can improve adherence to medications if added to a typical reminder-based mobile application.

- Perhaps the most prominent limitation of our study was that the application had to be running in the background. Several participants forgot to reopen the application after a phone restart in order to receive notifications, and this was not detected by us until the weekly questionnaire was received.
- Another limitation was that not all interested participants had Android; this considerably extended the recruitment period to get enough participants.
- I had no process in place to ensure that only when participants took their medications, that they entered this data. Users controlled the data they logged in, so if they choose to enter fake data of taking medications, the app does not provide any feature of figuring this behavior. Moreover, the database also does not provide information of whether the log in was by clicking on notification or not. As this might be a limitation, few participants communicated in the interviews that at times they entered taking medications after some

of receiving the notifications, but that they only did that when they really took the medication and not when they missed taking it.

- The sample size was limited, a larger sample size might be helpful to generate more statistically sound findings.
- The duration of the study was limited and thus it was hard to evaluate the effect of the persuasive feature on the sustainability of new behaviour. Klasnja, Cocsolvo, & Pratt [49] considered that claims about the effectiveness of technology in changing behaviour can not be made unless longitudinal studies were conducted. Marcus et al. [50] identified the duration of longitudinal studies to be at least 24 months. They also emphasized the importance of multi-year studies with repeated follow-ups to identify whether behaviors were sustained.

6.8 Future Work

In this section I will provide the implications for future research studies based on our findings and discussion section.

Since this might be one of very few studies (if not the first) that addressed the impact of penalty in medication adherence level, and it compared the impact of penalty to that of reward, then I suggest future work on further studying the impact of penalty. Suggested future work to address the limitations addressed in the above sections including the number of participants and the duration of the study.

In the discussion section, I addressed the effect of both reward and penalty. Participants in liked the persuasive features, and only two were indifferent for having a persuasive feature. However, participants who liked persuasive feature preferred reward feature to penalty. In the

discussion, the evidence supporting personality type as an explanation for accepting persuasive technology was presented. However, the literature does not provide an explanation of why some people prefer rewards to penalty or vice versa, so future work studying the personal factors that determine persuasive technology type preference is introduced.

Moreover, the findings showed that penalty were most effective, and this was theoretically explained by the concept of loss aversion. However, even the participants who did well with penalty expressed a psychological distaste and preference for rewards. So, the suggestion for merging the two features of rewards and penalty and studying their impact for future work was introduced in the discussion.

Other persuasive technologies are pivotal and were also suggested by our participants, including sharing. Sharing occurs when patients post their progress towards the goal and share this information with friends and family members through an app or through a link to social media [7][31]. Thus, future work of studying sharing and its impact on improving medication adherence is another suggestion.

Last, the importance of longitudinal studies to be able to determine whether the application could change and sustain behaviour.

CHAPTER 7 CONCLUSION

In this thesis, we presented the design and evaluation of three versions of a mobile phone app for promoting medication adherence called MAR. The primary objective of the study was to explore the impact of the persuasive techniques of reward and penalty on medication adherence. Our reward and penalty mechanisms were designed in consultation with partners in the pharmaceutical industry, who saw potential in offering loyalty rewards at a pharmacy for medication adherence. In a four-week field study conducted with 30 participants (10 users for each version), we find that most participants found a reminder application to be at least somewhat helpful for medication adherence. Adding reward or penalty as a persuasive technique reduced variance in adherence across participants; participants in the penalty condition in particular reported that it was effective in promoting compliance during the study. Interestingly, most participants across the three experimental groups felt that reward points were preferable to demerit points.

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Appendix A – Consent Form

CONSENT FORM

Project Title: Medication Adherence Reminder (MAR)

Lead researcher

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Supervisor: Derek Reilly, Faculty of Computer Science, reilly@cs.dal.ca

Student: Fatimah Alshammari, Faculty of Computer Science, ft997770@dal.ca

Introduction:

We invite you to take part in a research study being conducted by research group at the Faculty of computer Science at Dalhousie University. Taking part in the research is up to you; it is entirely your choice. Even if you do take part, you may leave the study at any time for any reason without penalty. To leave the study, please contact Khalid Tearo (tearo@dal.ca). The information below tells you about what is involved in the research, what you will be asked to do and about any benefit, risk, inconvenience or discomfort that you might experience.

Please ask as many questions as you like. If you have any questions later, please contact the lead researcher.

Purpose and outline of the research study:

We invite you to take part in the exploration of the Medication Adherence Reminder application (MAR). The research considers what factors influence the adoption and effective use of

smartphone medication adherence applications. In particular, we are assessing the impact of "smart" notifications and point-based rewards on medication adherence behavior.

What is MAR?

MAR is an adherence reminder application for mobile phones, developed by a group of researchers at Dalhousie University. This application provides features designed to encourage you to take medication as prescribed. MAR has two versions with different features, and you will use one version during the study. MAR-I provides a reminder when it is time to take medication, and MAR-II provides a smart reminder and collect reward points.

MAR is intended to supplement rather than replace your existing methods for taking medication; while participating in the study **you will continue to use any existing aids** (including other reminder systems, pill boxes, etc.). **You are evaluating an early version of MAR, do not rely on it to provide medication compliance support.**

Before joining the study make sure that you:

- Are taking medication in pills form.
- Are using Android device with data plan.

How many people are taking part in the study?

We are aiming to recruit 30 participants in total, 10 people per version of MAR.

What you will be asked to do:

To help us understand what factors influence the adoption and effective use of smartphone medication adherence applications, you will first be asked to complete a questionnaire about your current medication adherence behavior. After this one of the MAR versions will be installed on your smartphone, and you will be trained on how to use it. Using MAR will involve recording when you take your medication, but the specific details will vary depending on the version you are

using. You will use MAR for 4 weeks and will complete a short questionnaire once a week. After the 4-week period you will complete an interview to gather your overall feedback about MAR (your responses will be audio recorded) and you will be told how to remove MAR from your mobile device.

The entire study (from initial meeting to the final interview) will last 5 weeks. Khalid Tearo will be available by phone and email to answer any questions about the study or help with any problems you have when using MAR.

All personal data will be kept private and will not be shared. If you agree to let us quote you in publications, we will use a participant ID number instead of your name. This consent form and all research data will be kept in a secure location that only the researchers can access.

Possible benefits, risks and discomforts

Participating in the study might not benefit you personally, but we might learn things that will benefit others. An indirect benefit of the study is to contribute to knowledge about the usage of non-traditional medication adherence tools. Based on our analysis, we may discover how smart reminders and rewards can impact adherence and identify new research questions. There is a slight risk of social embarrassment when participating in the study. Specifically, participants might feel embarrassed about a low adherence level, or about medication reminders appearing on their phone. Adherence data is only shared with the researchers: no data is shared between participants, and no group meetings/discussions are held. We anticipate a slight privacy risk associated with divulging medication adherence data, but such data will be treated in a strictly confidential manner and presented only in aggregate form in publications.

What you will receive for taking part in our study?

To thank you for your time, we will give you a compensation based on your study group. If you are in group A you will receive $50 gift card after the exit interview or at any time you decide to withdraw from the study. If you are in group B you will receive $40 gift card, and for compliance level you will receive additional compensation up to $10 after the exit interview or at any time you decide to withdraw from the study. If you are in group C you will receive $50 gift card, and for penalty points you will lose up to $10 max (if you are not taking medication on time), or at any time you decide to withdraw from the study.

Members of all groups will do the same daily tasks; the only difference is the features provided on each application version.

How your information will be protected:

We understand that your medication information is personal and sensitive. Only researchers involved in the study will have access to the collected data, which will be recorded anonymously by using participant IDs. All data will be stored in a password protected file server, and access will be granted only to principal investigators. No data will be shared with a third party. In rare cases, other authorized officials at the University such as the Research Ethics Board or the Scholarly Integrity Officer may have access as well. Questionnaire data will be retained for five years and after this timespan the consent forms and questionnaires will be shredded, and the electronic data will be deleted permanently from the system. Your identity will be anonymous to all other participants; no group discussions or meetings will be conducted. This means that *you will not be identified in any way in our reports*. The people who work with your information have an obligation to keep all research information private. Also, we will use a participant number (not your name) in our written and computerized records so that the information we have about you

contains no names. All your identifying information will be kept in a separate file, in a secure place. All electronic records will be kept secure in a password-protected, encrypted file on the researcher's personal computer [or on a Dalhousie University secure server.

No member of the team has any financial interest in the application being developed.

If you decide to stop participating:

You are free to leave the study at any time. If you decide to stop participating at any point during the study, please contact Khalid Tearo. You can also decide whether you want any of the information that you have contributed up to that point to be removed or if you will allow us to use that information. If you leave the study, no penalty will be applied, and you will receive full compensation based on your group. If you are in group A, you will receive a full compensation no matter at which stage they withdraw.

If you are in the group B, you will receive a full base compensation + whatever points you managed to collect.

If you are in the group C, you will receive a full compensation minus whatever penalty points you have.

Project Title: Medication Adherence Reminder (MAR)

Lead researcher

Khalid Tearo, Faculty of Computer Science, tearo@dal.ca

Other researchers

Supervisor: Kirstie Hakwey, Faculty of Computer Science, hawkey@cs.dal.ca

Supervisor: Derek Reilly, Faculty of Computer Science, reilly@cs.dal.ca

Student: Fatimah Alshammari, Faculty of Computer Science, ft997770@dal.ca

Please answer yes/no to each of the following questions:

All of the following are REQUIRED to participate in the study.

"*I agree to let you quote any comments or statements made in any written reports and I understand that the you will use participant ID number to refer to me instead of my name.*"	Yes No
"I understand that my responses during the final interview will be audio recorded, and that this is a requirement of participation."	*Initials:*
"I would like to be notified by email when results are published" *If yes, please give an email address:* _____	Yes No

"I have read the explanation about this study. I have been given the opportunity to address any questions. By signing below, I consent to take part in the study. However, I understand that my participation is voluntary and that I am free to withdraw from the study at any time without penalty"

Participant	**Researcher**
Name:	**Name:**
Signature:	**Signature*:***
Date:	**Date:**

Appendix B – Baseline Assessment MAQ

Participant ID (…)

Age
- o 18-25
- o 26-35
- o 36-45
- o 45+

Sex
- o Male
- o Female
- o Other

Please answer the following:

Name of medication	Number of medication		
	Morning	Afternoon	Evening
1-			
2-			
3-			
4-			
5-			

1. Do you sometimes forget to take your medication?	(YES / NO)
2. Over the past two weeks, were there any days when you did not take your medicine?	(YES / NO)
3. Have you ever cut back or stopped taking your medication without telling your doctor because you felt worse when you took it?	(YES / NO)

4. When you travel or leave home, do you sometimes forget to bring along your medications?	(YES / NO)
5. Did you take your last medicine dose on time?	(YES / NO)
6. When you feel like your medical condition is under control, do you sometimes stop taking your medicine?	(YES / NO)
7. Taking medication every day is a real inconvenience for some people. Do you ever feel hassled about sticking to your treatment plan?	(YES / NO)
8. How often do you have difficulty remembering to take all your medication?	Never/Rarely Once in a while Sometimes Usually All the time
9- What adherence techniques do you follow?	

Appendix C – Experience Sampling

Hello!

Did you take all your prescribed medications today?

YES / NO

Did you take all your prescribed medications yesterday?

YES / NO

MAR helped me in managing my medication consumption

- Strongly Agree
- Agree
- Undecided
- Disagree
- Strongly Disagree

Did you receive your notifications on a proper time?

YES / NO

Do you have any comment?

……..……
……..……..……..……..……
……..……..……..……
……..……
…….

Appendix D – Semi-Structured Interviews

A- How do you feel about your experience with MAR?

B- What features do you like the most about MAR?

C- What features would you like improve? How?

D- Did you feel or notice any change in your overall adherence level? Please describe?

Appendix E - Recruitment Notice

We are recruiting participants to take part in a research study that evaluates medication adherence reminder app. We are looking for participants who are following a long-term medication prescription, and he/she must be 18 years or older. We need participants who have android devices with a cell phone data plan.

The study will contain of **two sessions** and be conducted on the 4th floor of the Mona Campbell building, Dalhousie University, and each session will take around 30 minutes. In the **first session**, you will meet with a researcher to go over an introduction section of the study, ask you to sign a consent form to participate in the study and, you will ask to fill a questionnaire. Then, a researcher will download the app on your device, so you must bring your own phone (android) and show you how to use the application. You need to use the app for four weeks. **Second session**, after four weeks, you will meet a researcher again for the final interview, that will be audio recorded, and show you how to uninstall the app. Compensation is $50 (gift card) for completion of the study.

Appendix F - Recruitment Poster

--Research participants wanted--

Do you take long term medications?
Do you sometimes forget to take your pills on time?
Do you want to explore how an application using smart reminders might help?

We are developing a medication adherence reminder application. If you are interested in testing our prototype and you are:

- Are following a long-term medication prescription (3 months or more).
- Are above 18 years old.
- Use an Android smartphone
- Have a cell phone data plan.

If you are initially interested in our study and would like to know more details, please contact:
Khalid Tearo (tearo@dal.ca)

Appendix G – Participants Payment Receipt

Acknowledgment Receipt of Payment

I, , have received from as a compensation for my participation in the Medication Adherence Reminder research study (REB File Number: 2006-4055).

Participant's name:	Researcher's name:
Date:	Date:
Signature:	Signature:

Appendix H – Social Sciences & Humanities Research Ethics Board Letter of Approval.

Social Sciences & Humanities Research Ethics Board
Letter of Approval

March 03, 2017

Khalid Tearo
Computer Science\Computer Science

Dear Khalid,

REB #: 2016-4055
Project Title: Medication Adherence Reminder (MAR)

Effective Date: March 02, 2017
Expiry Date: March 02, 2018

The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans*. This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Sincerely,

[redacted]

Dr. Karen Beazley, Chair
