Motivational reminder model for medication adherence : an internalization approach

Zhang, Yaming

2021

Zhang, Y. (2021). Motivational reminder model for medication adherence : an internalization approach. Master's thesis, Nanyang Technological University, Singapore.
<https://hdl.handle.net/10356/154950>

<https://hdl.handle.net/10356/154950>

<https://doi.org/10.32657/10356/154950>

This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0).

Downloaded on 26 Apr 2023 14:23:44 SGT

**NANYANG
TECHNOLOGICAL
UNIVERSITY**

SINGAPORE

**MOTIVATIONAL REMINDER MODEL FOR MEDICATION
ADHERENCE: AN INTERNALIZATION APPROACH**

ZHANG YAMING

School of Computer Science and Engineering

2021

MOTIVATIONAL REMINDER MODEL FOR MEDICATION ADHERENCE: AN INTERNALIZATION APPROACH

ZHANG YAMING

School of Computer Science and Engineering

A thesis submitted to the Nanyang Technological University
in partial fulfilment of the requirement for the degree of
Master of Engineering

2021

Statement of Originality

I hereby certify that the work embodied in this thesis is the result of original research, is free of plagiarised materials, and has not been submitted for a higher degree to any other University or Institution.

30/07/2021

• • • • •

Date _____

Zhang Yaming

Supervisor Declaration Statement

I have reviewed the content and presentation style of this thesis and declare it is free of plagiarism and of sufficient grammatical clarity to be examined. To the best of my knowledge, the research and writing are those of the candidate except as acknowledged in the Author Attribution Statement. I confirm that the investigations were conducted in accord with the ethics policies and integrity standards of Nanyang Technological University and that the research data are presented honestly and without prejudice.

30/07/2021

.....

Date

NTU NTU NTU NTU NTU NTU NTU NTU
NTU NTU NTU NTU NTU NTU NTU NTU
NTU NTU NTU NTU NTU NTU NTU NTU
NTU NTU NTU NTU NTU NTU NTU NTU
.....

Miao Chunyan

Authorship Attribution Statement

This thesis contains material from 1 paper published at a conference in which I am listed as an author.

Chapter 4 is published as Yaming Zhang, Yang Qiu, Zhengxiang Pan, Xinjia Yu and Chunyan Miao (2021). Infusing Motivation into Reminders for Improving Medication Adherence. In: Meiselwitz G. (eds) Social Computing and Social Media: Applications in Marketing, Learning, and Health. HCII 2021. Lecture Notes in Computer Science, vol 12775. Springer, Cham. https://doi.org/10.1007/978-3-030-77685-5_33

The contribution of the co-authors are as follows:

- Professor Chunyan Miao and I discussed the research direction.
- Professor Chunyan Miao also provided detailed supervision to the research.
- I came with the key ideas and prepared the manuscript drafts.
- Mr Yang Qiu designed the reminder application prototype.
- Dr Zhengxiang Pan and Dr Xinjia Yu provided feedback to the initial idea and revised the manuscripts.

30/07/2021

• • • • •

Date _____

Zhang Yaming

Acknowledgments

Foremost, I would like to express my sincerest gratitude to my supervisor, Professor Miao Chunyan for her expert guidance, insightful ideas, encouragement, understanding and opportunities she had provided me during my master's journey. She has set me on the path of my choice to pursue my graduate study by research. I am grateful to have such an experienced yet caring supervisor.

I would like to thank Dr Shen Zhiqi for his suggestions and feedback on my research studies; my colleagues from Joint NTU-UBC Research Centre of Excellence in Active Living for The Elderly (LILY): Ms Jessica Chan, Dr Cai Yundong, Dr Yu Xinjia, Dr Zhang Hao, Mr Benny Tan, Mr Qiu Yang and Mr Wang Hao for helping me along the road. In particular, as a graduate majoring in biological science, I am thankful to Dr Pan Zhengxiang for inspiring me to step out of my comfort zone, and pursue meaningful research in this domain. I would also like to thank all the elderly test users who participated actively in my study; and everyone who supported me in different ways with my master's program.

Last but not the least, I would like to specially thank my parents for their relentless support in pursuing my research interests. They are my pillars in encouraging me to believe in myself and stay focused on completing my master's degree.

Table of Contents

Acknowledgments	6
Table of Contents	7
List of Figures.....	11
List of Tables	12
Abstract.....	13
Abbreviations	15
Chapter 1 Introduction.....	16
1.1 Research Background	16
1.1.1 Medication Adherence and Obstacles.....	16
1.1.2 Understanding the Cause of Medication Non-Adherence.....	17
1.1.3 Motivation as a Promising Approach to Promote Adherence.....	19
1.2 Research Problem.....	19
1.2.1 State-of-the-art Solutions to Medication Adherence.....	19
1.2.2 The Research Gap: Reminders for Intentional Non-adherence	20
1.3 Research Questions	21
1.4 Thesis Outline	22
Chapter 2 Literature Reviews on Current Medication Adherence Methods.....	24
2.1 Medication Adherence Approaches	24
2.1.1 Predictive Analytics.....	25
2.1.2 Convenience Access	26
2.1.3 Compliance-Packaging.....	27
2.1.4 Reminders.....	28
2.2 Comparison of Current Solutions	31

2.3	Summary	32
Chapter 3	Organismic Integration Theory: Implications and Applications	34
3.1	Theoretical and Empirical Background on Motivation	34
3.1.1	Intrinsic and Extrinsic Motivations.....	35
3.2	The Organismic Integration Theory (OIT).....	38
3.2.1	The Concept of Internalization	39
3.3	Practical Applications of OIT.....	40
3.3.1	Human Resource.....	41
3.3.2	Education	42
3.3.3	Health Behaviour	44
3.4	Summary	46
Chapter 4	Motivational Reminder Model (MRM)	47
4.1	Introduction and Overview.....	47
4.1.1	MRM Definitions and Concepts	47
4.1.2	MRM Design Methodology	49
4.2	The Internalization Process	49
4.2.1	Definition of the Four Stages in OIT	50
4.2.2	Examining the Relationship Between the Internalization Process's Four Stages	52
4.3	Goal Net Modelling Technique.....	53
4.4	Proposed MRM Approach for each Stage in the Internalization Process.....	56
4.4.1	Obtaining Initial Adherence for Amotivation to External Regulation.....	56
4.4.2	Utilizing Gamification for External Regulation to Introjected Regulation	57
4.4.3	Cultivating Health Values for Introjected Regulation to Identified Regulation.....	58
4.4.4	Coaching and Setting Role Models for Identified Regulation to Integrated Regulation.....	60
4.4.5	Similarities between Integrated Regulation and Intrinsic Motivation.....	61
4.5	Implementing MRM Approaches as Motivational Messaging in Reminders	62

4.5.1	Initial Adherence via Extrinsic Rewards	62
4.5.2	Gamification	63
4.5.3	Cultivating Health Values.....	64
4.5.4	Coaching and Setting Role Models.....	64
4.6	Summary	65
Chapter 5	Study I: Secondary Research on Motivational Reminder Design	68
5.1	Secondary Research Question	68
5.2	Identification of the Dataset.....	69
5.3	Dataset Evaluation and Discussion	70
5.4	Significance of Task Importance for Motivational Reminders	71
5.5	Summary	72
Chapter 6	Study II: Implementing and Evaluating Motivational Reminders	74
6.1	Introduction	74
6.1.1	Serious Health Games: Pumpkin Garden.....	74
6.1.2	Study Objective and Outline.....	75
6.2	Study Methodology.....	76
6.2.1	Study Procedures	76
6.2.2	Participants Selection and Grouping.....	78
6.2.3	Study Materials.....	81
6.2.3.1	MRM Design Implementation.....	81
6.2.3.2	Pumpkin Garden Health Game.....	85
6.2.4	Evaluation Criteria and Tools	86
6.2.4.1	Adherence Score	86
6.2.4.2	Behavioural Regulation in Exercise Questionnaire (BREQ-2)	87
6.2.4.3	Intrinsic Motivation Inventory (IMI).....	88
6.2.4.4	Phenomenography Approach	90

6.3	Findings	92
6.3.1	Comparing Adherence Score	92
6.3.2	IMI for Comparing Intrinsic Motivation.....	94
6.3.3	BREQ-2 for Measuring Internalization.....	95
6.3.4	Phenomenographic Analysis: Experience with Different Motivational Reminder Approaches ...	98
6.3.4.1	Amotivated → External: Introducing new behaviour with extrinsic rewards	98
6.3.4.2	External → Introjected: Making progress personal and relatable	99
6.3.4.3	Introjected → Identified: Instilling health values.....	100
6.3.4.4	Identified → Integrated: Coaching as a source of motivation for adherence and performance.....	101
6.3.4.5	Summary of Phenomenographic Analysis	102
6.3.5	Significance of Findings	103
6.4	Summary	103
Chapter 7	Conclusion and Future Work	104
7.1	Motivational Reminder Model (MRM)	104
7.2	Future Work	105
7.2.1	Motivational Agent.....	105
7.2.2	Knowledge Graph.....	106
7.2.3	Natural Language Generation	107
7.2.4	Incorporating Coaching Models into MRM.....	109
Appendix A:	Secondary Data Set	110
Appendix B:	Modified Intrinsic Motivation Inventory (IMI)	112
Appendix C:	Modified BREQ-2	114
Appendix D:	Free-form Interview Questions.....	115
References		116

List of Figures

Figure 1. Overview of Self-Determination Theory.....	37
Figure 2. Implementation Flow of Self-Determination Theory.....	38
Figure 3. Visualized Internalization Process in OIT.....	39
Figure 4. Motivational Quality Continuum on Human Resource.....	42
Figure 5. Extrinsic Motivation Continuum for Weight Loss Program	45
Figure 6. A Depiction of Relationship between the Stages of Internalization.....	52
Figure 7. Goal Net of the Internalization Process.....	53
Figure 8. Goal Net Model Components.....	55
Figure 9. Internalization Process by OIT + MRM Approaches Summarized in Goal Net.....	66
Figure 10. Roadmap of Study II	73
Figure 11. Motivational Reminder Application.....	84
Figure 12. Pumpkin Garden Game Screenshot – Water Wheel Minigame	86
Figure 13. Focus of Phenomenographic Research [97]	91
Figure 14. Mean Adherence Scores	93
Figure 15. IMI Average Subscale Scores	94
Figure 16. Examining the Change of each RAI Component (BREQ Subscales)	97
Figure 17. Outcome Space – the Process of Achieving Internalization	102
Figure 18. Knowledge Graph Model	106
Figure 19. Using Knowledge Graph for Smart Motivational Agent	107
Figure 20. Sequential Architecture of NLG.....	108

List of Tables

Table 1. Types of Medication Non-adherence.....	18
Table 2. Medication Reminder App Features and Descriptions.....	30
Table 3. Comparison among the Current Solutions.....	32
Table 4. Process for Internalization Continuum Regulatory Styles.....	43
Table 5. Motivational Elements from a Goal-Oriented Perspective.....	48
Table 6. Secondary Analysis – Participants who were not Promised any Rewards	71
Table 7. Secondary Analysis – Participants who were Promised Rewards	71
Table 8. Other Potential Factors from Secondary Analysis.....	72
Table 9. Study II Inclusion and Exclusion Criteria.....	78
Table 10. Different Pools of Messages to Facilitate Different Transitions	79
Table 11. Categorization of Participants by Study Group and Pre-study BREQ-2	80
Table 12. Study II Procedures.....	80
Table 13. Development of BREQ in Literature	87
Table 14. Adherence Score Mean Difference t-test.....	94
Table 15. IMI Subscale Scores Mean Difference t-test	95
Table 16. Relative Autonomy Index Improvement (Δ RAI) Mean Difference t-test	96

Abstract

Resolving the issue of medication non-adherence is a top priority in order to tackle chronic diseases effectively. State-of-the-art solutions for patients typically focus on medication reminders, which did not address the issue for those who intentionally do not adhere to their medications. At the heart of medication adherence is motivation; self-initiated healthy behaviours tend to generate long-lasting healthy effects alongside desired satisfaction. The challenge therefore lies in motivating individuals to adhere to their medication schedules.

This thesis proposes a utilization of Self-Determination Theory (SDT) to design a Motivational Reminder Model (MRM). The model builds on the well-established stages of internalizing new behaviour, a process documented in detail in the Organismic Integration Theory (OIT, a sub theory of SDT). Design approaches are proposed and then used to craft motivational reminders for each internalization stage. The motivational messages in reminders aim to facilitate individuals' transition to subsequent internalization stages. Through the concept of stages, the proposed motivational reminder takes a goal-oriented approach in facilitating the internalization process of healthy behaviour by introducing various forms of motivation at different stages, ranging from extrinsic motivation to self-determined motivation. Delivered through reminders, these messages aim to curb both unintentional and intentional cases of medication non-adherence.

Two studies are conducted to enhance and validate the motivational reminder model. Study I presents a secondary analysis which displayed evidence that supports the importance of extrinsic regulation, the first stage of internalization process. The secondary analysis results also uncover key insights for designing motivational reminders to be tested in study II. In study II, the effectiveness of the designed motivational reminders is evaluated, in terms of improving

adherence rate, increasing self-determination and shifting individuals to the more autonomous side of the internalization continuum. Study results conclude that the implemented motivational reminders according to the proposed model is effective in facilitating internalization which leads to improved adherence.

In short, the proposed MRM can be used to generate effective motivational reminder messages. In addition, studies presented in this thesis show promising results that support MRM's effectiveness in encouraging behaviour change through the internalization process.

Keywords: Motivation, reminder, medication adherence, self-determination theory, internalization, phenomenography, messaging, extrinsic, intrinsic

Abbreviations

MRM	Motivational Reminder Model
SDT	Self Determination Theory
OIT	Organismic Integration Theory
MR	Motivational Reminder
UMR	Untargeted Motivational Reminder
BREQ	Behavioural Regulation in Exercise Questionnaire
IMI	Intrinsic Motivation Inventory
PD	Parkinson's Disease
RAI	Relative Autonomy Index

Chapter 1 Introduction

1.1 Research Background

Healthcare demands have been on the rise in recent years. The government national health expenditure has increased from \$11 billion to \$21 billion between 2010 and 2016 [1]. Among all diseases, chronic diseases are the main burden to Singapore's healthcare system. Singapore's healthcare expenditure is set to continue to increase, as Singaporeans are living longer than ever before. In 2020, Singapore's current average life expectancy is 83.66 years [2], ranking fifth in the world for aging. The estimate of the average lifespan will continue to raise to 85.4 years by 2040.

At the same time, chronic diseases such as diabetes, cancer, hypertension, high cholesterol, have also risen rapidly. As Singapore's population ages, the demand for medical management of chronic diseases is also increasing, most notably with the increasing of national health expenditure. In response to the posed challenges, interventions must adapt to the needs of people so that healthy behaviours are consistently practiced.

1.1.1 Medication Adherence and Obstacles

For effective chronic diseases management, better treatment has contributed to the maximization in life expectancy. One of the practices of effective treatment is taking medications correctly [3]. Medication adherence means that the patients with diseases should act in accordance with the prescribed interval and precise dosage of the medications [4]. For example, patients with high blood pressure are expected to take drugs that lower their blood pressure every morning, as directed by their doctors. However, the behaviour of consistently adhering medications can be challenging.

Failure to comply with the correct medication-taking behaviour can lead to potentially dire consequences. Medication non-adherence leads to health deterioration, which may result in poor quality of life, rise in healthcare cost, further risk of treatment complications, comorbid diseases and possibly premature death. A large observational study found that patients with chronic diseases, such as diabetes, hypertension, high cholesterol, cardiovascular diseases and cancer, have significantly higher hospitalization rates due to the low rate of medication adherence [5]. For example, cardiovascular medication non-adherence increases the risks of morbidity and mortality [6]. Therefore, resolving the issue of medication non-adherence is a top priority, so that it is possible to tackle chronic diseases effectively.

Solving the problem of medication non-adherence may have a greater impact on the overall population health, compared to the discovery of new therapies [6]. However, almost 50% of patients who are having chronic conditions do not comply with their long-term prescribed medications precisely [7]. Non-adherence is a very common and multifactorial problem [8].

1.1.2 Understanding the Cause of Medication Non-Adherence

Medication non-adherence is usually caused by the lack of medicine access or forgetfulness, or more conventionally, the result of deliberate choice made by patients [6]. In fact, medication-taking behaviour is a complex health behaviour and very substantial literatures are available to describe its predictors and influencing factors. Factors can be patient-related, physician-related or health system-related [7]. From a patient's perspective, duration of treatment, disease severity and treatment complexity (e.g. drug type, administration route, dosage, drug-specific instruction) are important factors which negatively affect a patient's rate of drug adherence.

Easthall and Barnett [9] classify medication non-adherence as either intentional or unintentional. Unintentional non-adherence relates to practical barriers, such as physical deficiencies or memory related problems. Although this group of patients is willing to take

their medications on time and regularly, they are unable to do so due to lack of capability or opportunity. Unintentional adherence may also occur when there are multiple medications to keep track of, and higher dosing frequency per day [10].

In contrast, patients who have the ability, but make conscious decisions not to take medicines regularly are known to be not adhering intentionally due to perceptual barriers. These perceptual barriers can be based off beliefs or real-world considerations. Dunbar-Jacob and Rohay [11] who investigated into intentional non-adherence found that socio-demographic factors (age, race, gender, years of education, employment status) tend to be weak predictors, whereas socio-psychosocial factors (illness perceptions, health beliefs) have been recognized as more powerful predictors of medication adherence. Such studies have found that patients' conscious decisions to adhere to medication-taking behaviour is more useful than exploring their practical barriers. Table 1 below summarizes the types of medication non-adherence with some examples.

Table 1. Types of Medication Non-adherence

Types	Barriers	Examples
Unintentional	Cognitive deficiency	Forgetting to take medication; difficulty remembering to take all medication; forget to bring along medication and inability to understand how to take medication
	Physical deficiency	Hard to swallow capsules, pills or tablets
Intentional	Illness perception	Personal understanding of a medical condition and its potential consequences, e.g. more medicines leading to faster recovery (overdose) or less medicines generate less side effects (underdose)
	Health belief	Self-recovery without taking any medicine; active decision to forego the prescribed medicine;
Mixed	Cost-related	Drugs cost too much; inability to afford a prescription

1.1.3 Motivation as a Promising Approach to Promote Adherence

Adherence is closely interlinked with motivation. As studies have shown, more passive forms of adherence are attributed to “obedience”, while more active forms of adherence are attributed to “motivation” [12]. Kaisu et al. [13] also saw fit in classifying their patients using this active-passive adherence concept, painting actively adherent patients as “interested in healthy lifestyle” and passively adherent patients as “uninterested in their own health”, taking medications out of obedience. Unsurprisingly, actively adherent patients fared better than their unmotivated counterparts in terms of avoiding death or permanent institutionalisation [13, Fig. 2].

Self-determined empowerment is an important approach in promoting medication adherence, especially among patients who intentionally skip their medications. Borrowing words from Reach [12, p. 528], “*empowerment through patient education can be understood as a process that replaces obedience-driven actions with motivated choices*”. Suffice to say, motivation is one of the key determinants for medication-taking behaviour. Self-motivated forms of medication adherence can induce satisfaction whenever medicines are taken on time.

Taking a motivational approach to promote medication adherence increases the possibility of other forms of healthy behaviour to take place, which in turn adds value to the patient’s quality of life in addition to medication adherence. In contrast, low motivation leads to poor understanding of the diseases, low perception of the medical benefits, fear of side effects, and ultimately low perceived needs for taking medicines.

1.2 Research Problem

1.2.1 State-of-the-art Solutions to Medication Adherence

As reported by Nieuwlaat et al. in a comprehensive systematic review [14], there is extreme heterogeneity in the methods of dealing with medication non-adherence. In clinical settings, these methods roughly include but are not limited to health counselling, cognitive behavioural intervention, visual education and intensive hospital discharge plan. Solutions that attempt to

address the patients' needs are typically "mostly complex and not very effective" as the comprehensive systematic review concluded after screening 26,312 records and examining 182 randomized controlled trials with stringent requirements [14].

There is still hope for new innovations to ride on the advent of technology to solve medication non-adherence. There have been recent attempts at utilizing digital technology to develop more automated forms of interventions. The project titled 99DOTS¹ [15] deploys an intervention that only require a cell phone to receive calls. Enrolled patients who only need to dial the number on the back of pill package to log their pill consumption. However, there is no guarantee that the call will be made by patients who really take the medication. Reminders are also lacking; patients will only be reminded indirectly by their friends or family.

By utilizing smartphone technology, patients can be reminded more directly and effectively, which is also more feasible in approach in Singapore's context. One recent smartphone based innovation is UbiMeds [16], an application that aims to remind users when it is time to take their medicines. Upon consumption, the users need to acknowledge the reminder prompts on their phones. Such application typically utilizes the reminding function to overcome *unintentional non-adherence*, which leaves a research gap where *intentional non-adherence* may not be addressed properly.

1.2.2 The Research Gap: Reminders for Intentional Non-adherence

Reminders are effective when an individual unintentionally forgets to take their medicines. Hence, the research gap is identified as "lack of reminder's coverage for *intentional non-adherence*". Since reminder is a common approach in developing digital-based interventions in medication adherence literature, it appears to be a solid approach to incorporate further

¹ Direct Observation Treatment, short courses use mobile devices to enable real-time remote monitoring of daily medication inputs.

enhancements in attempt to improve adherence results. The enhancements should cover the research gap by focusing on curbing cases of intentional non-adherence with motivational techniques. As mentioned in chapter 1.1 above, motivational theories were shown to be an important aspect in medication-taking behaviour. The most helpful, actionable concept in motivation theory is *internalization*, where the process of accepting and integrating new behaviour as part of the self is formalized as several stages with exhibition of distinct qualities. In line with this direction, this research puts less consideration on adherence in clinical settings, as medical personnel are around to administer and verify medication on schedule while educating hospitalized patients. Instead, this research emphasizes on medication adherence during transitions period of care, particularly in an outpatient setting where patients are not under direct care of medical personnel.

As it currently stands, there is no detailed literature on promoting internalization stage-by-stage in context of medication adherence. This thesis aims to fill the research gap by taking a goal-oriented approach to help facilitate the internalization of medication-taking behaviour. The problem of medication adherence is addressed and refined at the individual level using different approaches for different stages of internalization, thus emphasizing medication adherence as a personal responsibility. The optimal outcome would be self-determined individuals stepping up to “take their health matters into their own hands”.

1.3 Research Questions

Two research questions answered by this thesis are:

Question 1 : What kind of approaches can be taken in order to facilitate internalization for medication adherence?

Question 2: How to design motivational reminders to facilitate internalization?

For the first research question, the research gap of understanding towards transitions between different stages of the internalization process is highlighted. Then, several concepts from literature are proposed as solutions to facilitate transitions between stages; in other words, encourage individuals to internalize their motivations behind adopting healthy behaviour. The whole internalization process is modelled using the goal net modelling methodology.

For the second research question, the modelled internalization process is recontextualized into reminder applications. Through asking “how does reminder applications help individuals internalize their motivations to adhere to a certain task”, a motivational reminder model is proposed and evaluated in two separate studies: a secondary analysis, and a phenomenography-statistical mixed method study.

The proposed motivation reminder model (MRM) outlines a set of approaches that can help facilitate internalization, satisfying the 1st research question. To address the 2nd research question, MRM is implemented into reminder applications with a motivational mechanism that promotes self-determined behaviour, extending reminders’ coverage to address intentional non-adherence on top of unintentional non-adherence.

It is anticipated that the work presented in this thesis will enable a wide range of reminder applications in various areas for healthy behaviour change such as physical exercise, healthy diet, smoking cessation and learning. This research also positively impacts future strategies to motivate healthy behaviours among individuals by presenting a practical approach in adapting the internalization process for a specific health need.

1.4 Thesis Outline

This research details the understanding of how motivational strategies work in health domain (including medication adherence), the design methodology of motivational reminders, and two studies that establish promising results for the effectiveness of motivational reminders.

Chapter 1 describes the background, the broad research problem and specific research questions. Chapter 2 reviews current medication adherence approaches and evaluates their strengths and weaknesses. Chapter 3 discusses the theoretical framework describing the internalization process of extrinsic motivation, its existing applications and potential for instilling healthy behaviour. Chapter 4 presents the Motivational Reminder Model (MRM), structured using the Goal Net modelling approach. Chapter 5 covers study I which utilized secondary analysis to confirm the viability of the proposed approaches in creating motivational reminders. Chapter 6 details study II and reports qualitative and quantitative results to examine how the proposed MRM facilitates the internalization process among study participants. Chapter 7 concludes the thesis contribution, limitations and suggests future research direction on the motivational reminder model.

Chapter 2 Literature Reviews on Current Medication Adherence Methods

Older adults frequently have several chronic diseases that require multiple medications. One out of four adults aged between 65 to 69 takes five or more prescription drugs (polypharmacy) to control their chronic diseases [17]. They may become frustrated and overwhelmed with all medications and cease to take them as directed. Forgetfulness, wrong dosages (overdose or underdose), fear of side effects, lack of correct medical knowledge, self-recovery mindset and costs are the main concerns to be observed for medication non-adherence. For patients with multiple chronic diseases who are under polypharmacy, medication adherence becomes more challenging to cope with.

This chapter explores the different approaches to tackle medication adherence. This chapter focuses on two main aspects: current innovative medication adherence approaches and their strengths and weaknesses.

2.1 Medication Adherence Approaches

Today's rapidly changing healthcare scene saw the advancement of technology, the utilization of big data, increased patient engagement and increased motivators that drive development of solutions for medication non-adherence. Traditional methods to assess adherence include patients' self-report, pill counts, pick-up or refill rates and biological monitoring. Recently, the assistance of electronic devices has expanded the scope of tackling the problem of medication nonadherence.

More shifts to value-based care requires a more holistic approaches to ensure that patients are engaged and complying with their medication-taking behaviour. Many solutions have proven to have great potential in improving medication adherence.

2.1.1 Predictive Analytics

Predictive analysis of population health is a data-driven approach to anticipate the likelihood patients' medication nonadherence. Predictive analytics helps identify patients who are at high-risk of medication non-adherence based on their established likelihood using predetermined characteristics [18]. The examples of predetermined characteristics are low educational level, low socioeconomic status, existence of multiple chronic conditions and history of diseases, which are highly associated with medication non-adherence. Big data statistical techniques such as logistic regression, LASSO regression and random forest-generated models are applied to observe the incidents of medication non-adherence.

Predictive analytics also improve medication adherence by using medication prescription data (includes inpatient, outpatient and prescription medication). In a study that investigates lipid-lowering medication adherence [18], researchers identified patients who are likely experiencing problems with medication persistence between their initial dose and last dose. Through such early predictions, it is possible to determine who may more likely encounter adherence problems.

Datasets of non-adherence indicators are important to allocate the most appropriate intervention. The indicators, such as drug refill dates, days of therapy, medical bill claims, health records and other health related data, produce insights by leveraging on predictive analytical models. First, it provides information about patient demographic for tailoring customized intervention, so patients may reap maximum benefits from the intervention. For example, patients who are identified earlier will be helped to reduce their clinical inertia and improve clinical outcomes, thereby promptly achieving the treatment goals outlined in the clinical guidelines [19]. Second, it helps to timely predict and determine which patients are in need of long-term medication. Thus, early prediction and identification of patients who are at high risk of medication non-adherence helps determine the right strategies for these high-cost

health services; and plan the best intervention to ensure medication adherence [20]. Predictive analysis methods help translate the adherence results into strategies, so that the patients are engaged earlier for medication adherence interventions.

In short, predictive analytics enable healthcare systems to proactively identify patients at risk of non-adherence, then recommend suitable and matching interventions for improving their medication adherence in time. Therefore, predictive analytics can be a very effective preventive method to help minimize medication non-adherence among patients. There is a growing trend in pre-identification of patients at risk of medication nonadherence. Healthcare providers then plan and design an effective medication adherence strategy. The benefits of predictive analytics allow timely engagements in adherence-improving interventions and prevent the further complications caused by medication nonadherence. However, sharing of personal data and data integration may involve the third-party vendors, which require stricter security and data protection measures.

2.1.2 Convenience Access

Nowadays, patients do not only require quality services, but also convenient services that save non-monetary costs such as time and effort [21]. Due to the accessibility of the internet, online consultation services are growing at a fast pace. As new technologies become more widespread, access to visual consultation and medication delivery can either make or break a patient's adherence to their treatment plan.

One of the most common reasons patients stop taking medications is because they stop seeing their doctors [7]. In some cases, medication refills are dependent on in-person doctors' visits. Through consultations with health professionals through telemedicine service, patients are able to access a wider variety of options for disease consultation and medication refilling. Such telehealth services focus in providing convenience in order to increase patient satisfaction, as

a result improving medication adherence. Therefore, convenience access has a positive and significant impact on patient satisfaction towards medication adherence by gaining better knowledge of medicine in a more convenient way than traditional doctor visits.

The use of mobile health is not only limited to an application on a mobile device. It can also involve sensors to monitor health status. Another concept of convenience access can be the way of obtaining the medicine refills through mobile health. For example, the development of mobile application, PillPack helps arrange medication deliveries to patients' homes, with each medication packed based on the prescribed dose and delivered based on prescribed schedules [22]. This kind of innovation automates the whole process of medication refilling, thus making it more convenient and easier. Therefore, it is more convenient and effective to access medication, lowering the requirement on the patient's side. As a result, it helps to minimize the problem of medication non-adherence. However, such interventions are only useful for unintentional non-adherence, but not for intentional non-adherence.

2.1.3 Compliance-Packaging

Addressing medication adherence with right amounts of medicine intake through compliance packaging is an alternative approach. Medications may incur risks of side effects, complications or even permanent death due to wrong dosages. Therefore, it is critical to ensure that patients adhere to the correct dosage of medicines. It is estimated that medication non-adherence affected approximately 28% to 31% of patients with hypertension, hyperlipidaemia and diabetes in United States, while the usage of electronic drug packaging interventions managed to improve medication adherence [23].

Packaging interventions provide patients with a mechanism for self-monitoring on medication status, solve the physical barrier of taking the wrong dose, as well as prevent accidental or intentional overdose. In order to overcome the fear towards incorrect medicine dosages, many

compliance-packaging designs have been introduced to improve the adherence rate. For example, the use of smart blister packs can provide a visual indication of whether a patient is adhering to medication doses as prescribed. Another innovative form of compliance packaging to improve medication adherence is smart pill bottles, which is ideal for tracking instances of medicine intake as well as the dosage. Smart bottles work by using sensors and microcontrollers with predefined states. The smart bottle will not release another set of pills until the set time between two dosages has passed. It also allows third parties (e.g. caregivers) to monitor dose difference from the device [24].

Castellano et al. randomized 2,118 patients who were at the risks of cardiovascular disease. Patients who received the fixed-dose combination have the rate of medication adherence increased from 41% to 51% [25]. The study found that monitoring devices which incorporated smart dispensing capabilities that follow medication regimens can enhance the adherence rate by reducing patients' memory burden of their pill intake count. Hence, compliance packaging can be an exemplary method in medication regimen management.

2.1.4 Reminders

Reminders are the means of communication that can deliver the messages or a combination of any of the above. Reminders are useful when individuals need to remember routine tasks. Reminders can be in the forms of text, images and sound, taking shape in form of notes, letters, telephone calls, alarms and even in-person visits. With the advancement of technology, the utilization of reminder devices and reminder software are gaining higher acceptance rate and heavier usage rate than physical calendars, organizers, timers, cue cards and other types of traditional reminder tools.

Plenty of medication reminder applications help to automate notifications and track medication-taking behaviour, so that the patients are less likely to miss their pills. There is a

rapidly increasing number of medication reminders available on the market to support and improve medication adherence.

Here are three examples of free medication adherence applications that can be found in the Apple App Store. Pill Reminder – All in One (App) [26] allows users to track the reminding quantity of each medication and receive the alerts to take their pills, show a refill alert when pill count is running low and set reminders for medical appointments. These features are reflected in the four main buttons in the app: “*Medication*” button to add medication and set reminder, “*Reminder*” button to add medication and appointment reminders, “*Calendar*” button to have an overview of the reminders and trace past reminders, and “*Refill*” button to set refill reminders. This app also allows the users to email their medication reports to doctors from the app directly.

On the other hand, Medisafe Pill Reminder (App) [27] offers personalized reminders, drug interaction warnings, missed medication records, refill reminders, family scheduling tools, medication coupons and communication avenues with doctors. Both users and caregivers will get notification on tracked information. The app can be integrated with iPhone HealthKit to keep track of blood glucose, blood pressure, pulse, temperature and weight, and users are allowed to join in iPhone Family Sharing. The app helps users to discover and trace all medication related activities. Personalization options are also available, such as different types of notification ringtones and delivering methods.

MyTherapy (App) [28] is designed to aid the patients to stay in control of their own health. The app includes customized pill reminders, tracking, and health and exercise alerts. The charts help both patients and professionals to visualize the overview of adherence and progress. The highlight of this app is to help the professionals (doctor, nurse and pharmacist) support their patients to achieve their treatment goals.

Tabi et al. [29] reviewed 282 medication reminder apps from Google Play and Apple Store to support the patients in taking their medicines regularly. Common medication adherence functions are summarised as below [29] [30]:

Table 2. Medication Reminder App Features and Descriptions.

Feature	Description
History tracking	To record and track the medications and dosages taken accordingly.
Snooze option	To alert the users again when timely response is not possible.
Flexible scheduling	To schedule reminders to occur when and how with start and stop dates.
Refill reminders	To set the date and time when pills need to be filled.
Working offline	No internet connection is required for remaindering function and be able to work offline independently.
Data sharing	To export and share the medication information or data to family members, third parties or professionals (e.g., hospital, caregiver, doctor and parent).
Notification to others	To able to alter family members, third parties or professionals when to take medication or when if any missed doses are registered.
Multilingual	Many availabilities of different languages.
Rewards	To award the users when medication is taken on schedule.
Manage profiles of user	An option to input the medication profiles, such as patients' blood pressure, weight, pulse, symptoms of disease and medicine side effects.
Computer vision	Identify unknown pills through phone's camera.

2.2 Comparison of Current Solutions

Patients with chronic diseases are more vulnerable to poor health outcomes if they do not adhere closely to their medications. The process of sustaining medication adherence may be thwarted by challenges such as cost, side effects, the presence of polypharmacy, knowledge of the diseases, forgetfulness, cognitive impairments, ability to navigate the healthcare system, cultural and belief, reduced sense of urgency due to asymptomatic conditions (e.g., I don't feel sick) [31] and many more uncovered causes.

Patients vary across a continuum of willingness and ability to adhere medications. This variability among patients also extends to patients' different abilities to persist in medication adherence over time. As a result, promising medication adherence strategies must be patient-centric, multifaceted, and holistic, taking everything into account from lifestyle to beliefs. Among the characteristics, ease of educating patients about their conditions, including why and how to take medications could be the main factor for developing medication interventions. Continuous follow-up engagements with patients during the care process also help generate adherent medication-taking behaviour.

Low adherence or non-adherence is best tackled at the origin, at the patients' level. Based on current solutions, from patients' perspective, the constructs of *easy to use*, *easy to learn*, *easy to follow up*, *easy to engage* and *cost* are adopted to perform the comparison. Below is the summary table of the comparison among the four solutions to medication non-adherence mentioned in the earlier session:

Table 3. Comparison among the Current Solutions

	Easy to use	Easy to learn	Easy to follow up	Easy to engage	Cost
Predictive analytic	No, big data is needed	No, expert knowledge is needed	No, it is a long-term monitoring.	No	High
Convenience Access	Yes	Yes	Yes	No	Low
Compliance Packaging	Yes	Yes	No	No	High
Reminders	Yes	Yes	Yes	Yes	Low

Among all approaches, predictive analytic is more useful in alerting clinicians and professional of the likelihood of medication non-adherence and devising interventions before medication nonadherence occurs. The use of big data with expert knowledge helps detect the incidents of medication nonadherence and tailor personalized patient-centric interventions. Although helpful in the development of universal healthcare system, it has low accessibility to less established institutions. The cost of compliance packaging is relatively high, and it may become another form of barrier that prevents medication adherence. Convenience access also suffers from lack of engagement avenues to keep intentional non-adherence at bay. Hence from patients' perspective, reminders are the most suitable approach to encouraging medication adherence.

2.3 Summary

Medication reminders can remind users through delivering messages when they should take the specified medications at the scheduled timing. The delivery time and quantity of these push notifications are determined by user input. Sometimes, such reminder settings may lead to negative effects. Repeated messages do not stimulate self-determined interest in adhering to the reminders and eventually cause them lose interest in the activity. The reason may be

annoyance towards the repeated reminders, especially when they are pre-occupied or busy with other activities [32].

Thus, reminder features are important criteria for determining whether they will be continuously used. Features that determine the value of reminder apps include ubiquity, time-criticality, accessibility, convenience and personalization. The value of such reminder application can also be understood by the user experiencing the purpose behind the service. Many reminders are effective at improving the short-term activities or one-time events, such as dental appointment, lunch meeting, yearly health check and so on. However, long-term effects are not included in the consideration of existing reminders, especially for those that target medication adherence [33]. In addition, the mere presence of static messages in reminders have limited impact on goal-oriented behaviours, a much-needed trait in achieving medication adherence.

Motivational Reminder is proposed as a new form of reminders that generate long-lasting effect. To the best knowledge of the author, based on existing studies, there is weak exhibition of motivated experiences within current reminder platforms. Individuals' motivational experiences and perceptions of motivational reminder application are the main interests of the study. The MRM should be built based on theories that explain extrinsic and intrinsic motivation to maximize reward types by being adherent to medications. The next chapter examines one such motivational theory.

Chapter 3 Organismic Integration Theory: Implications and Applications

This chapter reviews Self-determination Theory (SDT), especially the theoretical and empirical background that supports the key components of SDT. This chapter also focuses on one of SDT's sub theories, Organismic Integration Theory (OIT), as well as existing applications of OIT. OIT appears to be a suitable foundation for MRM.

3.1 Theoretical and Empirical Background on Motivation

Motivation is the universal drive of an individual to internal or external stimuli that generates attention, interest and subsequently, action among individuals [34]. Different people have different types of motivation, and it is chiefly based on their interests. In an adverse health condition scenario, the goal is same for all individuals – to develop and maintain healthy behaviour that may improve their health condition.

“To be motivated” means to be moved to act on tasks, perform activities, behave in ways to achieve certain goals. It has been seen that motivation plays a critical role in the medication adherence. Conceptually, motivation can drive quests to achieve something purposeful in life through both emotional and behavioural constructs. The operational definition of motivation varies from situation to situation based on what the pursuit is. In this situation related to the research – where motivation is chosen as the key driving force – the definition of *motivation* can be very specific:

- Operational definition: A series of conscious drive or urge to achieve purposeful health betterment actions through medication adherence, experienced by a very rational and self-determined individual [35] [36].
- Constructive definition: A continuous process of motivation as being a regular part of achieving something of huge meaning and importance [37].

3.1.1 Intrinsic and Extrinsic Motivations

Intrinsic motivation involves doing something that is interesting, enjoyable and internally rewarding whereas extrinsic motivation occurs for instrumental reasons, such as monetary or tangible rewards [36]. To illustrate using employees' work motivation, employees who are intrinsically motivated stay longer at work because they believe that their work will make a great contribution to the organization or have a huge impact on society. In contrast, employees who are extrinsically motivated work harder due to annual performance bonus.

According to Deci and Ryan [38], extrinsic motivation creates short-term benefits easily, but its limitation lies in creating persistent behaviour change. Extrinsic motivation is to engage in behaviours for external rewards or punishment, such as logging in in to Shopee for daily coin rewards or avoid parking at loading bay to prevent any illegal parking fine. When people are driven by externally imposed rewards or punishments, they may feel pressured when deciding how to act. This consequence may cause people to experience little to no autonomy, but it generally creates short-term adherence out of wants and fears. Therefore, extrinsic motivation is best suited when attempting to get patients started in medication adherence, especially for those who intentionally decided not to adhere.

In contrast, intrinsic motivation is harder to achieve, but behaviours caused by intrinsic motivation are more enduring and long-lasting [39]. Intrinsic motivation is an inner drive that reflects the positive potential of human nature and elucidates the complexity of motivational life. Individuals become intrinsically motivated with permanent effects when they experience interest, satisfaction, pleasure, a sense of belonging and meaning, and personal achievement in doing a task [40]. As a result, intrinsic motivation can determine long-term medication-taking behaviour of patients that originates from their own volition, and should be cultivated and constantly encouraged along the way.

Motivation is a promising factor to enhance medication adherence through investigating how patients convince themselves to act, despite the difficulty in finding energy and effort to adhere to medication. Psychological well-being may make patients feel that they are in control their lives. The interplay of extrinsic forces and intrinsic values play a role in cognitive development to promote patients' well-being and the quality of their performance. These needs of human nature can be best addressed by Self-Determination Theory.

Self-Determination Theory (SDT)

Self-Determination Theory (SDT) highlights that both intrinsic motivation and extrinsic motivation are powerful driving forces in shaping personality developmental and behavioural self-management [40]. More importantly, SDT propositions posit that an individual must be self-determined to induce a lasting motivation. While the definition of an “self-determined” individual may vary, many can agree that a decision made by the self generally lasts for longer, generates better psychological health and effective performance [40]. Unlike other motivational theories, SDT maintains a full understanding of psychological development and well-being, which leads to desired outcome and gives the behavioural outcomes of psychological potency. This is because SDT allows people to feel in control towards their actions, choices, decisions, and lives.

SDT introduces the motivational spectrum ranging from *controlling* to *autonomous*. Likewise, SDT can explain motivational patterns in healthcare. It has been shown that SDT is a practical theory for applications in health domain [41][42]. Thus, SDT as a behaviour regulation theory is very relevant to applications in health promotion, disease prevention, and disease management.

Figure 1. Overview of Self-Determination Theory

The concept of “needs” within SDT intends to convey the essential psychological constructs that support motivation and wellness. SDT proposes three factors that enhance the level of self-determination, namely *autonomy*, *competence* and *relatedness* (see Figure 1). These three psychological needs are essential for understanding “*what*” (content) and “*why*” (process) of behavioural change [43]. They are also critical to promote intrinsic motivation, so that people will behave “for their own sake”. Motivated people are more likely to take practical steps towards addressing these three psychological needs.

Autonomy: to be the perceived source of individual’s own behaviour. Autonomy focuses on individuals’ need to feel in control of their own behaviours and goal. An individual is able to satisfy their autonomy by being allowed to make decisions independently without being forced by any external influence or pressure [44]. The individual is considered to have high autonomy when they act out of their own interest and integrated values.

Competence: to feel effective in individual’s ongoing interactions and express individual’s capacities. The concept of competence acknowledges an individual’s need to gain mastery of tasks and sense of accomplishment. Competence is achievable by practicing a certain skill regularly [41], which enables individuals to attain desired outcomes. As a result, people seek challenges to build their competence, to enhance their capacities and to develop skills that are important to them.

Relatedness: to have a sense of connection and belonging with others. The need of relatedness reflects the integrative human tendency of associating with other people. Relatedness focuses on the need to interact and experience care for others through their behaviours. The affectionate relationship with others is effectuated by making friends and creating trusted relationships [39].

People are able to become self-determined when their psychological needs are fulfilled, resulting in improved task performance and sustained effort to accomplish the task. Based on SDT framework, in order for a person to be motivated, their psychological needs of autonomy, competence, and relatedness should be met. These three psychological needs can be measured by the sense of choice, effectiveness in a given task and feeling of support and affection [45].

Figure 2. Implementation Flow of Self-Determination Theory

The implementation of three psychological needs (see Figure 2) helps to ensure the conditions that foster volition, motivation and engagement are met – setting the tone for the way medication-taking behaviour can be induced, in order to motivate people to work on improving their medication adherence.

3.2 The Organismic Integration Theory (OIT)

The *internalization process* of motivation is explained in detail by Organismic Integration Theory (OIT), a sub-theory of SDT. Deci and Ryan [46] suggested that motivation starts out to

be extrinsic, then gradually internalized to become intrinsic over time. This phenomenon of “internalizing” extrinsic motivation is known as the *internalization process*.

OIT outlines four stages as part of extrinsic motivation: external, introjection, identification and integration regulations, falling along a continuum of internalization [37].

3.2.1 The Concept of Internalization

Internalization is an integral and useful concept for cultivating new behaviour as deemed necessary by external forces. In Deci and Ryan’s own words [46, pp. 130–131]: “*The term internalization refers to the process through which an individual acquires an attitude, belief or behavioural regulation and progressively transforms it into a personal value, goal, or organization... Behaviors that the organism would not do naturally will have to be extrinsically motivated, but these behaviors may be integrated into the realm of self-determination (i.e., they can be valued and done willingly), even though they will never become intrinsically motivated.*”

From the description above, OIT posits that extrinsic motivation can be further expanded into four distinct stages that is in the same internalization continuum. The internalization process outlined in the OIT can be visualized in Figure 3 below:

Figure 3. Visualized Internalization Process in OIT

Expanding extrinsic motivation into stages of internalization accurately describes motivation for health-related behaviour like medication adherence. First, external prompts and incentives are used to encourage people to carry out an uninteresting activity. People then move in to introjected regulation, identify the value of activity and lastly integrate the regulation with their sense of self. When this occurs, individuals will be autonomous when enacting this extrinsically motivated behaviour. The phenomenon of internalization is framed as a natural process that transforms external regulation in which motivation is regulated by external forces into integrated regulation in which the drive to act is more self-determined and self-motivated [47].

Deci et al. [48] describe that an environment which fosters self-determination helps individuals internalize, whereas a low autonomy-support environment causes mere introjection (i.e. taking in a value but not accepting it as their own). There are three facilitators for internalization: provide meaningful rationale, acknowledge self-conflict and presentation of request (e.g. using “can you” instead of “you must”). The more internalization of the extrinsic motivation, the more self-determined the individual will be when formulating the behaviour. With all three proven facilitators, the process helps to generate higher internalization, therefore higher motivation. Among three psychological needs, OIT emphasizes that the support of autonomy and relatedness are more essential to the process of internalization, which may ultimately lead to the autonomous choice of performing a task for its intrinsic perceived joy and value.

Each stage in internalization process is presented in detail in section 4.2 below, as this thesis explores how we can motivate individuals along each stage.

3.3 Practical Applications of OIT

OIT has shown to be a useful theory to help individuals internalize new behaviour. Currently, there is extensive use of the OIT in many domains including workplace, education, and healthcare.

3.3.1 Human Resource

For more than half a century, organizations have been discussing the benefits of empowering employees with a more meaningful and pleasant work environment by solving the problem of motivation in the workplace [49]. Internalization has generated important insights about work motivation to focus on the strength of job satisfaction in their work, which has always been a challenge for human resource departments. Human resources oversee all activities associated with the management in people [50] and serve as the link between management and employees. Understanding the psychological needs helps both researchers and human resource partners in internalizing their tasks following OIT's stages, boosting satisfaction in order to improve work performance, individual growth and well-being, and acceptance of organizational change through psychological adjustment.

Specifically, OIT has provided a fundamental frame of reference on how different levels of motivation can support employees' well-being and happiness at their workplace. It presented a paradigm to better understand the levels of motivation. Internalization based on OIT maps out the step-by-step transition process from amotivation all the way to intrinsic motivation. This process helps devise ways to achieve personal empowerment and autonomy support in order to improve work performance. In addition, employees are motivated towards psychological growth and are willing to take on more responsibilities [51].

The motivational quality continuum can be classified into lower and higher motivational quality in the domain of human resource, as shown in Figure 4 [49].

Figure 4. Motivational Quality Continuum on Human Resource

Motivational quality continuum exemplifies how the lower motivational quality is different from higher motivational quality using the taxonomy of employee motivation in the organizational terms. When the employee is amotivated, the quality of motivation is the lowest in which results in lack of interest and ability to work. When the employee is motivated intrinsically, the quality of motivation is the highest and exhibits better learning, productivity, persistence, performance and other positive traits [49]. The employees' increased motivational quality directly affects their work outcomes. These positive benefits help to further improve organizational commitment and loyalty.

3.3.2 Education

Many scholars have aimed to create intrinsic motivation for learning purposes. Self-determination is important for learners in educational setting, especially in devising educational needs support for learners. The ideal inherent characteristic of human nature is to be interested in learning and developing new knowledge [52]. The use of OIT to education explains that how students are more successful in terms of learning and succeed when they experience intrinsic motivation compared to extrinsic motivation.

Educators often introduce external forces in the learning process, such as close supervising, monitoring and evaluating to reward or punish the students in order to facilitate learning. However, the feelings of satisfaction, enthusiasm and enjoyment often give way to the feelings of anxiety, boredom and alienation under the external forces. As a result, students lack interest in what they have learned. In view of SDT, the overarching theory behind OIT, intrinsic motivation should be the preferred way to maintain students' inner interest in learning rather than imposing external forces.

Intrinsic motivation provides a sense of self-determination for learning. Despite that, the inner satisfaction or sense of pleasure does not come immediately. For example, students may not find any joyful involvement of memorizing anatomical terms right after biology class. They may be interested in anatomy only when they discover the meaning behind learning the subject. Hence, the use of external forces to facilitate learning remain popular as results are immediate. These are desirable advantages to preserve when switching to promoting internal motivation.

OIT specifies four different types of extrinsic motivations, which vary from the degree of students' autonomy support and the degree of relevance to classroom practice and learning outcomes (Table 4 [52]).

Table 4. Process for Internalization Continuum Regulatory Styles

Regulation Styles	External Regulation	Introjected Regulation	Identified Regulation	Integrated Regulation
Associated Processes	Salience external rewards or punishments	Satisfy internal contingencies, ego involvement	Find value or importance in an activity	Synthesize identifications with other aspects of self

Extrinsic regulation is an initiation mechanism to achieve initial learning outcomes, even if the environment is inherently not interesting, pleasure nor enjoyable for learning. On the flipside, Black and Deci's study reported that students with higher self-regulation had higher perceived competence and lower anxiety for the organic chemistry course materials [53]. Thus, evidence

supports that intrinsic motivation is more likely to have positive relationship with the better academic performance. Students who transited closer to integrated regulation are able to synthesize identifications with other aspects the self, thereby they become motivated intrinsically. As such, strategies for enhancing learning experience include providing choices and meaningful rationales for learning activities, providing relevant feedback and conveying cares and concerns to the students.

3.3.3 Health Behaviour

In recent years, more health behaviour change interventions start to emphasize theory-based framework [41]. The stages in OIT explains the trends in health behaviour to expand basic scientific knowledge and develop practical interventions. When people feel that their own decisions are supported, they are more likely to perceive that their needs are met to achieve healthy behaviour.

One of the most common healthy behaviours is physical exercise. Exercise adherence is recognized as a significant challenge, emphasizing the need for structured support for promoting the sustainable exercise over time. A meta-analysis has summarized 21 SDT strategies employed by other researchers [54], providing an overview on operationalizing SDT in health behaviour interventions. Namely, OIT (as a sub theory of SDT) provides a framework for specific behavioural strategies to support and promote internalization. Internalization focuses on the role of personal functionality and domain-specific forms of motivation to highlight health values as the ultimate goal to pursue.

Figure 5. Extrinsic Motivation Continuum for Weight Loss Program

Williams et al. [55] studied the weight loss program of 128 patients over 26 weeks. In the first 13 weeks of the study procedure, all the patients started with low-calorie liquid diet. In the second 13-weeks stretch, they took the normal diet. The data from program attendance and BIM change were collected for result analysis. The findings demonstrated that greater autonomous self-regulation in weight loss program led to better program attendance and greater reduction in BMI change. The findings also confirmed that the participants who were self-motivated in losing weight felt more self-driven to attend the program regularly. The results exemplified the close correlation between perceived need for support and weight loss treatment outcome. Thus, OIT helps to predict individual's motivation, and motivation predicts healthy behaviours and subsequently, health outcomes [55].

3.4 Summary

OIT's internalization unique constructs are identified as avenues to create suitable motivational elements for solving the problem of medication non-adherence. However, intrinsic motivation is not easy to reinforce effectively. Fortunately, studies have shown that extrinsic motivation may have its merits. Motivation can start as extrinsic and then become assimilated through the act of internalization (as outlined in OIT), eventually becoming more long-lasting like intrinsic motivation. In particular, breaking down extrinsic motivation into several sub steps may help us to discover some of these beneficial facets. It remains debatable whether extrinsic motivation can be truly converted into fully intrinsic motivation (see 4.4.5, p. 61); despite that, each step made in the internalization process still brings us closer to enjoying the best traits of both extrinsic / intrinsic motivation.

Therefore, with “enjoying good health” being an extrinsic motivator, a goal-oriented methodological way of achieving each internalization step is crucial in uncovering the benefits of intrinsic motivation.

Chapter 4 Motivational Reminder Model (MRM) ²

This chapter answers the first research question posed in section 1.3 above: *What kind of approaches can be taken in order to facilitate internalization for medication adherence?*

4.1 Introduction and Overview

Human behaviour is goal-oriented and purposive in nature [56]. In other words, individuals act for a reason and their behaviour is sensitive to changes in where their goal is set. Therefore, the MRM seeks a goal-oriented approach to model the internalization process as specified in OIT. This model assumes Human Computer Interaction (HCI) as a basis of interaction, in which the approaches in crafting messaging content is proposed. Individuals' heightened motivations as a result therefore drive their behaviour towards their goals [44].

This chapter presents a set of approaches to move people's stage of internalization towards the autonomous, self-determined end and away from the controlling end. It is anticipated that the development of MRM can further guide the future implementation of actionable, digital solutions to help people internalize new behaviour that can improve their quality of life. The four-approach structure of MRM is put to test by being used to craft motivational reminder messages that outperform their static state-of-the-art counterparts. However, it is hypothesized that MRM can be recontextualized into other health applications that have similar goals of promoting new healthy behaviour.

4.1.1 MRM Definitions and Concepts

The proposed MRM is modelled based on the internalization process from OIT, where the motivational elements consist of (R, A, M) to enable users to take on goal-oriented behaviour

² The work in this chapter has been published in HCII 2021. Yaming Zhang, Yang Qiu, Zhengxiang Pan, Xinjia Yu and Chunyan Miao (2021). Infusing Motivation into Reminders for Improving Medication Adherence. In: Meiselwitz G. (eds) Social Computing and Social Media: Applications in Marketing, Learning, and Health. Lecture Notes in Computer Science, vol 12775. Springer, Cham. https://doi.org/10.1007/978-3-030-77685-5_33

in a self-determined manner. Table 5 below provides a brief explanation and state-of-the-art overview for each motivational element.

Table 5. Motivational Elements from a Goal-Oriented Perspective

Element	Description	Development in Literature
R	Type of <i>Regulation</i> that generates motivation	Initially introduced by Deci and Ryan [46], extrinsic motivation is further divided into 4 stages of internalization. Each stage progressively defines more autonomous “regulations” that create more self-determined motivation.
A	Proposed <i>approach</i> to implement the next regulation in the internalization continuum	This thesis attempts to recontextualize various existing motivational methods in literature into “generalizable approaches” to facilitate transition at each internalization stage. The approaches aim to land people at the “integrated regulation” stage.
M	<i>Messages</i> for directing and reminding user’s action, crafted based on the proposed approach	This thesis places emphasis on using the approaches mentioned above to craft motivational reminders, hence the Motivational Reminder Model.

The motivational elements (R , A , M) are used in the following procedure, expressed in pseudocode below.

```

Set R ← determine_current_regulation(user_behaviour)
While (R has not changed) Do
    Set A ← determine_approach_based_on_regulation (R)
    Set M ← craft_message_based_on_approach (A)
    display_to_user(M)
    Update R ← determine_current_regulation(user_behaviour)
End

```

4.1.2 MRM Design Methodology

A set of design *approaches* (the *A* element in Table 5) is first proposed, aimed at generating the appropriate type of motivation to move individuals along each internalization stage. Then, 6 stages from internalization process are extracted, in which 5 are deemed relevant when crafting reminder messages. Next, for each transition along the 5 stages, 4 messaging approaches are proposed and fitted into the internalization process. These proposed messaging approaches aimed at facilitating progress of internalizing new behaviour, therefore pushing individuals to the next stage. These approaches are then implemented as motivational *messages* (the *M* element in Table 5). The content of messages seeks to inaugurate human mind to make positive choice of goal orientation. Lastly, the deployment of Goal Net modelling technique is further proposed in order to generalize a structure for motivational reminder.

The following sections explain the essential detailed components and mechanism of the proposed MRM using the internalization process for adhering to new tasks or behaviours.

4.2 The Internalization Process

Internalization describes a continuum of self-determination where three broad stages are defined: amotivation, extrinsic motivation and intrinsic motivation. The more a regulation is internalized, the more it becomes part of integrated self and the easier it becomes to behave in a more self-determined way. In other words, the person can be motivated to shift towards the right end of the internalization continuum.

Here we use healthy behaviour as an example to describe the stages of the internalization process. Although cultivating healthy behaviour is indisputably important for every human being, not every individual finds it intuitive or personally important to maintain healthy behaviour. Individuals are initially considered to be “amotivated” when they are not interested

in cultivating a healthy behaviour. When they see enough benefits from healthy behaviour, they move from an amotivated state to an extrinsically motivated stage.

4.2.1 Definition of the Four Stages in OIT

OIT proposes breaking down the “extrinsic motivation” state into four substates. These substates can be differentiated based on how the environment (stage 1) or the individuals themselves (starting from stage 2 and onwards) regulate their behaviour.

1. External Regulation means that most regulations come from external sources, Externally regulated behaviour is driven by the desire for reward and avoidance of threats or punishments [57]. It is the least autonomous form of extrinsic motivation. For instance, when people first start to engage in exercise activities, they found it easier to start if they had a free-access gym pass on top of advice on benefits of exercising. While benefits of exercise requires more internalization to drive behaviour, the free gym pass creates an instant invitation to “use it before it expires” [58].
2. Introjected Regulation occurs when the external regulation is remembered and recalled “as it is” to drive motivation for behaviour. In this stage, the external regulation needs not be fully present in order to have an individual respond with the new behaviour. The reasons for adopting new behaviour are considered to be the same as the External Regulation stage; the main differentiator being the absence of external motivators that starts the new behaviour in the first place. Introjection creates a dilemma people face when learning self-control, where the controller and the controlled are the same person. This is unlike External Regulation where the controller is an external entity [46, p. 136].
3. Identified Regulation describes a deeper form of internalization where self-determined behaviour is more prominent and autonomous motivation starts to build up [59]. This stage signifies a person identifying with the regulation itself instead of identifying with the authority that endorses the regulation. Once they are able to directly identify with

the regulation, they could then better appreciate the outcomes of the new behaviour that stems from the regulation. Less pressure and greater flexibility are experienced when carrying out the new behaviour [46, p. 137]; further studies also confirmed that identified benefits produce better outcomes than introjected benefits [38].

4. Integrated Regulation generates the strongest motivation out of the four and represents the last stage of internalization in extrinsic motivation. At this stage, the new behaviour or belief is comfortably integrated into a person's existing values. They would have come to terms with any pre-existing conflict between the new behaviour and their existing beliefs. Acting on Integrated Regulation means a person is now confident in understanding the consequences of their actions and is willing to quickly accept the consequences should they choose to carry it out. The belief in their own ability to judge the situation case-by-case and make sound decisions to act on indicates that self-determination has been achieved for this new behaviour in this person.

Exclusion of Intrinsic Motivation in the Design of Motivational Reminders

While Integrated Regulation involves integrating external behaviour (and its value in extension) into one's values, it is still categorized under extrinsic motivation. On the other hand, intrinsic motivation is defined as being motivated through pure interest, enjoyment and satisfaction emanating from the self. It is arguable whether something that originated externally can truly be internalised to the extent that motivation can be fully self-initiated. Despite the small differences in definition, Integrated Regulation and Intrinsic Motivation have been shown to both exhibit similar levels of self-determination [61, p. 1006] and hence produce similarly lasting behaviours. Thus, the process of transitioning from Integrated Regulation to Intrinsic Motivation will *not* be extensively explored for reminder model, as it is anticipated that the small differences between these two stages will no longer be in the purview of reminders.

4.2.2 Examining the Relationship Between the Internalization Process's Four Stages

Hagger et al. [62] presented OIT's internalization process as 4 independent "states of being". These different states appear to be different qualitatively as they satisfy discriminant validity. However, they still can be arranged on a continuum. One end of the continuum represents a controlling situation (i.e. low autonomy) while the other features automotive motives (i.e. high autonomy). Figure 6 below is extracted out from [62, p. 286], showing the relationship between each stage.

Figure 6. A Depiction of Relationship between the Stages of Internalization

Two states are positively correlated in the sense that if a person exhibits traits that indicate the first state, then they are likely to demonstrate traits that indicate the second state. An interesting observation surfaces from Figure 6: States that are adjacent to each other on the continuum show positive correlation while states further away show weaker correlations (until it becomes negative correlation). These traits suggest that the person is not "in one definite the state at a single point in time". Rather, these states function as actionable checkpoints along the self-determination continuum, on which researchers can then attempt to describe.

Hence to push an individual towards the *Autonomous* side of the continuum, it is necessary to take a step-by-step approach, using these stages established in OIT as the next goal to aim for.

As individual's inclinations shift along the continuum, the approach could gradually change to accommodate different qualities of each stage, easing them into the next stage. The step-by-step approach can be modelled using the Goal Net.

4.3 Goal Net Modelling Technique

Health behaviour change such as promoting medication adherence can be a complex process, but the internalization continuum with well-defined stages backed by literature provides a good starting structure. Goal Net is deemed suitable as a modelling technique for the internalization process.

Figure 7. Goal Net of the Internalization Process

While Figure 7 above looks similar to Figure 3 (see p. 39), there are new concepts being introduced. Goal Net as a modelling technique makes transitions along different states in the internalization process more actionable. This is because:

- Every state is modelled as a goal to be achieved, and
- Goal Net also specifies that action items are mandatory to transition to the next goal.

With this goal-oriented approach in mind for crafting motivational messages, existing literature on goal setting and specifically goal net is reviewed below.

Goal Setting and Goal Net

Goals direct attention and action. Goals tell individuals what the needs to be done and how much effort will need to be expended [63]. Specific goals increase performance while difficult goals generate a higher level of output.

Setting challenging but realistic goals enable successful behaviour change. This indicates that humans have a need to achieve goals, and thus humans are potentially willing to commit to difficult yet realistic goals. In this case, goal setting meets the physical needs of competency and autonomy, and generates a form of motivation with the maximum intensity. Accomplishment of goals can cause satisfaction to further motivate people or vice versa [64]. Hence, goal setting is very closely related to motivation. A model used to model goals will be beneficial in structuring the internalization process in a more actionable manner.

Goal Net is a modelling technique that adopts a goal-oriented approach in identifying steps to achieve and pursue goals [65]. Goal Net helps to facilitate the reasoning mechanisms for both goal and action selections. A general form of Goal Net can be denoted using a tuple (S , t , Arc , Br , $Token$) where:

- S is a set of goal states that are intended to achieve.
- t is a set of transitions that are used for presenting tasks.
- Arc is a set of arcs that connect goal states to transitions. It also specifies the relationship between goal states and transitions.
- Br is a set of branches as dashed lines to denote the boundary of sub-goals of a composite goal state.
- $Token$ presents dynamic behaviours of a process and the goal pursuing status as block dot.

A common Goal Net with the components mentioned above is illustrated in Figure 8 below:

Figure 8. Goal Net Model Components

Goal Net decomposes a complex task in a top-down manner, where the hierarchy of sub-goals is managed conveniently and comprehensively. Two types of goal relationship are presented in Figure 8 to link a starting goal to an ending goal: *Sequence* and *Choice*. Sequence transition demonstrates that the starting goal goes directly to the ending goal, while choice transition has a selection of variables from the starting goal to the ending goal, such as of S1 or S2 to S3.

Applying Goal Net to Model the Internalization Process

Here are practical suggestions when attempting to use Goal Net to enhance motivation. Firstly, a root goal needs to be broken down into other sub goals through state decomposition. Secondly, the relationship and process between the sub goals need to be specifically defined. These acts line up well with OIT; extrinsic motivation is broken down into 4 sub-goals which makes the internalization process more accessible with intermediate stages. Concrete approaches can then be derived from literature to facilitate transition between each sub-goal.

While OIT provides detailed descriptions of the stages throughout the internalization process, it does not explicitly state ways to help individuals transition along the states. Thus in this thesis, the action items for each transition are investigated in detail.

4.4 Proposed MRM Approach for each Stage in the Internalization Process

Motivational process should serve the purpose of assisting individuals quickly internalize a new behaviour, and gain more motivation to carry it out by their own volition. *In other words, individuals' transition along the internalization stages could be sped up by effective motivational reminders.* While the literature review of OIT above serves to introduce what are the stages of internalization and clarify the borders between each stage, this thesis attempts to further key into what can be done to facilitate transition along the stages before applying them into reminder applications for goal-oriented health behaviour. Reminders' potential in helping individuals internalize their motivations is realized using the OIT, specifically, the transitions between different states of motivation.

Various techniques that appear to be viable at different stages or transitions are highlighted below. These proposed techniques fill in transition gaps in the goal net (i.e. action 1 to action 5 in Figure 7, p. 53).

4.4.1 Obtaining Initial Adherence for Amotivation to External Regulation

- Transition: Amotivation (AMOT) to External Regulation (EXT)
- Proposed Approach: Offer Extrinsic Rewards to Obtain Initial Adherence

Adherence to a certain behaviour is a main outcome that reminders try to achieve. Adherence is defined as “the extent to which persons' behaviour corresponds with agreed recommendation from a healthcare provider” by World Health Organization [66]. Reminders can (and typically do) encourage a short-term adherence to a particular behaviour, especially if there are extrinsic rewards for the subject.

Below we illustrate how motivational reminders can be applied to encourage healthy behaviour. Healthy behaviour such as medication adherence may not be enjoyable and pleasant by

themselves, but individuals can be motivated to adopt healthy behaviours for their health outcomes. Thus, when getting an individual started with a particular healthy behaviour, messages presented need to serve its role as the “external motivator”; the call to action. This may be able to encourage willing (albeit forgetful) individuals to carry out the tasks successfully. However for individuals who were less motivated, more incentives typically need be paired with the reminders to get them started.

According to Deci and Ryan [46, p. 134], mastery of this stage is reached when the subject has proven to be able to:

- anticipate the external demands
- and control their own actions to adhere to these demands.

Anticipation defeats the purpose of reminder applications since if a person can anticipate upcoming reminders, they no longer need reminders anymore. Action control is still relevant in reminder’s context. Hence in reminder applications, mastery of this transition (i.e. the 2 points above) is synthesized into the following:

- The ability to consistently respond to reminders in a timely manner.

If subjects are able to consistently respond to reminders and demonstrate behaviour adherence, the reminder function should then transit to the next stage and start to help them introject their regulations. If subjects fail to adhere to reminders at the start, it may be a sign of continued amotivation. In this case, further extrinsic incentives should be explored to get them started with the healthy behaviour (e.g. free gym passes to encourage physical exercise [58]).

4.4.2 Utilizing Gamification for External Regulation to Introjected Regulation

- Transition: External Regulation to Introjected Regulation
- Proposed Approach: Utilize Gamification (more abstract forms of extrinsic rewards)

In this stage, the messages displayed by the reminder originate from real-world value, and orient more towards fulfilling psychological needs. Individuals who are under introjected regulation do things to avoid guilt and shame from the peer pressure [62, p. 285]. The contrary can be true when designing reminder messages; individuals can receive rewards that bolster their ego and self-worth.

Gamification is a concept that excels in reinforcing psychological needs. Gamification refers to the act of motivating beneficial (albeit uninteresting) behaviour through rewards like badges, points and achievements [67] without much compromise to the behaviour's requirements. These gamified elements are a prime example of psychological rewards; they are not as tangible compared to real world items, but they still create enough affirmation for the individual that can motivate them to maintain a healthy behaviour.

The practice of gamification is closely related to the SDT [43]. Various studies that apply SDT have retrofitted gamification elements onto cultivating healthy behaviour [69] or education [70] with certain success. Prior research supports the notion that gamification helps subjects introject the external demands of the task by providing rewards that affirm their efforts [71], [72]. Thus, it is fair to imply that these extrinsic forms of rewards provide a sense of satisfaction that is partially intrinsic to the individual, as they become invested into the “feel good” experience that is ultimately extrinsic. Reminder systems could utilize gamification at this stage to help subjects introject new healthy behaviour that they still perceive to be fully extrinsic (i.e. only for the benefits) up until now.

4.4.3 Cultivating Health Values for Introjected Regulation to Identified Regulation

- Transition: Introjected Regulation to Identified Regulation
- Proposed Approach: Cultivate Health Values (start introducing intrinsic forms of rewards)

While incentives and gamified rewards presented above are relatively extrinsic, health values can be explored as a form of intrinsic reward. The gamification approach proposed in the previous section is still relevant. It is believed that incorporating goal setting and health values into gamification help us to design reminder messages that is supportive towards individuals' autonomy. This maximizes subjects' chances of reaching the Identified Regulation stage and subsequently, establishes a long-lasting *regulatory schema* within the subject, reinforcing the behaviour as a persistent habit.

To reach this stage, the reminder system has to help subjects identify the value of their action outcomes [59] instead of having them simply follow along out of submission (external) or self-worth (introjected). In the case of healthy behaviour change, the subjects need to understand the health values behind the healthy behaviour they all the while have been led to do and set goals which are more related to their real-world health condition instead of arbitrary gamified rewards. The values behind their actions are the key differentiator for this transition, which makes it significant.

Thus at this stage, messaging content shifts away from *rewarding* the subject and towards *initiating action* for the subject. Subjects should be encouraged to set their own health goals in this stage. The reminder system can then provide timely reports of their health goals achievement process. Incorporating goal setting and positive health values into reminder messages help to explicate the positive experience of their actions, how their actions have benefitted them, and ease them out from the relatively “controlling” rewards provided by gamified elements without context. While the subject may keep up their behaviour to obtain gamified rewards in the Introjected Regulation stage, they now start to learn about the health benefits through the same process, and how their own participation and “investments” directly relate to their own beliefs.

4.4.4 Coaching and Setting Role Models for Identified Regulation to Integrated Regulation

- Transition: Identified Regulation to Integrated Regulation
- Proposed Approach: Coaching & Forming Imagery of Role Models (show motivated individuals how to do it)

When subjects have identified with the values behind their healthy behaviour, the last role for reminder systems is to help subjects visualize how they might perform well in behaving healthily, on top of curbing cases of forgetfulness. The rationale of choosing this approach is simple: once subjects agree that achieving certain behaviour is important to them. If they can see the way an ideal role model behaves, they are able to simply follow. It is important to note that this transition focuses on the “how” instead of the “why” in the previous stages.

Coaching is a promising strategy here in helping subjects achieve consistent adherence to new behaviours when they have already identified with the benefits of the new behaviour. According to Palmer et al. [73], coaching helps subjects improve performance or develop new skills through a rapid feedback loop of performance evaluation and goal-setting. On the other hand, imagery interventions add the perspectives to goal-setting and have been successful in improving levels of Integrated Regulation in encouraging people to exercise [74]. It is generally a well-accepted strategy for enhancing performance in the domain of sports. One of the sub-types of imagery intervention is centred around creating motivation through imagining flawless execution, scoring specific goals, along with the associated positive experiences felt upon achieving success [75, p. 9].

Thus, reminder messages for subjects under identified regulation could utilize coaching techniques to further motivate them to take action. Goal setting could be done by asking “what does a role model look like for this particular behaviour”. Messages could utilize role model

imageries (i.e. visualizations) to encourage the subject to take action, derive satisfaction from tasks done well, and ultimately “integrate” the healthy behaviour as part of themselves, thus achieving Integrated Regulation.

4.4.5 Similarities between Integrated Regulation and Intrinsic Motivation

Intrinsic Motivation is described as doing something out of pure satisfaction with full self-determination. While it is considered the ideal final source of motivation for behaviour change, studies are still inconclusive whether individuals are able to achieve full Intrinsic Motivation on an externally imposed behaviour, or are the long-lasting behaviour changes coming from Integrated Regulation. From Deci and Ryan’s own attempt to redefine the distinction between the two states:

“Integrated forms of motivation share many qualities with intrinsic motivation, being both autonomous and unconflicted. However, they are still extrinsic because behaviour motivated by integrated regulation is done for its resumed instrumental value with respect to some outcome that is separate from the behaviour, even though it is volitional and valued by the self... Yet, as implied above, this does not mean that as extrinsic regulations become more internalized they are transformed into intrinsic motivation.” [36, p. 62]

From a behavioural perspective, the border between integrated regulation and intrinsic regulation remains unclear. Thus, for the case of designing reminders, integrated regulation and intrinsic regulation should not be differentiated. Coaching remains as the final approach for creating Integrated Regulation, or possibly Intrinsic Regulation. Both outcomes are considered equally valid in terms of evaluating reminder effectiveness.

4.5 Implementing MRM Approaches as Motivational Messaging in Reminders

Focusing on the internalization process does more than inducing short-term adherence; it also generates persistent motivation to carry out the new behaviour. Each internalization stage is described in 4.2.1 and corresponding approaches to move into the next stage are proposed in section 4.4. A sequential transition emerges, describing the flow from external regulation to introjected regulation, then to identified regulation, and lastly, to integrated regulation. The 4 proposed actions help facilitate the sequential transitions along the 5 stages. In goal net terms, internalization stages are the “sub goals” and transitions are primarily triggered by the proposed “actions” (i.e. the 4 proposed messaging approaches). The 4 “actions” play significant role in keeping the internalization process functional, and are the backbone mechanisms of the MRM. In the context of a given stimulus from the proposed action, the behaviour will be established to the given sub goal (regulation) [56]. This section attempts to further refine the 4 proposed messaging approaches into motivational reminder messaging content, for the development of different regulations to be effectuated.

4.5.1 Initial Adherence via Extrinsic Rewards

Everyone may be familiar with the concept of motivation. Through motivation, people are moved to expend effort to achieve their goals [63]. Lack of motivation can be explained by two reasons. First, people are not interested enough in the event. Second, people are not feeling sufficiently competent in the task; or they experience some barriers to perform the activity. By providing both implicit and explicit reinforcements, the motivational model ensures adherence to proposed course of action. Therefore, extrinsic rewards activate the motivation-action-reward pathway, and generate initial adherence via external regulation.

To achieve external regulation, the first stage of internalization, motivational reminder messages can be drafted based on immediate consequences implications on their success or failure of adherence. Examples of relevant messages are:

- Rewarding → You will gain certain tangible incentives (cash, voucher or token) when you have good adherence rate.
- Punishment → Your conditions will worsen due to your poor adherence rate.

4.5.2 Gamification

Gamification is proposed to help the users *introject* their external regulation. Motivational reminders will be designed with scores, badges, and achievements to reward players who performed well in adhering to the reminders. This also provides incentive for players who did not perform well a goal to achieve gratification of acknowledgement. Once players perform better while they pursue gamified rewards, they would have invested enough into the activity that makes them interested in knowing more about the activity itself.

The motivational reminder messaging with the use of *gamification* as cheering actions to encourage and motivate people [76]. The term helps to stimulate the interest and willingness of people to participate in the activity or task. The gamified context provides people a sense of enjoyment to promote them to engage the activity or task enthusiastically. For example, the brand Nike makes people to realize that running is just like playing a game. The experience of gaming guides people to enjoy the running process, thereby establishing a dependency on their products, improve people's persistence and encourage long-term engagement. In short, gamification mechanism helps to increase the engagement and has been successful in boosting brand awareness. Therefore, applying gamification into motivational reminder messaging help to influence continued intent to adhere to medication-taking behaviour.

Examples of gamified motivational messages are:

- Rejoice → You have unlocked this token for your performance.
- Goal-Setting → You have X more sessions to go.
- Pressure → You forfeit this achievement if you miss the activity this time.

4.5.3 Cultivating Health Values

Having recipients to understand health values behind their actions that help them *identify* well with their actions (section 4.4.3 above). When players reach the pre-set level of adherence (i.e. earned a specific milestone achievement in the gamified reminder above), reminder message can start to motivate players by applying the health benefits they have acquired, while they consistently play the health game. Messages should establish the necessary context to encourage value-based decision making – deciding to perform certain actions for the health outcomes instead of arbitrary rewards.

Examples of cultivating health values message are:

- Functional → The task is beneficial to your health.
- Outcome → You are capable of living a better life if you perform the task.
- Acceptance → You will eventually appreciate the health outcomes.

Feedback can be obtained by asking individuals if they value the health benefits provided by the activity. When it is ascertained that message recipients know of the health benefits well enough, they are ready to start integrating the regulations as part of themselves.

4.5.4 Coaching and Setting Role Models

When recipients see the values behind their actions, reminder messages can help them to *integrate* their motivations by showing them how to do it. This can be accomplished through short, expressive GIF animations of “optimal performance”, or tips to help subjects find ways

to achieve the next milestone. The resulting mastery indicates that recipients are now comfortable with the new behaviour, and would have been deemed to accept the behaviour as part of themselves. Examples of coaching messages are:

- Challenge yourself to see if you can attain this performance.
- Your performance puts you among the top X% of other users, keep going!

The Goal-Oriented Storytelling Model [77], [78] may be explored in the future to create more structured, convincing coaching messages.

4.6 Summary

State-of-the-art reminders focus on having people to carry out tasks consistently upon receiving the reminder message. Motivational Reminders are established on existing reminder mechanisms, and are hypothesized to expand existing reminders' capabilities to encourage certain action or behaviour from people who are deliberately disobey. The stages of internalization outlined in OIT is a continuum where progress can be made. Utilizing the stages of internalization, strategic goal-oriented design of reminder messages was proposed as part of the MRM. As a result from motivational reminder messages, individuals may originally get motivated to an event, task or activity due to the external regulation, such as reward or punishment. The person may then start to enjoy the event, task or activity intrinsically by receiving adaptive motivational messages over time following OIT.

Improvising from Figure 7 above (page 53), Figure 9 below fills in the discussed proposed potential actions into the transitions of Goal Net. Stages of the internalization process (external, introjection, identification and integration regulations) are shown as goals, while relevant approaches for designing reminder messages suggested in section 4.5 are shown as transitions. This set of design recommendations for motivational reminders demonstrates capacity to be further refined into concrete implementations and help facilitate the internalization process

among individuals attempting to cultivate and maintain healthy behaviours such as medication adherence.

Figure 9. Internalization Process by OIT + MRM Approaches Summarized in Goal Net

The proposed approach to design the MRM forms the roadmap of what more can be further investigated. Goal Net is employed to model the motivational methodology. The proposed approaches help to transit from one regulation to another. Providing extrinsic rewards activates external regulation that promotes behaviour only when the rewards persist. To gain personal involvement, maintain self-esteem and avoid guilt, the transition from external regulation to introjected regulation utilizes gamification. Through cultivating health values, identified regulation is triggered to have a conscious acceptance of the behaviour required for achieving healthy outcomes. Coaching via setting role models stimulates integrated regulation and assists

individuals to engage the behaviour with their sense of self. The customised motivational messages adapt to multiple stages of internalization with logical, planned messaging content, hence assisting individuals with the internalization of healthy behaviours.

Chapter 5 Study I: Secondary Research on Motivational Reminder Design

This chapter attempts to answer the second research question posed in section 1.3 above: *How to design motivational reminders to facilitate internalization?*

The aim of study I is to evaluate how well reminders can improve adherence by providing external regulation to recipients who were initially unmotivated. This is also known as the first stage of internalization process from amotivation to external regulation. There were already preliminary efforts to incorporate extrinsic motivation into reminder design for improving adherence rate [79]. Hence, it is possible to re-use existing data by performing secondary analysis [80].

5.1 Secondary Research Question

Secondary research is a research method that involves re-identifying, re-using, re-analysing, re-interpreting, re-reviewing and re-evaluating on the existing dataset [81]. The purpose of this secondary research is to investigate a smaller but important research question, focused on the design of reminder for encouraging motivation. The key to secondary analysis is to utilize existing data to derive insights that improve the Motivational Reminder Model.

The secondary research questions below aim to provide more insights to the design of motivational reminders for subsequent use in study II:

- *Does extrinsic regulation motivate people to adhere to reminders?*
- *What are other motivators for people to adhere to reminders?*

5.2 Identification of the Dataset

The dataset used for this secondary analysis was collected in study that was conducted by Hou [79]. Twelve participants were recruited to study whether they remember to carry out a certain task after 5 hours. The original research used the data collected to evaluate a fuzzy cognitive map that predicts prospective memory task outcomes based on 7 proposed factors. In this study, the dataset was studied in a different perspective: to highlight how relevant factors that motivate people to perform a task may be used to enhance the MRM.

The secondary dataset has recorded whether each reminder task was carried out, as well as 7 factors that may have influenced the outcome: gender, age, presence of extrinsic reward (monetary incentive), delay between reminder and task execution, complexity of the ongoing task (ongoing task reported by participants and complexity rated by researcher), importance of task (rated by participants). Potential factors that may affect reminder adherence were analysed:

- Participant *age* might have affected the usability and efficacy of the reminder system.
- There might have been different response rate of reminder system between different *genders*.
- *External incentive* in the form of cash rewards affected the reminder adherence outcome.
- The “ongoing task” was designed as background work. Participants needed to perform a scheduled task which required attention to be shifted away from the “ongoing task”.
The *complexity of ongoing task* affected whether participants followed the reminders and successfully switched their attention to the scheduled task to complete it.
- *Relatedness of task* described the how related is the scheduled task compared to the ongoing task.
- The *importance of task* referred to scheduled task’s perceived importance.

The existing dataset has provided several factors that influences reminder outcomes, which fits well to the secondary research question. The dataset also addresses potential design elements for MRM's development and refinement.

5.3 Dataset Evaluation and Discussion

The dataset of all 12 participants between the ages of 48 to 88 was extracted to evaluate which characteristics that may affect reminder adherence. In the original study, 4 participants were promised to receive an incentive of 5 Chinese Yuan after each successful completion of the designated task. This group was re-interpreted as the “experiment group” in Table 7. Eight remaining participants were not given any incentive or other rewards for completing their designated tasks. This group was re-interpreted as the “control group” in Table 6. In this case, the cash reward represents extrinsic regulation. Two different scheduled tasks of *submitting a paper* and *texting someone* were split evenly between the control and experiment groups.

The next step of answering the secondary research question was to re-evaluate and re-analyse the dataset. Relevant results were sieved out from [79, p. 79] and presented below according to the different participant groups described above.

Under the condition of 5 hours delay, all 4 participants who were promised with rewards remembered to complete the task, yielding a success rate of 100% under external incentive (see Table 7). In contrast, 6 out of 8 participants remembered the task from the control group, yielding a success rate of 80% (see Table 6). When motivation was presented in form of incentives, the performance of tasks is improved. This result demonstrates that the participants were more likely to remember their tasks under the presence of external regulation.

Table 6. Secondary Analysis – Participants who were not Promised any Rewards

Participant No.	1	2	7	8
Age	51	52	63	63
Delay	5hr	5hr	5hr	5hr
Remember or Forget	F	F	R	R

Participant No.	9	10	11	12
Age	65	64	55	88
Delay	5hr	5hr	5hr	5hr
Remember or Forget	R	R	R	R

Table 7. Secondary Analysis – Participants who were Promised Rewards

Participant No.³	3	4	5	6
Age	51	48	53	55
Delay	5hr	5hr	5hr	5hr
Remember or Forget	R	R	R	R

Dataset from this secondary analysis supports the usage of external regulations as the first step of the internalization process. The result supports motivational reminder model's approach of using external rewards to induce external regulation, the first stage of internalizing new behaviour.

5.4 Significance of Task Importance for Motivational Reminders

Aside from external regulation, increasing the scheduled task's importance could also improve the adherence rate through self-determined behaviour. The importance of the task is also known as participant's perceived value of the scheduled task.

³ The IDs are preserved from the original study where participants 3 – 6 are labelled as experiment group.

Table 8. Other Potential Factors from Secondary Analysis

Participants	1	2	7	8	9	10	11	12
Complexity of ongoing task*	4	3	2	5	2	4	2	4
Relatedness of task**	3	1	1	1	3	1	2	2
Importance of Task	1	1	6	5	7	7	7	7
Result (Remember or Forget)	F	F	R	R	R	R	R	R

* 2=Watching TV, 3=Driving, 4=Playing Mahjong / Cooking, 5=Working

** 1=Not reminded, 2=Saw the clock, 3=Saw reminder on phone

Table 8 presents the control group (same group as Table 6) along with their perceived task importance. It is observed from Table 8 that 2 out of 8 participants from control group forgot to perform their task, with the reason being participants believed that the importance of task is not high. Perceived task importance appeared to be an additional potential factor affecting the results of remembering the task.

Hence, task importance should be emphasized in the 3 subsequent internalization stages after external regulation. The proposed approaches of gamification, health values and coaching in MRM should aim to encourage interjection, identification, and integration through improving the perceived *importance of task*. Moving forward when designing the implementation for motivational reminders in study II (section 6.2.3.1 below), *task importance* is an aspect that will become the focus of internalization efforts. If subjects can identify with why the task is important (e.g. health benefits of health games), they will carry out the task more willingly via identified / integrated regulation (e.g. play more health games for the health benefits).

5.5 Summary

Results from study I provide evidence for supporting the key elements of the motivation reminder model by showing the feasibility of extrinsic rewards as part of reminders. Furthermore, *task importance* is key for developing an effective motivational reminder

application. The next chapter reports on the evaluation of a motivational reminder application as-a-whole, by introducing both extrinsic and intrinsic motivation to improve adherence rate.

Figure 10. Roadmap of Study II

This analysis represents the first stage of the internalization process, as shown in green in the goal net (see Figure 10). In study II, Motivational Reminders are designed for all transitions (rectangles) and are trialled with test users to evaluate their effectiveness in inducing adherence and motivation.

Chapter 6 Study II: Implementing and Evaluating Motivational Reminders

6.1 Introduction

Study II is designed to evaluate the effectiveness of the proposed MRM. Motivational Reminders are designed using MRM specifically for the study, where participants are expected to adhere to a regular schedule of playing short segments of health games.

Reminders have been used in prior studies [16] [29] to promote medication-adherence by simply reminding them to carry out a short task. In this study, the short task is simulated using a short segment of health game. If participants can be motivated to consistently adhere to the reminder and carry out such short tasks, it is anticipated that this adherence should carry over to medication-taking activities.

The health game selected for use in this study is Pumpkin Garden, which is used for Parkinson's Disease early detection and rehabilitation [82], [83].

6.1.1 Serious Health Games: Pumpkin Garden

As far as Parkinson's Disease (PD) is concerned, there is no direct cure [84]. But there are medications that may help to control the symptoms with the problems of walking, movement and tremor, such as Levodopa, Mirapex, Requip, Zelapar, MAO B and so on. Medicines come in a variety of types or forms. Commonly, the active parts of medicine can be combined with liquid, tablet, capsules, creams or lotions. The other forms of active part of medicine can be released by inhalers, injections, implants or patches. Depending on the different conditions of the disease, different types of medicines are given in very specific circumstances.

The symptoms of PD patients may be significantly improved if there is primitive treatment at the early stage of disease. However, the benefits of drugs frequently diminish, become less

consistent or come with serious side effects [85]. Therefore, PD patients need to control their symptoms via other forms of treatment such as rehabilitation.

Rehabilitation is a form of medical specialty designed to help patients regain their body functions lost due to their poor physical conditions. The goal of rehabilitation is to optimize functionality and to reduce the experience of disability in individuals to interact with their environment [86]. One of the rehabilitation examples can be the use of prescribed medicine (e.g. exercise programme or training) to reduce muscles stiffness for patient who had the car accident. Rehabilitation helps to reduce and manage the impact of health conditions (e.g. both acute diseases or chronic diseases, illness or injuries) or prevent other complications (e.g. further injury, stroke or fracture) associated with existing health conditions.

A serious game called “Pumpkin Garden Game” is designed as daily rehabilitation exercise for Parkinson’s disease patients [83]. Rehabilitation treatment is an important form of medicine to delay disease progression and improve the quality of life of the PD patients. Pumpkin Garden game tasks for PD rehabilitation stimulates dexterity of hand and finger movement and cognitive function training. Multiple cueing techniques are integrated in the game design, for example, the visual effect and background music are designed as part of the game elements. The serious game is designed to improve the health conditions of bradykinesia (slow movement) and freezing (temporary or involuntary inability to move) [83].

This study investigates whether MRM is able to induce motivation for adherence to the behaviour of playing health games. This study also investigates MRM’s effects in starting and retaining the potentially healthy behaviour of playing the Pumpkin Garden game.

6.1.2 Study Objective and Outline

Study II aims to uncover whether a MRM-based reminder application (described in section 4.5) helps individuals internalize the action of playing health games. The Pumpkin Garden Game

is used in conjunction with an application that contains different Motivational Reminders. Reminder messages are either the same every time (control group) or crafted using MRM's motivational approach (experiment group) to encourage self-determined adherence to the scheduled Pumpkin Garden game tasks.

6.2 Study Methodology

6.2.1 Study Procedures

A total of 45 healthy adults aged 50 years old and above were recruited for the study. Participants were briefed on risks of Parkinson's Disease among their population. They were then introduced to the Pumpkin Garden Health Game, a serious game aimed at early detection of PD symptoms. Reminders (both general and motivational) took the form of a notification issued by the Motivational Reminder Application developed for the study. Reminders would be sent to the participants twice per day, at 11am and 7pm, for a total of 7 consecutive days. Different participant groups received different types of reminders, which will be elaborated in 6.2.2 below.

Fourteen reminders were sent in total through the course of the study. Upon being reminded, they had a 2-hour window to launch the game (11am – 1pm, 7pm – 9pm) and completed a single round of water wheel minigame. One round usually took between 30 seconds to 1 minute to complete, and was only registered as complete when they have spun the water wheel enough to fill up the blue progress bar (see Figure 12 on page 86). Participants' adherence to this gameplay schedule (i.e. whether they have responded to the reminder and played the game) was recorded through the Motivational Reminder Application itself and these records are extracted from participants' mobile devices.

Before the participants proceeded the gameplay study, they first filled in the BREQ-2 questionnaire which reveals their current stage in internalizing the behaviour of playing health

games regularly. This “current stage” is essential in how Motivational Reminders will behave, and is separately elaborated in 6.2.2 below.

Participants were then briefed from the start that they will be rewarded with several bottles of hand sanitizers at the end of the 1-week study, depending on how many times they followed the reminders. They would also receive a simple report on their PD risk, which is calculated from their gameplay performance. This report is referred to as the “PD report”⁴ in later sections of this chapter. The reward in the form of hand sanitizers represents *rewards*, an extrinsic motivator for adhering to their gameplay schedule⁵. The PD report, on the other hand, represents *task importance*, which is a more intrinsic motivator for health game adherence.

After the 7th day, participants filled in the IMI and BREQ-2 questionnaires. The researcher also contacted each participant individually through phone call or meetup to conduct a verbal exit interview. Participants then receive a debrief that the PD report is the result of experimental technology: an explicit disclaimer was made to not use the PD report as clinical advice but merely as a reference to decide whether to go for further check-ups. Lastly, the sanitiser bottles and a physical copy of the PD report were handed to participants.

The researcher then conducted quantitative and phenomenography studies on different responses between UMR group and MR group to compare the efficacy of each approach for each internalization stage.

⁴ The primary purpose of the PD report is to get participants concerned with their health. The PD report merely contains a score that is higher when they turn the water wheel in a more circular motion. This calculation method is not revealed to the participant; rather, participants are advised to go for further check-ups should they feel concerned.

⁵ The study was conducted in Singapore during March 2020, a period when hand sanitizers are in high demand especially among older adults. Thus it is fair to consider hand sanitizers to be a compelling extrinsic reward.

6.2.2 Participants Selection and Grouping

The 45 participants recruited for study II were randomly sampled and screened for eligibility from the community. The inclusion and exclusion criteria are listed in Table 9.

Table 9. Study II Inclusion and Exclusion Criteria

Inclusion	Adults, aged 50 years and above
	Able to read messages on the phone
	Understand simple English
	Have ability to play game by themselves
Exclusion	No mobile device

Participants in study II were randomly divided into 3 different groups: the control group, the Untargeted Motivational Reminder group (UMR group), and the Motivational Reminder group (MR group), with each group consisting of 15 participants.

During the study, the control group received the same message every time: “*Time to play the Pumpkin Garden game!*” Whereas both UMR and MR groups received messages randomly selected from a pool of pre-crafted messages.

The MR group received different reminder message types based on their current internalization stage, as specified in the proposed MRM in 4.4 above (page 56). To achieve this, 4 message pools are defined to facilitate 4 different transitions between internalization stages, shown in Table 10.

Table 10. Different Pools of Messages to Facilitate Different Transitions

Message Pool Name	Transition to Facilitate	Messaging Approach
msg_amotivated	Amotivation → External Regulation	Obtain Adherence via Extrinsic Rewards
msg_external	External → Introjected Regulation	Gamification
msg_introjected	Introjected → Identified Regulation	Cultivate Values
msg_identified	Identified → Integrated Regulation	Coaching

In the MR group, one of the 4 message pools is assigned to each participant, based on the subscale they scored highest as indicated in the pre-study BREQ-2 questionnaire. They would then only receive messages randomly selected from this message pool so that the messages are theoretically tailored to them as specified in MRM. For example, participants who scored highest in the *Amotivation* subscale before the study would receive pre-crafted messages from the *msg_amotivated* message pool throughout the 7-day study period. Message pool contents are presented separately in section 6.2.3.1 below.

On the other hand, the UMR group would receive untargeted messages, randomly selected from a random message pool every time. The UMR group simulates the approach of motivational reminders but without matching the approach with its intended recipient.

Comparing the MR group with the control group determines if MRM's "targeted content" approach creates significant change in motivation and adherence. Whereas the UMR group and the MR group shares the "content" but differs in the "targeted" aspect. It is hypothesized that MRM's "targeted content" approach should produce most prominent results in the MR group, out of the three groups. In other words, each approach should only be most effective towards individuals in specific internalization stages.

Table 11 below summarizes the participants grouping in study II. Table 12 below summarizes the study procedure.

Table 11. Categorization of Participants by Study Group and Pre-study BREQ-2

		Number of Users for each Message Type					Total
		Amotivated	External	Introjected	Identified	Integrated	
Study Groups	Control	5	5	0	4	1	15
	UMR	10	1	3	0	1	15
	MR	9	2	2	1	1	15
	Total	24	8	5	5	3	45

Table 12. Study II Procedures

Steps	Control Group	Untargeted Motivational Reminder (UMR) Group	Motivational Reminder (MR) Group
1.	Introduction of Pumpkin Garden Health Game		
2.	Pre-study questionnaire: BREQ-2		
3.	7-day of gameplay with general reminder	7-day of gameplay with messages randomly selected from a pool of pre-crafted messages.	7-day of gameplay with different reminder message types based on their current internalization stage
4.	Post-study questionnaire: fill in both IMI and BREQ-2		
5.	Exit interview on experience of using Motivational Reminders		

6.2.3 Study Materials

6.2.3.1 MRM Design Implementation

MRM is implemented to suit the use case of study II. The approaches suggested in section 4.4 and 4.5 above are slightly refined with study I findings to design the motivational reminders used in study II.

In study II, participants are encouraged to adhere to a regular schedule playing Pumpkin Garden Health Game. Hence, the messages used in the study address some elements specific to the study, such as hand sanitisers, health values of the Pumpkin Garden health game etc. The 4 proposed messaging approaches are refined as follows:

1. Obtain adherence – use tangible rewards to create external regulation for amotivated individuals.

For amotivated participants, reminders highlight that if they adhere to their gameplay schedule, they will get additional sanitiser rewards at the end of study. The opposite is true; they are also reminded that they will get less rewards if they do not follow the reminders. The full message pool to shift participants from Amotivation to External Regulation (*msg_amotivated*) is as follows:

- Play the game now to receive 1 more bottle of sanitizer at the end of study!
- You earned X bottles of sanitizers so far, play now and get up to Y!
- You will not get any rewards if you don't follow the schedule at least X times.
- You need X more game to be eligible for the first 2 sanitizer bottles.

(X and Y are variables which are dependent on participants' performance)

2. Utilize gamification to improve *task relatedness*: reward scores, badges and achievements to players who performed well in adhering to the reminders.

For participants motivated by external regulation, motivational reminders attempt to increase their esteem by using gamified elements such as Adherence Scores, Combo streak, and continuous progress updates on how far the user is to reach the next achievement. These psychological rewards attempt to stimulate participants' relatedness towards the task of playing the game on time. Two types of achievements with three tiers are designed for this type of reminders:

- Completionist: complete your 1st / 6th / 12th game
- Perfectionist: play 3 / 7 / 11 games in-a-row

The full message pool to shift participants from External Regulation to Introjected Regulation (*msg_external*) is as follows:

- You have achieved Perfectionist-BRONZE for adhering to your gameplay 3 times in a row!
- Stick to your gameplay schedule 2 more times to unlock the Completionist-GOLD award!
- One game left for your Perfectionist-GOLD award, you will be the first to get it!
- Unlocking Perfectionist-SILVER puts you among the top 10%, keep going!

(Achievements are specific to participants' performance; player position on leaderboard is presented as seen fit to encourage players)

3. Cultivate values to promote *task importance* – educate users to understand the values behind their actions.

For participants who are under introjected regulation, messages should present health facts about the Pumpkin Garden Health Game. More attention is directed towards valuing their PD report instead of the extrinsic rewards. The full message pool to shift participants from Introjected Regulation to Identified Regulation (*msg_introjected*) is as follows:

- Check on your PD risk by playing the Pumpkin Garden game.
- X% among your age group is at risk of PD, play to find out if you are at risk.
- Play regularly to get more accurate PD diagnosis results!
- The game can improve your coordination skills, play now!
- Your health is important, don't forget to play consistently!

4. Coaching – help users integrate their motivation by showing them how to do it.

For participants who have achieved identified regulation, messages need to occasionally “paint a role model” and utilize coaching methods to drive the user towards the role model. In the case of our study where the activity is short and simple, and the main goal is to achieve the highest possible adherence score. Reminders at this stage should remind the player their achievable best score, and provide tips on ideal ways to play to result in PD reports that reports low risk of PD. The full message pool that aims to shift participants from Identified Regulation to Integrated Regulation (*msg_integrated*) is as follows:

- 2 days left, keep going to achieve your best score of 12!
- Keep your movement circular; it produces more accurate PD health reports.
- You want to do better, stick to your scheduled games and you will improve!
- It's ok that you have missed a game, it's not too late to get back on track!
- It is unlikely you have PD, show it by completing the game!

Although the MRM specifies an ideal motivational reminder that transitions between different approaches as the user shifts through different internalization stages, we narrow the study scope to use only 1 form of reminder that lasts for 1 week, tailored for the participant's internalization stage in the pre-study BREQ-2. This ensures the approach's appropriateness for promoting internalization at its intended stage.

Motivational Reminder Application

An application is built using the messages crafted in MRM design implementation. The app generates notifications containing the messages to remind subjects to play the Pumpkin Garden game at 11am and 7pm daily throughout the 7-day study period.

Figure 11. Motivational Reminder Application

Participants were briefed to react to the reminders by pressing “Play Now” button or “Remind Later” button (shown in Figure 11). If “Play Now” is pressed, users will be brought to the Pumpkin Garden game to complete the water wheel minigame, after which the app will record the current attempt as successful. If “Remind Later” is selected, participants will be notified again after 1 hour. If “Remind Later” is pressed again in the 2nd notification, the attempt is considered failed, and the app moves on to the next scheduled gameplay time.

6.2.3.2 Pumpkin Garden Health Game

Pumpkin Garden Game is a health game used to simulate medication-taking behaviour in the study. The study lasts a week, simulating taking a course of medication in real life. The Pumpkin Garden game is developed to train players’ coordination skills and other cognitive functions through game-like interactions and provide some degree of rehabilitation functionality [83]. It is a farming-themed game played on mobile tablets, consisting of four mini games with different farming components. Each mini game is designed to cooperate with symbolic PD rehabilitation exercises of coordination, agility and cognition. Everyone can easily play the game at their own convenience, without the need for expert support. The game is used to train users’ movement synchronization and micrography. Furthermore, the users’ in-game behaviour, activity patterns and responses in the game can be tracked to understand the progress of rehabilitation, as well as used to adjust rehabilitation plan when necessary. One of the mini games named as Watering task was chosen for research. The task of the game follows the theme of farming, requiring users to draw circles with their fingers to run the waterwheel to water the farm. Using background music and visual as clues, the users move their fingers on the screen in a way that may incur freezing situation, thus integrating PD detection as the part of the game design features [83].

The Pumpkin Garden game was modified for this study to only feature the water wheel minigame and work together with the Motivation Reminder app mentioned above.

Figure 12. Pumpkin Garden Game Screenshot – Water Wheel Minigame

6.2.4 Evaluation Criteria and Tools

Motivational Reminders are expected to perform better than general reminders through better adherence results. It is hypothesized to accomplish the above through facilitating the internalization process, thus we employ tools that measure levels of intrinsic motivation as well as the different stages of internalization.

6.2.4.1 Adherence Score

As mentioned in 6.2.1 (Study Procedures), participants' success or failure to comply with the reminders were recorded digitally. Adherence scores are obtained by counting how many times participants successfully comply to reminders: finish 1 round of water wheel minigame within 2 hours of reminder prompt. Since participants were reminded twice daily for a week, possible adherence scores range from 0 to 14.

6.2.4.2 Behavioural Regulation in Exercise Questionnaire (BREQ-2)

The Behavioural Regulation in Exercise Questionnaire (BREQ-2) [87] which has been validated in prior studies [84] [85] and is used in this study to measure the individual's stage of internalization, both before and after the study. Differences captured by BREQ-2 can then be compared to determine MRM-driven reminders' effectiveness in facilitating internalization towards the new behaviour of playing health games.

Initial development of the BREQ only validated 4 states, while the remaining internalization stages were added in subsequent publications. Table 13 below summarizes the development of BREQ over time.

Table 13. Development of BREQ in Literature

Scale Name	Proposed Internalization Stages	Citation
BREQ	External (EXT), Introjected (IJ), Identified (ID), Intrinsic (IM)	[90]
BREQ-2	Stages in BREQ + Amotivation (AMOT)	[87]
BREQ-2R	Stages in BREQ-2 + Integrated (IN) Regulation	[91]

BREQ-2 with 5 stages (AMOT, EXT, IJ, ID, IM) by Markland and Tobin [87] is selected out from the 3 versions. This is due to a number of reasons:

- Compared to BREQ, BREQ-2 contains amotivation as a stage while BREQ does not. Since the study focuses on older adults, amotivation is expected to be a prominent phenomenon for older adult's attitudes towards health games, as not many are affluent with digital games / technology and would have little motivation to engage with it.
- Compared with BREQ-2R, BREQ-2 contains more appropriate questions to describe the health game experience in stages with higher levels of internalization. For example, "I play health games because it's fun" can help researchers better

understand if participants find the health game intrinsically motivating to play. For comparison, an example of an omitted question from BREQ-2R would read as following: “I consider playing health games to be part of my identity”. This is less likely to be applicable in health games’ settings, especially among older adults who do not grow up playing digital games.

While in MRM, we specify the last stage of internalization (in context of reminder design) is Integrated Regulation, whereas BREQ-2 skips this stage and instead specifies Intrinsic Motivation (IM) as the final stage. While the original BREQ-2 term “IM” will continue to be used, for purposes of this study, IM is treated as equivalent of Integrated Regulation. This is to ensure the questionnaire items use words like “fun” and “enjoyable” to describe the game, not words like “part of identity” which would likely not sit well with our participants who did not grow up playing digital games.

For this study, the activity featured in BREQ is recontextualized from *exercise* to asking if the subject has *adhered to their gameplay reminders*. The word “exercise” is generally swapped with either “gameplay” (e.g. gameplay sessions) or “follow / miss reminders” (e.g. I feel guilty when I missed a reminder).

The original BREQ also highlights peer pressure as external regulations for exercise behaviour, e.g. “I exercise because my friends/family/spouse say I should.” They have been replaced with the actual extrinsic reward presented in this study, which is the hand sanitizers they are expected to receive after completing the study. Appendix C: Modified BREQ-2 shows the full adapted version of BREQ for this study.

6.2.4.3 Intrinsic Motivation Inventory (IMI)

Intrinsic Motivation Inventory (IMI) is a multidimensional measurement device intended to assess participants’ subjective experience when playing with the Pumpkin Garden health game.

As its name implies, IMI has been used in several experiments to measure intrinsic motivation and self-regulation since 1982 [92]. However, IMI is useful not just for measuring intrinsic motivation, but also for measuring autonomy, self-determination and the extent of internalization that has taken place.

For this study, 25 items that form the *Activity Perception Questionnaire* are selected from post-experimental IMI [93] to assess participants' interest/enjoyment, value/usefulness and perceived choice.

- *Interest/enjoyment* represents participants' intrinsic motivation to play the health game. *Fun* and *enjoyment* are recurring words throughout this subscales' questions as motivators.
- *Value/usefulness* represents the more extrinsic or utilitarian side of motivation. Prominent words in IMI describing this concept include *important*, *improve*, *beneficial*, *has value*.
- *Perceived choice* describes whether participants felt a sense of autonomy when they are reminded to play the health game. Relevant questions revolve around *choice* where phrases like "I had to" is contrasted with "I want to".

This version of IMI is theorized to be an effective predictor for the measure of internalizing an activity and has been used in previous studies such as [48]. The 25 IMI items have been modified slightly to fit the activity conducted for our study, namely playing the Pumpkin Garden serious game. "Health game" is used to describe the activity participants were asked to do throughout the study. The concepts of "health benefits" and "health improvement" are used to refer to the value / usefulness of health games. An example IMI question used for this study is "*I think this health game is important for improving my health*". Appendix B: Modified Intrinsic Motivation Inventory (IMI) lists the full adapted questionnaire used in study II.

6.2.4.4 Phenomenography Approach

Phenomenography is an empirical qualitative research methodology to discover different ways in which people experience, conceptualize, realize and understand various aspects of phenomenon around them [94]. Historically, phenomenography was applied to study the aspects of phenomena on the learning experience and the different ways of experiencing the content learned. Starting in the 1970s, phenomenography was first used by Swedish researchers Marton, Saljo, Svensson and Dahlgren to investigate both surface and deep approaches of learning experience on how to learn better. Using an example of learning the subject of physics, phenomenographic surface approach is to study how students to learn by following formulas, memorizing notes, reproducing the textbook content and completing the assignments. Whereas the deeper phenomenographic approach is to understand the learning goal of students and seek in depth of the inner voices not been heard towards their learning goal.

The main feature of phenomenographic research is the focus on human experience in a given phenomenon, not the phenomenon itself [95]. Phenomenographic investigation *is not direct at the phenomena, but at the variation in people's ways of understanding the phenomenon* [96], also known as second order perspective. Phenomenography constitutes a relation between subjects, researchers and aspect of world. By interacting with the phenomenon, the basic concept of phenomenography is about different ways of understanding on the phenomenon to create a meaning.

Figure 13. Focus of Phenomenographic Research [97]

Phenomenography imposes a coherent research process from study planning to data collect to data analysis and results presentation. Phenomenographic data is the information about individual's conceptions in a given phenomenon through their open-ended interviews and observations from their actions. For example, interviews are conducted to reveal interviewees' experiences and the subsequent interview questions are generated from interviewees' responses. Those responses are the direct reflections on their experience on the aspect of the certain activity. In display of fairness, no judgemental comments were made during the interview [98].

Although phenomenographic data is collected at individual level, the findings use collective awareness to present an internal relationship between the experiencer and the experienced. The principle and process of analysing phenomenographic data involve both discovery and construction. The findings are not known in advance, but tracked down from the interview transcripts. It is because data analysis in phenomenography is a "bottom up" of working to obtain results, rather than a "top down" of research flow from the proposed hypothesis. The analysis process also involves identifying variation across the set of transcripts that provide the sources of evidence on how people experience. The phenomenographic result is a logically structured complex, termed as outcome space [98] [99]. Outcome space is a set of categories

that describes how an experienced phenomenon has been interpreted in various formats of tables, diagrams or figures.

Here are the key benefits of applying phenomenography:

- Depict a series of different interpretations to create meaning
- Emphasis on actual live experiences to understand “what” and “how” aspects
- Provide a structured description for the different aspects of the phenomenon
- Have a better understanding of the complexity of inner voice

Phenomenography focusses on investigating human experiences and their subsequent perceptions of phenomenon, which fit the current research aim of motivation experience. The second order perspective of phenomenography ensures the feedback on motivational reminder application is from individuals’ perspective and not the researcher’s interpretation. Phenomenographic research approach is adopted for this study to identify variations in motivational experiences of using the motivational reminder application.

6.3 Findings

6.3.1 Comparing Adherence Score

The number of times participants adhere to their gameplay schedule (out of 14 attempts) are summed to form an “adherence score”. The adherence scores of the 15 participants in each group are then averaged to form a group average adherence score. The confidence interval ($\alpha = .05$) is also computed and presented as error bars.

Figure 14. Mean Adherence Scores

There is significant improvement in adherence scores for MR group when compared to control group. Participants who used Motivation Reminders scored an average of 9.8 (± 1.07) while those who used general reminders scored an average of 4.67 (± 1.04). Those who received the Untargeted Motivational Reminders scored slightly better than the control group, at 6.2 (± 0.98). However, UMR group's improvement does not seem to be as significant as the MR group, which do not have overlapping error margins with the control group. In addition, the "Mean Difference from MR Group" column in Table 14 shows t-test results to signify the adherence score improvements of MR group.

Table 14. Adherence Score Mean Difference t-test

Group	Mean	Std. Deviation	Mean Difference from MR Group
Control group	4.67	2.127	5.133**
UMR group	6.20	1.935	3.6**
MR group	9.80	2.111	-

**t-test is significant at the 0.01 level (2-tailed)

6.3.2 IMI for Comparing Intrinsic Motivation

The *Activity Perception Questionnaire* is used to measure the level of Intrinsic Motivation at the end of the 7-day study; higher scores indicate that more internalization has occurred. All questions are scored on a 7-point Likert scale with responses scored from 1 to 7. The 3 subscales that are administered include interest/enjoyment, value/usefulness and perceived choice. Subscale scores are averaged for each participant group and then compared. Results are presented in Figure 15 below.

Figure 15. IMI Average Subscale Scores

The MR group scored higher for all 3 subscales compared to other groups. A t-test is performed to confirm the significance of the mean differences.

Table 15. IMI Subscale Scores Mean Difference t-test

Subscale	Group	Mean	Std. Deviation	Mean Difference with MR group
Interest/enjoyment	Control	3.54167	1.474233	1.266667*
	UMR	3.55000	1.549626	1.258333*
	MR	4.80833	1.015358	-
Value/usefulness	Control	3.84440	1.211860	1.296333**
	UMR	3.88893	1.258440	1.251800**
	MR	5.14073	0.939543	-
Perceived choice	Control	3.46667	1.364789	1.458333**
	UMR	3.31667	1.163878	1.608333**
	MR	4.92500	0.869626	-

*t-test is significant at the 0.05 level (2-tailed)

**t-test is significant at the 0.01 level (2-tailed)

Improvements can be observed in their mean scores, backed by significance from t-tests. This shows that Motivational Reminders in their intended targeted approach can be effective tools to stimulate autonomy, help players gain more appreciation towards health games' values like usefulness and fun, and thus encouraging self-determined behaviour in adhering to their health game schedule. In the UMR group, this effect is significantly diminished with absence of targeted messages that match participants' exhibited internalization stage.

6.3.3 BREQ-2 for Measuring Internalization

Quantifying internalization - The Relative Autonomy Index (RAI) in BREQ-2

The 5 subscales in BREQ-2 correspond to the stages in the internalization process of playing health games, whose scores are denoted by AMOT, EXT, IJ, ID, IM. A decrease in subscales describing earlier internalization stages (AMOT, EXT, IJ) and increase in subscales describing

later internalization stages (ID, IM) indicate the occurrence of internalization. To quantify this shift in subscale scores, the Relative Autonomy Index (RAI) of each individual is computed. RAI is obtained through the equation (refer to Table 1 method C in [100]):

$$RAI_{BREQ-2} = \sum ((AMOT \times -3) + (EXT \times -2) + (IJ \times -1) + (ID \times 1) + (IM \times 3))$$

RAI is a score that quantifies the degree to which participants feel self-determined. Each participant's RAI is computed twice: from the BREQ-2 responses *before* the study, and the BREQ-2 responses *after* the study. The improvement in RAI (denoted by ΔRAI) indicates the shift of participants' self-determination. A positive ΔRAI shows improvement while a negative ΔRAI shows a decrease in self-determination. A t-test is performed on mean values of ΔRAI , and the significance of their differences is presented in Table 16.

Table 16. Relative Autonomy Index Improvement (ΔRAI) Mean Difference t-test

	Group	ΔRAI Mean	Std. Deviation	Mean Difference with MR group
ΔRAI	Control	2.89987	8.435077	13.183267**
	UMR	1.24993	9.540251	14.833200**
	MR	16.08313	9.006617	-

**t-test is significant at the 0.01 level (2-tailed)

The control group recorded an average increase of RAI by 2.89987 at the end of experiment, while the MR group recorded 16.08313 improvement RAI value. Thus, it is observed that there is significant occurrence of internalization (i.e. improved self-determination) when they use Motivational Reminders. The UMR group, interestingly, recorded the worst RAI improvement at 1.25, suggesting that the random message styles did not induce much internalization within participants.

Breaking down Δ RAI into its components, it is observed that the change in each individual subscale before / after the study can be calculated. Figure 16 below summarizes how much each subscale score has changed for the 3 groups. The values are obtained by subtracting post-study BREQ scores from pre-study BREQ scores.

Figure 16. Examining the Change of each RAI Component (BREQ Subscales)

Analysis from Figure 16 above reveals the trend of more prominently reduced Amotivated / External subscale scores, and more prominently increased Identified / Integrated subscale scores for the MR group. This same trend is not as pronounced in the 2 other groups. Thus, the higher Δ RAI among the MR group (see Table 16) can be attributed to this trend. This shows that the use of Motivational Reminders is more effective in reducing the *controlling* type of motivation and increasing the more *autonomous* type of motivation, thus exemplifying the occurrence of internalization (Figure 6 at p. 52 explains the terms “controlled” and “autonomous”).

All in all, quantitative methods like t-tests of mean differences are used to compare general reminders and Untargeted Motivational Reminders with Motivational Reminders. Motivational Reminders are shown to improve adherence to new behaviour, enhance intrinsic motivation and facilitate the internalization process of the said new behaviour. It remains a promising approach to improve medication adherence among people who stand to benefit the most from a regular medicine-taking schedule.

6.3.4 Phenomenographic Analysis: Experience with Different Motivational Reminder Approaches

Participants from both MR group and UMR group received a short exit interview on their experience of receiving their assigned reminder type throughout a week. Based on their experience sharing, the phenomenon under investigation is defined as follows:

What are the key themes and experiences when progressing through the different stages of internalization?

The MRM-based reminder approaches to each of the 4 transitions are investigated, and relevant quotes are presented.

6.3.4.1 Amotivated → External: Introducing new behaviour with extrinsic rewards

Similar to Study I's conclusion, extrinsic motivation (in the form of tangible rewards) appears to be effective in creating short-term adherence to health games. Participants who scored highest on the Amotivated (AMOT) BREQ-2 subscale before the study have received reminders that constantly cite sanitisers as the reason they should play the game. Below are several interview excerpts:

MR_AMOT_1⁶: I was not very good at using my tablet. This is my first time learning and playing health games.

Researcher: You still managed to follow some of the reminders, what motivated you?

MR_AMOT_1: It reminded me that I have sanitiser bottles to claim if I play... sanitisers are scarce recently and I'd rather have more to keep with me.

For these participants who did not seem engaged with health games initially, the prospect of a reward motivated them to heed the reminder's instruction and play the game on time.

The motivational reminders which tracked how many sanitiser bottles they are eligible at the end of the study also created more relevant reminder messages.

MR_AMOT_2: I found it very helpful that it tracks how many more bottles I can earn. I started to plan ahead and catch the upcoming reminders to maximize my earnings.

Amotivated participants in UMR group were generally not interested in the untargeted messages. However, reminders that contained these extrinsic rewards stood out to them and garnered their interest:

UMR_AMOT_1: I totally forgot what the reminders are for, until one day it said I could receive those sanitiser bottles... turns out the task wasn't as hard as I thought.

Thus, for disinterested participants, reminding them about the desired tangible rewards is an effective way to have them to adhere to their gameplay schedule.

6.3.4.2 External → Introjected: Making progress personal and relatable

Participants who received exclusively gamified reminder messages are those who predominantly expressed intent in engaging with health games with presence of extrinsic rewards (i.e. scored highest for "External Regulation (EXT)" subscale in pre-study BREQ-2 questionnaire). The gamified reminders appealed to their self-worth; participants shared about experiencing an additional form of motivation as the study progressed.

⁶ Participants are labelled with the following format: <group name>_<internalization stage before study>_<id>

MR_EXT_1: I counted the next possible achievements and tried to go for them too!

Researcher: Was that on top of looking forward to the hand sanitizers promised upon completing this study?

MR_EXT_1: Yes. But turns out, there is something else I can look forward to. The 7-day wait (for the sanitizers) was a little lengthy, but at least in the meantime, I get recognized for achieving something too.

Individuals in the E2 group who scored highest for EXT often mention gamified reminder messages together with extrinsic reward reminder messages.

Researcher: Do you remember the content of the reminders that managed to convince you to open the game?

UMR_EXT_1: Definitely those reminders that helped me track the good stuff I can get if I open the game.

Researcher: What kind of good stuff caught your interest?

UMR_EXT_1: Those hand sanitizers you promised, and the occasional satisfaction for getting the in-game achievements!

While extrinsic rewards work for both amotivated and extrinsically regulated participants, gamified reminders helped provide another avenue of recognition that addressed their self-worth. It has added a little more personal involvement and made adherence less dependent on external factors.

6.3.4.3 Introjected → Identified: Instilling health values

Participants who cared about their performance and adherence expressed guilt and dissatisfaction when they missed the reminders when they filled in the pre-study BREQ-2 questionnaire. They received reminder messages which emphasized on health values, such as the importance of PD early detection. The importance of the PD report at the end of study is also emphasized.

MR_IJ_1: The notifications reminded me playing this health game is like a health check-up. Sometimes when I missed the reminder, I felt bad. It's like I'm keeping myself in the dark about my health condition... it worries me.

The reminders on health values shifted some participants' focus from extrinsic rewards to having more awareness towards their own health. In terms of rewards, motivational reminders

achieved the effect of shifting some expectation from sanitisers (extrinsic reward) to the PD report (intrinsic reward).

MR_IJ_2: I wanted to know how prone I am to PD. In fact, I wanted to have the sanitisers too, I wanted both!

Researcher: Were you as keen in your health at the start of the study?

MR_IJ_2: Actually, I was thinking of the sanitizers at the beginning. But those reminders over a week made their point, it reminded me to be more health conscious in the process too. It's not like I will lose my original reward, so why not?

In group E2 however, the group of participants who are under Introjected Regulation did not receive consistent messages on the importance of health. As a result, they are not as sure as experiment group participants about the health aspect of health games.

UMR_IJ_1: I have a vague feeling that I should be following these reminders. The messages seem a bit arbitrary though, so I just open the notification whenever I see it... only when I don't have anything urgent to do though!

6.3.4.4 Identified → Integrated: Coaching as a source of motivation for adherence and performance

For participants who already acknowledge and value the health benefits of the Pumpkin Garden game, the reminder messages they receive focuses on motivating and coaching them to the ideal state. In the scope of this study, the ideal state is to reach the highest adherence score they could, and play the game in the best possible way to create more accurate PD reports at the end.

MR_ID_1: I was interested in doing my best to find out my PD risk. I'm glad the reminders seem to pick up on my interest, and provide me with useful tips along the way.

Through refining techniques and self-improvement, another participant was able to better enjoy the health game.

MR_ID_2: I realized I could complete the game faster when following the reminder's tips. It made the game a little more fun to play, especially in this once-in-a-while format.

These messages enact a role model and coach participants to work towards becoming more like the role model. Such messages were suitable for participants who were already interested from

the start. The messages helped them play the game in a more fun and enjoyable way, in which they are able to relate back to the Pumpkin Garden game's health values.

6.3.4.5 Summary of Phenomenographic Analysis

The whole motivation experience consists of 3 rough phases: pre-motivation phase, motivation phase and post-motivation phase. In the first phase, extrinsic motivation is induced; participants went from amotivated to externally motivated. In the second phase, extrinsic motivation is gradually internalized by shifting reliance from real-world objects to self-worth (External, Introjected). In the third phase, internalization focuses on convincing individuals that the new healthy behaviour is personally relevant, and they should integrate the behaviour as part of themselves.

Figure 17. Outcome Space – the Process of Achieving Internalization

Although experienced by different individuals, these themes when strung together back-to-back adequately describe the internalization process of the behaviour of adhering to a regular health game schedule. Amotivated individuals require extrinsic regulation to capture their initial interest, while gamified reminders build self-worth, in the process shifting the extrinsic rewards away from the physical world. When individuals start to personally care about their adherence performance, motivational reminders then start to highlight the true value behind the action, further internalizing their motivation. Eventually through use of role models and coaching techniques, Motivational Reminders drive self-determination to adhere to the new behaviour. Both quantitative and qualitative observations suggest these 4 approaches can be viable methods to encourage medication adherence among patients who need it.

6.3.5 Significance of Findings

The proposed MRM is shown to help design effective interventions for enhancing motivation in new behaviour adherence. The ways motivational reminders react to different internalization stages is potentially applicable for other purposes. These encouraging results pave the way for further motivational reminder applications to improve adherence to different healthy behaviours, especially for medication-taking behaviour. Better adherence to healthy behaviour is the key factor for improving care and population health, and reducing health care costs. Thus, improving adherence to healthy behaviour can create long-term health benefits for individuals as well as society as a whole.

6.4 Summary

The proposed MRM takes a goal-oriented approach to facilitate the internalization process. Both IMI and BREQ-2 questionnaires revealed the effectiveness of motivational reminders in creating adherence to the new behaviour of playing health games. The results provide evidence that the proposed MRM is able to facilitate internalization among study participants, inducing motivation that is more intrinsic in nature that encourages health game adherence based on health values.

All in all, Motivational Reminders are shown to improve adherence to new behaviour, enhance intrinsic motivation and facilitate the internalization process of the said new behaviour. It remains a promising approach to improve medication adherence among people who stand to benefit the most from a regular medicine-taking schedule. With that being said, more participants and longer study periods are required to confirm Motivational Reminders' effectiveness in larger and more diverse populations.

Chapter 7 Conclusion and Future Work

7.1 Motivational Reminder Model (MRM)

This research has tackled the issue of adherence to new behaviour using MRM. Current medication adherence approaches from literature are identified and then compared in the literature review. From the perspective of the patients, reminders appear to be the most appropriate method to solve the issue of non-adherence. Currently, there is a lack of exploration on how the concept of motivation and internalization can be infused into the design of reminder system to better address intentional medication non-adherence.

In this thesis, the MRM was proposed, focusing on speeding up the internalization process of new behaviour. Several motivational elements and their effects are identified through the secondary data analysis in study I, which provided insights to crafting motivational messages and the design of motivational reminders in general. In the subsequent study II, Motivational Reminders were developed and tested. Study results showed that Motivational Reminders can encourage adherence to new behaviours through helping participants internalize the behaviour of playing health games.

In conclusion, the proposed MRM was found to improve adherence to playing short segments of health games, and its effects may well extend into tackling medication adherence. Further studies are required to formalize a mechanism to alternate between different reminder styles for prolonged use, as individuals' stage of internalization is likely to change over time. A larger and more diverse study population will also add value to its applicability among other age groups or health groups. Persistence of the adherence induced by Motivational Reminders should also be evaluated in future longitudinal studies.

7.2 Future Work

This section features future work to further enhance MRM and its applications. Future building blocks can leverage machine learning techniques to enhance generation and delivery of motivational reminders.

7.2.1 Motivational Agent

Agents are powerful repertoire of tools, techniques and metaphors that have the potential to improve the way in which people conceptualise and implement many types of software [101]. Motivational agents can be constructed to enable interaction with users to take place with the proposed motivational reminder messages. With the advance of technology, it has become easier to design a computer-based environment to support the interactions between amotivated individuals and computers. This facilitates the development of motivational agent. In context of motivational reminders, the motivational agent can be used as human-like avatar that appear on screen. Motivational agents can present the motivational messages to stimulate users to perform a task and or maintain a healthy behaviour, and is smart enough to know what he wants in the conversation with the end-users and how to express it in his motivating practice.

The core architecture of motivational agent is intelligence. Intelligence, however, is not a single dimension. The pillars of intelligence include knowledge and reasoning. Knowledge refers to facts, procedures, data, skills that can be looked up and accessed when needed. Reasoning is the ability to inference logically. Both concepts can be achieved through knowledge graph (7.2.2 below) and natural language generation (7.2.3 below) to enhance the agent's intelligence and fluency of speech. These areas pave very important directions for future research and development of MRM.

7.2.2 Knowledge Graph

Motivational agents need knowledge to provide answers that make meaning and sense. The power of knowledge graph enables the motivational agent to initiate a motivational conversation and answer questions on structured knowledge base. A Knowledge Graph (KG), also known as knowledge base is a way of storing information that is particularly useful for conversational purpose [102].

KG helps establish a common understanding of information that is being communicated. KG can map complex things (document, image or graph) into a fixed length vector or a metric that captures key features while reducing the dimensionality. KGs are the structured information in the form a graph. Entities (e.g.: people, places, objects) are represented as nodes, and relationships between entities (e.g.: how they are related to) are represented as edges [103]. Two entities (nodes) connected by a relationship (edge) form a fact. In the case of binary random variable $X \in \{0, 1\}$ where 1 represent existence and 0 represents absence, if the tuple (h, r, t) exists, $X = 1$, otherwise $X = 0$.

Figure 18. Knowledge Graph Model

The main tasks of KG are link prediction, entity resolution and link-based clustering. Practical uses of KG include making chatbots [104]. It enables the conversational platform to generate knowledge by inferring potential relations between entity pairs by interpreting the graph-based databases. Therefore, the motivational agent is fed with knowledge from the KG in order to better communicate and interact with the end-users meaningfully.

KG can also be used for dialog-based access to motivational messages, because KG helps to achieve a better understanding of natural language dialogs. Figure 19 below is an example of KG application scenario for MRM.

Figure 19. Using Knowledge Graph for Smart Motivational Agent

KG provides more benefits in terms of convenience and fast access to information and support through the entire motivation experience through the agent system. The technology of natural language generation can be built on top of KGs to create intelligent, fluent conversations.

7.2.3 Natural Language Generation

Natural Language Generation (NLG) is a subset of Natural Language Processing (NLP) and can potentially be used for automated motivational text generation. NLG is the process of producing meaningful phrases and sentences in the form of natural language that enables the motivational agent to analyse text and also integrate it. For example, NLG can be used to explain medical information in a patient-friendly way or produce conversation about the object described in knowledge base [105].

NLG generates narratives that describe, summarise or explain the input structured data in human-like manner to write the sentences and paragraphs for motivational agent. NLG turns the set of ideas locked in data into language that end-users can comprehend easily. As it turns out, motivational agents can automate communication tasks. NLG is beneficial as it can record data in real-time and react accordingly, generating narratives that interact and inform the users about them. Therefore, motivational agents can communicate timely with the end-users.

The process of NLG begins with a particular goal. To satisfy the goal, NLG tasks of content selection (information to be mentioned), documents structuring (how the text should be structured), lexicalization (choice of particular words), aggregation (sentence composition), referring expression generation (using of pronouns and anaphors) and linguistic realization (natural language) are carried out by the sequential NLG architecture [106]. Document planner decides which information should be expressed by text and how the chosen content should be structured in a coherent manner. Sentence planner deals with mapping of document plan to linguistic format and groups information into sentences. The output which is the motivational text is completed by transforming the specification of each word or phrase in an appropriate sequence for end users.

Figure 20. Sequential Architecture of NLG

NLG combines knowledge about language and the application domains to automatically produce motivational messages. NLG can be used to build authoring aids to help end users create routine texts, which help quickly produce good words. Applying NLG into the

motivational agent as an authoring aid helps to build motivation for adhering to a health behaviour. These building blocks has potential to create an effective agent as a user-friendly interface that enhances the applicability of MRM. Intelligent agents is also a vibrant and rapidly expanding area of research. Motivational agents can be developed with exciting technologies from this field of research to create responsive, proactive and lively characters that people can interact with. Enhancing MRM with intelligent agents remain as a promising topic for future research.

7.2.4 Incorporating Coaching Models into MRM

Future development of MRM can also incorporate the Goal-Oriented Storytelling Model as part of the last internalization step [77], [78]. A systematic method to show individuals how to accomplish given tasks may significantly improve their self determination and allow them to perform well with faster transition to integrated regulation stage.

It is anticipated that MRM's future development can be enhanced with the help of AI technologies and coaching models.

Appendix A: Secondary Data Set

S/N	Gender	Age	External incentive	Delay of task	Complexity of ongoing task	Relatedness of task	Importance of Task	Result
1	F	51	No	5 hours	Play Mahjong	Saw phone	Low	Delay 45mins
2	M	52	No	5 hours	Driving	None	Low	Delay 10mins
3	F	53	Yes	5 hours	Housework	None	6	Remember
4	M	55	Yes	5 hours	Sleeping	Saw other playing phone	6	Delay 4mins
5	M	51	Yes	5 hours	Working	None	6	Remember
6	F	48	Yes	5 hours	Resting	None	7	Remember
7	F	63	No	5 hours	Watching TV	None	6	Remember
8	M	63	No	5 hours	Working	None	5	Remember

S/N	Gender	Age	External incentive	Delay of task	Complexity of ongoing task	Relatedness of task	Importance of Task	Result
9	F	65	No	5 hours	Watching TV	Saw phone	7	Remember
10	M	64	No	5 hours	Playing Mahjong	None	7	Remember
11	F	55	No	5 hours	Watching TV	Saw the clock	7	Remember
12	M	88	No	5 hours	Cooking	Saw the clock	7	Remember

Appendix B: Modified Intrinsic Motivation Inventory (IMI)

		Not at all true			Somewhat true			Very true
	Activity Perception Questionnaire Items*	1	2	3	4	5	6	7
1	I believe that playing this health game could be of some value for me							
2	I believe I had some choice about playing this health game							
3	While I was playing this health game, I was thinking about how much I enjoyed it							
4	I believe that playing this health game is useful for improved concentration							
5	This health game was fun to play							
6	I think this health game is important for improving my health							
7	I enjoyed playing this health game very much							
8	I really did not have a choice about playing this health game							
9	I played this health game because I wanted to							
10	I think this is an important health game							
11	I felt like I was enjoying the health game while I was playing it							
12	I thought this was a very boring health game							
13	It is possible that this game could improve my health							
14	I felt like I had no choice but to play this health game							
15	I thought this was a very interesting health game							
16	I am willing to play this health game again because I think it is somewhat useful							

17	I would describe this health game as very enjoyable							
18	I felt like I had to play this health game							
19	I believe playing this health game could be somewhat beneficial for me							
20	I did this health game because I had to							
21	I believe playing this health game could help me do better in health							
22	While playing this health game I felt like I had a choice							
23	I would describe this health game as very fun							
24	I felt like it was not my own choice to play this health game							
25	I would be willing to play this health game again because it has some value for me							

*Interest/enjoyment: 3, 5, 7, 11, 12(R), 15, 17, 23

Value/usefulness: 1, 4, 6, 10, 13, 16, 19, 21, 25

Perceived choice: 2, 8(R), 9, 14(R), 18(R), 20(R), 22, 24(R)⁷

⁷ Scoring information: The (R) after an item number indicates that the item score is the reverse of the participant's response on that item.

Appendix C: Modified BREQ-2

	Original BREQ-2 Activity: Exercise External: Pressure from friends/family	Modified BREQ-2 Activity: Play Health Games External Regulation: Hand Sanitizers (in midst of COVID-19 pandemic)
AMOT	<ul style="list-style-type: none"> • I don't see why I should have to exercise • I can't see why I should bother exercising • I don't see the point in exercising • I think that exercising is a waste of time 	<ul style="list-style-type: none"> • I don't see why I should play health games • I can't see why I should bother playing health games • I don't see the point in playing health games • I think playing health games is a waste of time
EXT	<ul style="list-style-type: none"> • I take part in exercise because my friends/family/spouse say I should • I exercise because others will not be pleased with me if I don't • I feel under pressure from my friends/family to exercise 	<ul style="list-style-type: none"> • I play health games because I can get rewarded • I play health games because I won't get rewarded if I don't play • I feel under pressure to play health games
IJ	<ul style="list-style-type: none"> • I feel guilty when I don't exercise • I feel ashamed when I miss an exercise session • I feel like a failure when I haven't exercised in a while 	<ul style="list-style-type: none"> • I feel guilty when I don't play health games • I feel ashamed when I miss a health game reminder • I feel like a failure when I miss multiple health game reminders
ID	<ul style="list-style-type: none"> • I value the benefits of exercise • It's important to me to exercise regularly • I think it is important to make the effort to exercise regularly • I get restless if I don't exercise regularly 	<ul style="list-style-type: none"> • I value the benefits of playing health games • It's important for me to play health games regularly • I think it is important to make effort to play health games regularly • I get restless if I don't play health games regularly
IM	<ul style="list-style-type: none"> • I exercise because it's fun • I enjoy my exercise sessions • I find exercise a pleasurable activity • I get pleasure and satisfaction from participating in exercise 	<ul style="list-style-type: none"> • I play health games because it's fun • I enjoy my gameplay sessions • I find playing health games a pleasurable activity • I get pleasure and satisfaction from playing health games

The modified BREQ-2 is shuffled and printed on paper for participants to fill in, once before the study and once after the study.

Appendix D: Free-form Interview Questions

The questions are designed to understand more qualities of the motivational experiences:

Do you find the reminders useful? Why?

Do you find the reminders to be motivating? Why?

Has the content in the reminders helped you change your mind? Why?

Do reminders help you know the importance of the gameplay? Why?

Do reminders motivate you to adhere to the gameplay schedule? Why?

Do you like to have such reminder app? Why?

Do you prefer to play the game with reminders or without reminders? Why?

Other feedback

References

- [1] “Ministry of Health (MOH) News Highlights.” <https://www.moh.gov.sg/news-highlights/details/peech-by-mr-gan-kim-yong-minister-for-health-at-the-ministry-of-health-committee-of-supply-debate-2019> (accessed Dec. 23, 2020).
- [2] “Singapore Life Expectancy 1950-2020.” <https://www.macrotrends.net/countries/SGP/singapore/life-expectancy> (accessed Dec. 14, 2020).
- [3] J. A. Cramer, Á. Benedict, N. Muszbek, A. Keskinaslan, and Z. M. Khan, “The significance of compliance and persistence in the treatment of diabetes, hypertension and dyslipidaemia: a review,” *Int J Clin Pract*, vol. 62, no. 1, pp. 76–87, Jan. 2008, doi: 10.1111/j.1742-1241.2007.01630.x.
- [4] “Medication Compliance and Persistence: Terminology and Definitions,” *Value in Health: The Journal of the International Society for Pharmacoeconomics and Outcomes Research*, vol. 11, no. 1, pp. 44–47, Jan. 2008, doi: 10.1111/j.1524-4733.2007.00213.x.
- [5] M. C. Sokol, K. A. McGuigan, R. R. Verbrugge, and R. S. Epstein, “Impact of medication adherence on hospitalization risk and healthcare cost,” *Med Care*, vol. 43, no. 6, pp. 521–530, Jun. 2005, doi: 10.1097/01.mlr.0000163641.86870.af.
- [6] M. T. Brown, J. Bussell, S. Dutta, K. Davis, S. Strong, and S. Mathew, “Medication Adherence: Truth and Consequences,” *Am J Med Sci*, vol. 351, no. 4, pp. 387–399, Apr. 2016, doi: 10.1016/j.amjms.2016.01.010.
- [7] M. T. Brown and J. K. Bussell, “Medication Adherence: WHO Cares?,” *Mayo Clinic Proceedings*, vol. 86, no. 4, pp. 304–314, Apr. 2011, doi: 10.4065/mcp.2010.0575.
- [8] A. Gast and T. Mathes, “Medication adherence influencing factors—an (updated) overview of systematic reviews,” *Systematic Reviews*, vol. 8, no. 1, p. 112, May 2019, doi: 10.1186/s13643-019-1014-8.
- [9] A. Ricci, L. Gosetto, K. Blondon, and F. Ehrler, “The New Smart-Meds: Redesign of a Gamified App to Improve Medication Adherence Using a Mixed Methods Design,” in *Studies in Health Technology and Informatics*, A. Värri, J. Delgado, P. Gallos, M. Hägglund, K. Häyrynen, U.-M. Kinnunen, L. B. Pape-Haugaard, L.-M. Peltonen, K. Saranto, and P. Scott, Eds. IOS Press, 2020. doi: 10.3233/SHTI200719.
- [10] K. S. Ingersoll and J. Cohen, “The impact of medication regimen factors on adherence to chronic treatment: a review of literature,” *J Behav Med*, vol. 31, no. 3, pp. 213–224, Jun. 2008, doi: 10.1007/s10865-007-9147-y.
- [11] J. Dunbar-Jacob and J. M. Rohay, “Predictors of medication adherence: fact or artifact,” *J Behav Med*, vol. 39, no. 6, pp. 957–968, Dec. 2016, doi: 10.1007/s10865-016-9752-8.
- [12] G. Reach, “Obedience and motivation as mechanisms for adherence to medication: a study in obese type 2 diabetic patients,” *Patient preference and adherence*, vol. 5, p. 523, 2011, doi: 10.2147/PPA.S24518.
- [13] K. H. Pitkala, T. E. Strandberg, and R. S. Tilvis, “Interest in healthy lifestyle and adherence to medications: Impact on mortality among elderly cardiovascular patients in the DEBATE Study,” *Patient Education and Counseling*, vol. 67, no. 1, pp. 44–49, Jul. 2007, doi: 10.1016/j.pec.2007.01.016.

- [14] R. Nieuwlaat *et al.*, “Interventions for enhancing medication adherence,” *Cochrane Database of Systematic Reviews*, no. 11, 2014, doi: 10.1002/14651858.CD000011.pub4.
- [15] A. Cross *et al.*, “99DOTS: a low-cost approach to monitoring and improving medication adherence,” in *Proceedings of the Tenth International Conference on Information and Communication Technologies and Development*, New York, NY, USA, Jan. 2019, pp. 1–12. doi: 10.1145/3287098.3287102.
- [16] J. M. Silva, A. Mouttham, and A. El Saddik, “UbiMeds: a mobile application to improve accessibility and support medication adherence,” in *Proceedings of the 1st ACM SIGMM international workshop on Media studies and implementations that help improving access to disabled users*, New York, NY, USA, Oct. 2009, pp. 71–78. doi: 10.1145/1631097.1631109.
- [17] C. J. Charlesworth, E. Smit, D. S. H. Lee, F. Alramadhan, and M. C. Odden, “Polypharmacy Among Adults Aged 65 Years and Older in the United States: 1988–2010,” *J Gerontol A Biol Sci Med Sci*, vol. 70, no. 8, pp. 989–995, Aug. 2015, doi: 10.1093/gerona/glv013.
- [18] L. L. Zullig *et al.*, “Novel application of approaches to predicting medication adherence using medical claims data,” *Health Services Research*, vol. 54, no. 6, pp. 1255–1262, 2019, doi: <https://doi.org/10.1111/1475-6773.13200>.
- [19] A. Patel, E. Kuti, K. Dale, S. Shah, C. White, and C. Coleman, “Effect of a medication assistance program on clinical outcomes in patients with diabetes,” *Formulary (Cleveland, Ohio)*, vol. 41, pp. 518–522, Oct. 2006.
- [20] A. O. Iuga and M. J. McGuire, “Adherence and health care costs,” *Risk Manag Healthc Policy*, vol. 7, pp. 35–44, 2014, doi: 10.2147/RMHP.S19801.
- [21] S. Mehmood and A. Najmi, “Understanding the impact of service convenience on customer satisfaction in home delivery: Evidence from Pakistan,” *International Journal of Electronic Customer Relationship Management*, vol. 11, p. 23, Jan. 2017, doi: 10.1504/IJECRM.2017.086752.
- [22] F. T. Shaya and N. D. Eddington, “Disruptive Innovation in Pharmacy: Lessons from the Amazon Frontier,” *JAMA Health Forum*, vol. 1, no. 1, p. e200038, Jan. 2020, doi: 10.1001/jamahealthforum.2020.0038.
- [23] K. D. Checchi, K. F. Huybrechts, J. Avorn, and A. S. Kesselheim, “Electronic medication packaging devices and medication adherence: A systematic review,” *JAMA*, vol. 312, no. 12, pp. 1237–1247, Sep. 2014, doi: 10.1001/jama.2014.10059.
- [24] P. H. Rivers, “Compliance aids--do they work?,” *Drugs Aging*, vol. 2, no. 2, pp. 103–111, Apr. 1992, doi: 10.2165/00002512-199202020-00004.
- [25] J. M. Castellano *et al.*, “A polypill strategy to improve adherence: results from the FOCUS project,” *J Am Coll Cardiol*, vol. 64, no. 20, pp. 2071–2082, Nov. 2014, doi: 10.1016/j.jacc.2014.08.021.
- [26] “Pill Reminder - All in One,” *App Store*. <https://apps.apple.com/us/app/pill-reminder-all-in-one/id816347839> (accessed Jun. 09, 2021).
- [27] “Medisafe App - Download the app and never miss another med,” *Medisafe*. <https://www.medisafeapp.com/> (accessed Jun. 09, 2021).
- [28] “Medication Reminder and Pill Tracker App – MyTherapy.” <https://www.mytherapyapp.com> (accessed Jun. 09, 2021).

- [29] K. Tabi *et al.*, “Mobile Apps for Medication Management: Review and Analysis,” *JMIR Mhealth Uhealth*, vol. 7, no. 9, Sep. 2019, doi: 10.2196/13608.
- [30] K. Santo, S. S. Richtering, J. Chalmers, A. Thiagalingam, C. K. Chow, and J. Redfern, “Mobile Phone Apps to Improve Medication Adherence: A Systematic Stepwise Process to Identify High-Quality Apps,” *JMIR Mhealth Uhealth*, vol. 4, no. 4, Dec. 2016, doi: 10.2196/mhealth.6742.
- [31] “Thinking Outside the Pillbox: A System-wide Approach to Improving Patient Medication Adherence for Chronic Disease.”, Accessed: Jan. 29, 2021. [Online]. Available: <https://psnet.ahrq.gov/issue/thinking-outside-pillbox-system-wide-approach-improving-patient-medication-adherence-chronic>
- [32] D. J. Finitis, J. A. Pellowski, and B. T. Johnson, “Text Message Intervention Designs to Promote Adherence to Antiretroviral Therapy (ART): A Meta-Analysis of Randomized Controlled Trials,” *PLOS ONE*, vol. 9, no. 2, p. e88166, Feb. 2014, doi: 10.1371/journal.pone.0088166.
- [33] L. Dayer, S. Heldenbrand, P. Anderson, P. O. Gubbins, and B. C. Martin, “Smartphone medication adherence apps: Potential benefits to patients and providers,” *Journal of the American Pharmacists Association*, vol. 53, no. 2, pp. 172–181, Mar. 2013, doi: 10.1331/JAPhA.2013.12202.
- [34] G. A. Morgan, R. J. Harmon, and C. A. Maslin-Cole, “Mastery Motivation: Definition and Measurement,” *Early Education and Development*, vol. 1, no. 5, pp. 318–339, Jul. 1990, doi: 10.1207/s15566935eed0105_1.
- [35] E. L. Deci, “Conceptualizations of Intrinsic Motivation,” in *Intrinsic Motivation*, E. L. Deci, Ed. Boston, MA: Springer US, 1975, pp. 23–63. doi: 10.1007/978-1-4613-4446-9_2.
- [36] R. M. Ryan and E. L. Deci, “Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions,” *Contemporary Educational Psychology*, vol. 25, no. 1, pp. 54–67, Jan. 2000, doi: 10.1006/ceps.1999.1020.
- [37] R. M. Ryan and E. L. Deci, “Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being,” *American Psychologist*, vol. 55, no. 1, pp. 68–78, 2000, doi: 10.1037/0003-066X.55.1.68.
- [38] E. L. Deci and R. M. Ryan, Eds., *Handbook of Self-Determination Research*. Rochester, NY, 2004.
- [39] S. Nicholson, “A RECIPE for Meaningful Gamification,” in *Gamification in Education and Business*, T. Reiners and L. C. Wood, Eds. Cham: Springer International Publishing, 2015, pp. 1–20. doi: 10.1007/978-3-319-10208-5_1.
- [40] E. Deci and R. Ryan, “Motivation, Personality, and Development Within Embedded Social Contexts: An Overview of Self-Determination Theory,” *The Oxford Handbook of Human Motivation*, Jan. 2012, doi: 10.1093/oxfordhb/9780195399820.013.0006.
- [41] H. Patrick and G. C. Williams, “Self-determination theory: its application to health behavior and complementarity with motivational interviewing,” *Int J Behav Nutr Phys Act*, vol. 9, p. 18, Mar. 2012, doi: 10.1186/1479-5868-9-18.
- [42] J. Y. Y. Ng *et al.*, “Self-Determination Theory Applied to Health Contexts: A Meta-Analysis,” *Perspect Psychol Sci*, vol. 7, no. 4, pp. 325–340, Jul. 2012, doi: 10.1177/1745691612447309.

- [43] E. L. Deci and R. M. Ryan, "The 'What' and 'Why' of Goal Pursuits: Human Needs and the Self-Determination of Behavior," *Psychological Inquiry*, vol. 11, no. 4, pp. 227–268, Oct. 2000, doi: 10.1207/S15327965PLI1104_01.
- [44] P. Evans, "Self-determination theory: An approach to motivation in music education," *Musicae Scientiae*, vol. 19, no. 1, pp. 65–83, Mar. 2015, doi: 10.1177/1029864914568044.
- [45] V. Monteiro, L. Mata, F. Peixoto, V. Monteiro, L. Mata, and F. Peixoto, "Intrinsic Motivation Inventory: Psychometric Properties in the Context of First Language and Mathematics Learning," *Psicologia: Reflexão e Crítica*, vol. 28, no. 3, pp. 434–443, Sep. 2015, doi: 10.1590/1678-7153.201528302.
- [46] E. L. Deci and R. M. Ryan, "Toward an Organismic Integration Theory," in *Intrinsic Motivation and Self-Determination in Human Behavior*, 1st ed., Springer, US, 1985, pp. 113–148.
- [47] C. Levesque, K. J. Copeland, M. D. Pattie, and E. L. Deci, "Intrinsic and Extrinsic Motivation," in *International Encyclopedia of Education (Third Edition)*, P. Peterson, E. Baker, and B. McGaw, Eds. Oxford: Elsevier, 2010, pp. 618–623. doi: 10.1016/B978-0-08-044894-7.00612-6.
- [48] E. L. Deci, H. Eghrari, B. C. Patrick, and D. R. Leone, "Facilitating Internalization: The Self-Determination Theory Perspective," *Journal of Personality*, vol. 62, no. 1, pp. 119–142, 1994, doi: <https://doi.org/10.1111/j.1467-6494.1994.tb00797.x>.
- [49] C. S. Rigby and R. M. Ryan, "Self-Determination Theory in Human Resource Development: New Directions and Practical Considerations," *Advances in Developing Human Resources*, vol. 20, no. 2, pp. 133–147, Apr. 2018, doi: 10.1177/1523422318756954.
- [50] P. Boxall and J. Purcell, *Strategy and Human Resource Management*. Macmillan International Higher Education, 2015.
- [51] E. Marescaux, S. De Winne, and L. Sels, "HR practices and HRM outcomes: the role of basic need satisfaction," *Personnel Review*, vol. 42, no. 1, pp. 4–27, Dec. 2012, doi: 10.1108/00483481311285200.
- [52] C. P. Niemiec and R. M. Ryan, "Autonomy, competence, and relatedness in the classroom: Applying self-determination theory to educational practice," *Theory and Research in Education*, Jun. 2009, doi: 10.1177/1477878509104318.
- [53] A. E. Black and E. L. Deci, "The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective," *Science Education*, vol. 84, no. 6, pp. 740–756, 2000, doi: 10.1002/1098-237X(200011)84:6<740::AID-SCE4>3.0.CO;2-3.
- [54] P. Sheeran *et al.*, "Self-determination theory interventions for health behavior change: Meta-analysis and meta-analytic structural equation modeling of randomized controlled trials," *Journal of Consulting and Clinical Psychology*, vol. 88, no. 8, pp. 726–737, 2020, doi: 10.1037/ccp0000501.
- [55] G. C. Williams, V. M. Grow, Z. R. Freedman, R. M. Ryan, and E. L. Deci, "Motivational predictors of weight loss and weight-loss maintenance," *J Pers Soc Psychol*, vol. 70, no. 1, pp. 115–126, Jan. 1996, doi: 10.1037//0022-3514.70.1.115.
- [56] A. W. Kruglanski and E. Szumowska, "Habitual Behavior Is Goal-Driven:," *Perspectives on Psychological Science*, Jun. 2020, doi: 10.1177/1745691620917676.

- [57] A. O. Olanipekun, "Applying the self-determination theory (SDT) to explain the levels of motivation for adopting green building," *International Journal of Construction Management*, vol. 18, no. 2, pp. 120–131, Apr. 2017, doi: 10.1080/15623599.2017.1285484.
- [58] L. C. Ortís *et al.*, "Exercise motivation in university community members: A behavioural intervention," *Psicothema*, vol. 19, pp. 250–255, 2007.
- [59] R. Ryan, H. Patrick, E. Deci, and G. Williams, "Facilitating health behavior change and its maintenance: Interventions based on Self-Determination Theory," *Eur. Health Psychol.*, vol. 10, Nov. 2007.
- [60] A. Assor, M. Vansteenkiste, and A. Kaplan, "Identified versus introjected approach and introjected avoidance motivations in school and in sports: The limited benefits of self-worth strivings," *Journal of Educational Psychology*, vol. 101, no. 2, pp. 482–497, 2009, doi: 10.1037/a0014236.
- [61] R. J. Vallerand, L. G. Pelletier, M. R. Blais, N. M. Briere, C. Senecal, and E. F. Vallieres, "The Academic Motivation Scale: A Measure of Intrinsic, Extrinsic, and Amotivation in Education," *Educational and Psychological Measurement*, Sep. 2016, doi: 10.1177/0013164492052004025.
- [62] M. S. Hagger, N. L. D. Chatzisarantis, and S. J. H. Biddle, "The influence of autonomous and controlling motives on physical activity intentions within the Theory of Planned Behaviour," *Br J Health Psychol*, vol. 7, no. Part 3, pp. 283–297, Sep. 2002, doi: 10.1348/135910702760213689.
- [63] R. T. Golembiewski, *Handbook of Organizational Behavior, Second Edition, Revised and Expanded*. CRC Press, 2000.
- [64] F. C. Lunenburg, "Goal-Setting Theory of Motivation," *International Journal of Management, Business, and Administration*, vol. 15, no. 1, p. 6, 2011.
- [65] Z. Shen, "Goal-Oriented Moedling For Intelligent Agents and Their Applications," Nanyang Technological University, 2005. [Online]. Available: <https://hdl.handle.net/10356/3240>
- [66] World Health Organization, "Adherence to Long-Term Therapies: Evidence for Action," World Health Organization. Accessed: Dec. 25, 2020. [Online]. Available: https://www.who.int/chp/knowledge/publications/adherence_Section1.pdf
- [67] B. Botte, S. Bakkes, and R. Veltkamp, "Motivation in Gamification: Constructing a Correlation Between Gamification Achievements and Self-determination Theory," in *Games and Learning Alliance*, Dec. 2020, pp. 157–166. doi: 10.1007/978-3-030-63464-3_15.
- [68] A. F. Aparicio, F. L. G. Vela, J. L. G. Sánchez, and J. L. I. Montes, "Analysis and application of gamification," in *Proceedings of the 13th International Conference on Interacción Persona-Ordenador - INTERACCION '12*, Elche, Spain, 2012, pp. 1–2. doi: 10.1145/2379636.2379653.
- [69] M. Schmidt-Kraepelin, S. Warsinsky, S. Thiebes, and A. Sunyaev, "The Role of Gamification in Health Behavior Change: A Review of Theory-driven Studies," presented at the Hawaii International Conference on System Sciences, 2020. doi: 10.24251/HICSS.2020.155.

- [70] L. Shi and A. I. Cristea, "Motivational Gamification Strategies Rooted in Self-Determination Theory for Social Adaptive E-Learning," in *Intelligent Tutoring Systems*, Jun. 2016, pp. 294–300. doi: 10.1007/978-3-319-39583-8_32.
- [71] A. Wintermeyer and K. Knautz, "Meaningful Implementation of Gamification in Information Literacy Instruction," in *Information Literacy: Moving Toward Sustainability*, Oct. 2015, pp. 350–359. doi: 10.1007/978-3-319-28197-1_36.
- [72] L. de M. Ortega, A. García-Cabo, and E. G. López, "Towards the social gamification of e-learning: a practical experiment," *The International journal of engineering education*, vol. 33, no. 1, pp. 66–73, 2017.
- [73] S. Palmer, I. Tubbs, and A. Whybrow, "Health coaching to facilitate the promotion of healthy behaviour and achievement of health-related goals," *International Journal of Health Promotion and Education*, vol. 41, no. 3, pp. 91–93, Jan. 2003, doi: 10.1080/14635240.2003.10806231.
- [74] L. R. Duncan, C. R. Hall, P. M. Wilson, and W. M. Rodgers, "The use of a mental imagery intervention to enhance integrated regulation for exercise among women commencing an exercise program," *Motiv Emot*, vol. 36, no. 4, pp. 452–464, Dec. 2012, doi: 10.1007/s11031-011-9271-4.
- [75] J. Cumming and R. Ramsey, "Imagery interventions in sport," in *Advances in Applied Sport Psychology: A Review*, 2009, pp. 5–36. doi: 10.13140/2.1.2619.2322.
- [76] H.-P. Lu and H.-C. Ho, "Exploring the Impact of Gamification on Users' Engagement for Sustainable Development: A Case Study in Brand Applications," *Sustainability*, vol. 12, no. 10, Art. no. 10, Jan. 2020, doi: 10.3390/su12104169.
- [77] Z. Pan, H. Zhang, Y. Zhang, C. Leung, and C. Miao, "A Goal Oriented Storytelling Model for Improvement of Health Game Experiences Among Older Adults," in *Human Aspects of IT for the Aged Population. Supporting Everyday Life Activities*, vol. 12787, Q. Gao and J. Zhou, Eds. Cham: Springer International Publishing, 2021, pp. 135–152. doi: 10.1007/978-3-030-78111-8_9.
- [78] Z. Pan, Y. Zhang, H. Zhang, and Z. Shen, "Coaching Older Adults in Health Games: A Goal Oriented Modelling Approach," in *Social Computing and Social Media: Applications in Marketing, Learning, and Health*, vol. 12775, G. Meiselwitz, Ed. Cham: Springer International Publishing, 2021, pp. 424–442. doi: 10.1007/978-3-030-77685-5_31.
- [79] J. Hou, "Coping with prospective memory failures : an effective reminder system design," Nanyang Technological University, 2018. doi: 10.32657/10220/47737.
- [80] G. Payne and J. Payne, *Key Concepts in Social Research*. 1 Oliver's Yard, 55 City Road, London England EC1Y 1SP United Kingdom: SAGE Publications, Ltd, 2004. doi: 10.4135/9781849209397.
- [81] M. Johnston, "Secondary Data Analysis: A Method of Which the Time has Come," *Qualitative and Quantitative Methods in Libraries*, vol. 3, pp. 619–626, Jan. 2014.
- [82] S. Liu, C. Miao, M. J. McKeown, J. Ji, Z. Shen, and C. Leung, "Pumpkin Garden: A Mobile Game Platform for Monitoring Parkinson's Disease Symptoms," in *Human Aspects of IT for the Aged Population. Applications in Health, Assistance, and Entertainment*, Cham, 2018, pp. 546–560. doi: 10.1007/978-3-319-92037-5_38.

- [83] S. Liu, Z. Shen, Y.-M. Yuan, J. Ji, and M. McKeown, “Pumpkin Garden : A Tablet Game Platform for Parkinson ’ s Disease Rehabilitation,” 2018. /paper/Pumpkin-Garden-%3A-A-Tablet-Game-Platform-for-%E2%80%99-s-Liu-Shen/5e2b09a9ba41fdf9d65e49e0f860bc5fb171e4d6 (accessed Dec. 27, 2020).
- [84] I. Zahoor, A. Shafi, and E. Haq, *Pharmacological Treatment of Parkinson’s Disease*. Codon Publications, 2018. doi: 10.15586/codonpublications.parkinsonsdisease.2018.ch7.
- [85] J. Jankovic and L. G. Aguilar, “Current approaches to the treatment of Parkinson’s disease,” *Neuropsychiatr Dis Treat*, vol. 4, no. 4, pp. 743–757, Aug. 2008.
- [86] “Rehabilitation.” <https://www.who.int/news-room/fact-sheets/detail/rehabilitation> (accessed Apr. 28, 2021).
- [87] D. Markland and V. Tobin, “A Modification to the Behavioural Regulation in Exercise Questionnaire to Include an Assessment of Amotivation,” *Journal of Sport and Exercise Psychology*, vol. 26, no. 2, pp. 191–196, Jun. 2004, doi: 10.1123/jsep.26.2.191.
- [88] R. Mahony, C. Blake, J. Matthews, G. O. Donnoghue, and C. Cunningham, “Physical activity levels and self-determined motivation among future healthcare professionals: Utility of the Behavioral Regulation in Exercise Questionnaire (BREQ-2),” *Physiotherapy Theory and Practice*, vol. 35, no. 9, pp. 884–890, Sep. 2019, doi: 10.1080/09593985.2018.1457112.
- [89] M. L. D’Abundo, C. L. Sidman, J. Milroy, M. Orsini, and K. Fiala, “Construct Validity of College Students’ Responses to the Behavioral Regulation in Exercise Questionnaire (BREQ-2),” *Recreational Sports Journal*, Apr. 2014, doi: 10.1123/rsj.2013-0006.
- [90] E. Mullan, D. Markland, and D. K. Ingledew, “A graded conceptualisation of self-determination in the regulation of exercise behaviour: Development of a measure using confirmatory factor analytic procedures,” *Personality and Individual Differences*, vol. 23, no. 5, pp. 745–752, Nov. 1997, doi: 10.1016/S0191-8869(97)00107-4.
- [91] P. M. Wilson, W. M. Rodgers, C. C. Loitz, and G. Scime, ““It’s Who I Am ... Really!’ The Importance of Integrated Regulation in Exercise Contexts1,” *Journal of Applied Biobehavioral Research*, vol. 11, no. 2, pp. 79–104, 2006, doi: <https://doi.org/10.1111/j.1751-9861.2006.tb00021.x>.
- [92] R. Bénabou and J. Tirole, “Intrinsic and Extrinsic Motivation,” *The Review of Economic Studies*, vol. 70, no. 3, pp. 489–520, Jul. 2003, doi: 10.1111/1467-937X.00253.
- [93] E. McAuley, T. Duncan, and V. V. Tammen, “Psychometric Properties of the Intrinsic Motivation Inventory in a Competitive Sport Setting: A Confirmatory Factor Analysis,” *Research Quarterly for Exercise and Sport*, vol. 60, no. 1, pp. 48–58, Mar. 1989, doi: 10.1080/02701367.1989.10607413.
- [94] F. Marton, “Phenomenography—A Research Approach to Investigating Different Understandings of Reality,” *Journal of Thought*, vol. 21, no. 3, pp. 28–49, 1986.
- [95] G. Åkerlind, J. Bowden, and P. Green, “Learning to do phenomenography: A reflective discussion,” 2005, pp. 74–100.
- [96] J. Larsson and I. Holmström, “Phenomenographic or phenomenological analysis: does it matter? Examples from a study on anaesthesiologists’ work,” *International Journal of Qualitative Studies on Health and Well-being*, vol. 2, no. 1, pp. 55–64, Jan. 2007, doi: 10.1080/17482620601068105.

- [97] L. Mann, G. Dall’Alba, and D. Radcliffe, “Using phenomenography to investigate different ways of experiencing sustainable design,” *ASEE Annual Conference and Exposition, Conference Proceedings*, Jan. 2007.
- [98] G. Åkerlind, “Learning about phenomenography: Interviewing, data analysis and the qualitative research paradigm,” in *Doing Developmental Phenomenography*, 2005, pp. 63–73.
- [99] F. Han and R. A. Ellis, “Using Phenomenography to Tackle Key Challenges in Science Education,” *Front. Psychol.*, vol. 10, 2019, doi: 10.3389/fpsyg.2019.01414.
- [100] P. M. Wilson, C. M. Sabiston, D. E. Mack, and C. M. Blanchard, “On the nature and function of scoring protocols used in exercise motivation research: An empirical study of the behavioral regulation in exercise questionnaire,” *Psychology of Sport and Exercise*, vol. 13, no. 5, pp. 614–622, Sep. 2012, doi: 10.1016/j.psychsport.2012.03.009.
- [101] N. R. Jennings, K. Sycara, and M. Wooldridge, “A Roadmap of Agent Research and Development,” *Autonomous Agents and Multi-Agent Systems*, vol. 1, no. 1, pp. 7–38, Mar. 1998, doi: 10.1023/A:1010090405266.
- [102] J. Bockhorst, D. Conathan, and G. Fung, “Knowledge Graph-Driven Conversational Agents,” p. 12, 2019.
- [103] M. Nickel, K. Murphy, V. Tresp, and E. Gabrilovich, “A Review of Relational Machine Learning for Knowledge Graphs,” *Proceedings of the IEEE*, vol. 104, no. 1, pp. 11–33, Jan. 2016, doi: 10.1109/JPROC.2015.2483592.
- [104] D. Fensel *et al.*, “Why We Need Knowledge Graphs: Applications,” in *Knowledge Graphs: Methodology, Tools and Selected Use Cases*, D. Fensel, U. Şimşek, K. Angele, E. Huaman, E. Kärle, O. Panasiuk, I. Toma, J. Umbrich, and A. Wahler, Eds. Cham: Springer International Publishing, 2020, pp. 95–112. doi: 10.1007/978-3-030-37439-6_4.
- [105] E. Reiter and R. Dale, “Building applied natural language generation systems,” *Natural Language Engineering*, vol. 3, no. 1, pp. 57–87, Mar. 1997, doi: 10.1017/S1351324997001502.
- [106] K. Staykova, “Natural Language Generation and Semantic Technologies,” *Cybernetics and Information Technologies*, vol. 14, Jan. 2014, doi: 10.2478/cait-2014-0015.