REINFORCEMENT FRAMEWORK: STRENGTHENING IMPLEMENTATION INTENTIONS TO SUPPORT HABIT FORMATION

by

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A thesis submitted to
The University of Birmingham
for the degree of
DOCTOR OF PHILOSOPHY

School of Computer Science
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December 2020

Abstract

Mobile apps targeting the formation of new habits are gaining popularity in the market. Although the majority of these apps support repetition of behaviours using reminders, it could lead to a dependency and hinder the development of habits. On the other hand, simple techniques such as implementation intentions remain underused despite having promising results to support habit formation.

This thesis proposes a mechanism to form new habits by using reinforced implementation intentions. Even though it has been suggested that implementation intentions could help to form new habits, they are prone to forgetfulness. We used mood tracking as the intended habit in this study, considering the benefits of regularly tracking mood for mental-health. We proposed a framework for reinforcements targeting the underlying processes of implementation intentions, mainly strengthening the link between a cue and its associated response. We investigated the framework's application in Mood Journal app through a series of empirical studies using different reinforcement strategies: passive, active, and context-aware.

We measured the impact of reinforcements on two important aspects of habits: compliance and automaticity. Our findings suggest that adding reinforcements could maintain the compliance level, but it is not necessarily the same in terms of automaticity. We also discuss how the potential use of reinforcements can be improved in the future.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my supervisors Professor Russell Beale and Dr Robert Hendley, for their continuous support, encouragement and guidance throughout my study. Thank you for introducing me to the world of behaviour and habit that still fascinates me. Your constant feedbacks are really valuable to me.

Also, thanks to Indonesia Endowment Fund for Education (LPDP) for giving me support and financial assistance for the whole duration of my study.

I would like to express my gratitude to amazing friends I have met in Birmingham and have become my family, making me feel at home in the UK, Dawlish family: Febri, Arum, Cecil, Sodik, Desy, Irni, Adi, Naeli. As well as my friends Ade, Poppy, Nina, Rainer, and many others. Special thanks to Rian Fatah who has helped me a lot during my time in Manchester. Also thanks to my friends at School of Computer Science: Ferdian, Syahril, Made, Wad, Aditya, Charlie, Paul. Thanks for wonderful times and memories. Thanks to my thesis group members: Dr Peter Hancox and Dr Rowanne Fleck for giving valuable comments on my work. I am really grateful.

Deepest gratitude to both my parents and family who always pray for me, and always give me constant support to finish my study. Most importantly, I would also thank my dearest wife Pingkan, who always be there, supporting me every day, and always believing in me. Thanks for your enormous support. Finally, to my beloved daughter Amira who always give me reasons to be better and have added laughter at home. I love you all.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Regularly tracking mood can help people to maintain their emotional well-being (Caldeira et al., 2017). Mood tracking does not only benefit healthy individuals but also people with mental health problems (Nicholas, Larsen, Proudfoot, & Christensen, 2015). Smartphones have become a popular tool for people to keep track of their health-related data due to their ubiquity, including mood patterns. Mood tracking apps such as Daylio[2], Reflectify[3], eMoods[4], and Moodflow[5] have attracted millions of users.

With the connectivity and ubiquity of smartphones, researchers have started to study the use of smartphones apps to help people form good habits (Renfree, Harrison, Marshall, Stawarz, & Cox, 2016; Stawarz, Cox, & Blandford, 2015). According to a report from Ofcom in 2018, 78% of adults in the UK use smartphones, and on average, they spend 24 hours each week online (Ofcom, 2018). Due to their popularity, habit formation apps are not only available in experimental settings but also widely accessible from popular app stores, such as Apple App Store and Google Play Store. Many habit formation apps use reminders to help their users stay engaged and remember to perform their intended behaviour (Renfree et al., 2016). However, reminders can hinder the formation of new habits due to the nature of dependency

[2]https://play.google.com/store/apps/details?id=net.daylio
[3]https://play.google.com/store/apps/details?id=com.reflectlyApp
[4]https://play.google.com/store/apps/details?id=my.tracker
[5]https://play.google.com/store/apps/details?id=com.moodpixel

(Renfree et al., 2016). Despite the growing popularity, important features that support the formation of new habits such as defining the situation (cue) that triggers the intended action are not present in the majority of habit formation apps (Stawarz et al., 2015). A study in 2015 reviewed habit formation apps on the app stores and found that among 859 apps, only 3% of those allow people to define the contextual cues when planning to form new habits, instead, the majority of these apps focus on using task tracking (77%) and reminders (44%) as their main features (Stawarz et al., 2015).

Even though both features are good in supporting repetition and adherence to the targeted behaviour, they could lead to dependency, making people depend on the reminders coming from the app to execute the intended behaviour (Renfree et al., 2016). The dependency on reminders is bad for habit formation because a person will associate the reminders with the intended action. Instead of creating dependency through reminders, habit formation apps should help people to form a strong association between the situation (cue) and the intended action. The strength between a cue and its associated action is essential during habit development.

The accessibility of cues is important for a habit to work, including the habit of tracking mood regularly. When a behaviour has become habitual, it will be performed automatically when the cue that triggers the intended behaviour is encountered (Verplanken & Aarts, 1999). Habits can only be formed when there is a strong association between the cue and its response. Habit formation apps targeting regular mood tracking should help their users to associate the task of tracking mood with particular cues (e.g. existing routines) with the aim to create a strong cue-response association, allowing the mood tracking to become habitual.

1.2 Problem definition & objectives

Forming new habits requires repetition of the intended behaviour in stable contexts (Lally & Gardner, 2013). Habitual behaviours tend to be performed automatically when the contexts are encountered (Lally, Van Jaarsveld, Potts, & Wardle, 2010). Contrarily, for new behaviour, it relies on the intentions to be performed (Gollwitzer, 1993). Having intentions alone may

not be enough to form new habits because the strength of the context-response association can overpower the intention to perform the intended behaviour (Neal, Wood, Labrecque, & Lally, 2012; Ouellette & Wood, 1998; Wood & Neal, 2007). Since habitual behaviour will delegate control over environmental cues to trigger the intended behaviour, developing habitual behaviour requires someone to have high accessibility to contextual cues. The current design of the majority of habit formation apps, including the ones targeting mood tracking, do not facilitate cue-response association (Stawarz et al., 2015). Instead, these apps tend to focus on using reminders that could lead to dependency on the reminders (Renfree et al., 2016).

On the other hand, implementation intentions have the potential to support habit development by increasing the accessibility of the cue and its associated response. Implementation intentions delegate the control of performing a behaviour to the environmental cues, improving the chance of executing the intended behaviour when the cues are encountered. Previous studies found that implementation intentions are effective in promoting different types of behaviours, including fruit consumption (Armitage, 2007), following a weight-loss program (Luszczynska, Sobczyk, & Abraham, 2007), drivers' compliance with speed limit (Elliott & Armitage, 2006), physical activity (Hall, Zehr, Ng, & Zanna, 2012), healthy eating (Verplanken & Faes, 1999), cervical cancer screening (Sheeran & Orbell, 2000), and class attendance (Webb, Christian, & Armitage, 2007).

Despite the promising potential, implementation intentions remain prone to forgetfulness. This is due to how implementation intentions works, similar to a prospective memory task which requires a person to remember the specified plan consisting of the cue (defined in the "if" condition) and its associated response (defined in the "then" condition). Because consistently remembering to perform a specified plan in the future is difficult, implementation intentions need to be reinforced to minimise the risk of forgetfulness.

There are several ways implementation intentions can be strengthened. A simple strategy is to add reinforcement, a special type of reminder that aims to help a person remember the specified implementation intention. Unlike normal reminders that aim to prompt the intended

task immediately, reinforcements aim to strengthen the link between the situational cue that triggers the planned intention, and its associated behavioural response. We call this type of reinforcement "passive" because a person does not need to take any actions, just acknowledge the message.

However, passive reinforcement might not be enough to strengthen implementation intentions in the long term, this is due to the lack of immediate response towards the reinforcement. It could still lead to forgetfulness. This is where the second strategy comes into play: active reinforcements. Instead of only reminding the cue and its response, active reinforcements add a mental imagery task that requires a person to vividly imagine the situation in which the behaviour will be performed. Existing research has suggested that a mental imagery task has improved the performance of prospective memory tasks, but only a small amount of research investigate its impact on implementation intention.

Because active reinforcements ask a person to take action by vividly imagining the real situation when they perform the intended behaviour, the person must be available when they receive the reinforcement. Otherwise, the reinforcement can be ignored, or it could even cause adverse effects such as disrupting the ongoing task. Therefore, active reinforcement needs to be delivered at opportune moments to ensure that the recipient can perform the mental imagery task immediately. This is where the third strategy is needed: context-aware reinforcement. This type of reinforcement will utilise the context of the recipient by collecting a smartphone's data, allowing the app to predict the opportune moments. Even though there has been a high amount of research investigating the use of context on smartphones, only a few of them were looking into the use of context to support habit formation, especially through implementation intentions.

Therefore, we identify a gap between theoretical works and the application of habit formation using smartphone apps. More specifically, we address the lack of understanding of how implementation intentions can be applied to smartphone apps targeting the development of new habits such as mood tracking.

1.3 Motivation

Making mood tracking habitual allows it to persist for a prolonged time and can be regularly performed. When a behaviour has become habitual, the strength of the habit will overpower the behavioural intention (Verplanken & Aarts, 1999). Additionally, habitual behaviour will require less cognitive effort, and it will be performed automatically when a specific situation is encountered (Lally & Gardner, 2013; Lally et al., 2010; Orbell & Verplanken, 2010; Wood & Neal, 2007). The rapid growth of smartphone usage has opened a new opportunity for developing mobile-based interventions targeting habit formation.

Despite the growing popularity of habit formation apps, only a small amount of them are built based on the theories of habit. According to (Stawarz et al., 2015), the majority of apps that aim to help people form new habits are focused on self-tracking and reminders, neither of which are suitable for supporting habit formation. For example, Streaks, a top-rated habit formation app, guides its users to build new habits by creating a repetitive goal called a "streak". The app does not give any guidance on associating the intended goal with existing cues. Instead, the app uses reminders to keep the consistency of the repeated behaviour by its users.

Although reminders might work for a short period, they can lead to dependency, making an individual rely upon the reminders' availability instead of the actual cues that should trigger the habitual behaviour (Renfree et al., 2016). Reminders also inhibit automaticity (the unconscious enacting of the behaviour) as the essential characteristic of habit. When the reminders are removed, people tend to forget to act upon their intended behaviour. Therefore, a better approach is needed to design effective habit formation apps.

Whereas the majority of habit formation apps rely on self-tracking and reminders as the key features in helping people to develop habits, some important features and techniques that support habit formation remain overlooked (Stawarz et al., 2015). Habits are consistent actions that follow a cue in the presence of a constant environment (Verplanken & Aarts, 1999). One of the techniques that can be used to strengthen this effect and support habit formation is implementation intentions (Holland, Aarts, & Langendam, 2006).

Implementation intentions are a specific action plan which follows a pattern *"If situation X happens, then I will do Y"* (Gollwitzer, 1999). Implementation intentions have been found to be effective in supporting habit formation and increasing the automaticity of behaviour by heightening the accessibility of the cue and strengthening the mental link between the cue and its associated response (Adriaanse, Vinkers, De Ridder, Hox, & De Wit, 2011; Holland et al., 2006; Lally & Gardner, 2013). Implementation intentions are also effective in helping people to achieve their goal (Webb & Sheeran, 2007). Currently, implementation intentions remain underused in smartphone apps targeting habit formation (Pinder, Vermeulen, Wicaksono, Beale, & Hendley, 2016).

However, despite early promising results, implementation intentions may well only have a weak effect, especially when the intention to perform the targeted behaviour is not strong enough (Prestwich, Lawton, & Conner, 2003; Sheeran, Webb, & Gollwitzer, 2005). Therefore, positive reinforcement is needed to strengthen the effect of implementation intentions.

Research in the area of enhancing implementation intentions remains scarce. One of the suggested techniques that can be used to enhance the effect of implementation intentions is reinforcements (Prestwich & Kellar, 2014). In the previous studies, the content and the delivery time of the reminders were unclear as participants were allowed to decide both the content and delivery (time, day, and frequency) of the reminders (Prestwich, Perugini, & Hurling, 2009, 2010). If the reminders of implementation intentions were sent at the due time when the behaviour was supposed to be performed, then it would diminish the effect of implementation intention by creating a dependency on the reminders. Therefore, we are interested in trying a different approach and conducted a study to investigate how implementation intentions can be enhanced by adding a particular type of reminder that we refer to as *reinforcements*. Reinforcements are different from reminders in terms of their respective goal. Whilst reminders aim to prompt the intended behaviour, reinforcements for implementation intentions aim to strengthen the mental link between the cue and its associated behavioural response. With reinforcements, people will be made more aware that they have an intention to change behaviours, and the reinforcement aims to increase the saliency of the cue that triggers

the intended behaviour. It therefore tries to reinforce the habit-forming approach itself.

Since there is a limited amount of research investigating the effect of adding reinforcements to implementation intentions, we explore the potential use of technology to address this issue. More specifically, we investigate how mobile apps can be used to deliver reinforcements of implementation intentions to support the formation of new habits.

1.4 Research questions

Based on the discussion in our previous sections, we identify the gap between habit formation theories and their implementation in smartphone apps. More specifically, we identify the weakness of using reminders that could lead to dependency. On the other hand, despite the promising potential, we found that implementation intention remains underused in HCI studies.

As a result, the primary goal of this thesis is to investigate the use of different reinforcement strategies on implementation intentions to support habit formation.

To achieve the goal of this thesis, we run several empirical studies and propose a framework of reinforcement to strengthen implementation intentions. The empirical studies that we have conducted seek to answer the following research questions:

- **Research Question 1:** How can implementation intentions be strengthened to support habit formation?
- **Research Question 2:** How does passive reinforcement affect implementation intention?
- **Research Question 3:** How can we use active reinforcement to improve the impact of reinforcement of implementation intention?
- **Research Question 4:** How can we utilise context to deliver reinforcement of implementation intention at opportune moments?

1.5 Contributions and thesis outline

This thesis aims to investigate the use of reinforced implementation intentions to support habit formation. The key contributions of this thesis are outlined in the following chapters

- In Chapter 2, we discuss the underpinning theories of habits. We argue that mood tracking is important for mental health and why it is necessary to make it habitual. We discuss the relationship between mood tracking as a prospective memory task, how implementation intentions can improve its performance, how different strategies of memory aids can be used, and give several examples of existing works around smartphone apps for mood tracking. We end this chapter by outlining the potential use of memory aids as reinforcements to strengthen implementation intentions and describe their requirements.

- In Chapter 3, we propose a framework of reinforcement to strengthen the impact of implementation intentions. We provide a detailed explanation of how reinforcement works and why it is different from reminders. We also give a more detailed discussion around the mechanism of reinforced implementation intentions to support mood tracking as a prospective memory task. We also discuss the design and development of the Mood Journal app as an important software in this study. We conclude this chapter by proposing the implementation of this framework using three different strategies: passive, active, and context-aware, and how each strategy will be evaluated.

- In Chapter 4, we present a practical implementation of the framework using mobile apps by conducting a study using passive reinforcements. Based on our findings, we suggest that adding reinforcements enhances implementation intentions in terms of compliance but not necessarily in terms of automaticity.

- in Chapter 5, we discuss a follow-up study by making the reinforcements active. We added a mental imagery task to rehearse the implementation intentions immediately when the reinforcements were sent. We investigated the impact of active reinforcements on the compliance level and automaticity. In addition, we also analysed the response

towards reinforcement itself.

- In Chapter 6, we present another study based on the previous findings. In this study, we investigate the use of context gathered from smartphones data to deliver active reinforcements. We propose a mechanism to gather a smartphone's data to infer opportune moments using a simple technique.

- In Chapter 7, we conclude this thesis by summarising the findings and contributions in the area of habit formations. We also suggest potential areas to investigate for future research.

1.6 Publications

Several works and results from empirical studies in this thesis have been published and presented in the following journal and conferences:

Journal paper

Adhi Wicaksono, Robert J. Hendley, Russell Beale. 2019 Investigating the Impact of Adding Plan Reminders on Implementation Intentions to Support Behaviour Change, Interacting with Computers, Volume 31, Issue 2, March 2019, Pages 177–191. DOI: https://doi.org/10.1093/iwc/iwz012

Conference paper - Full

Adhi Wicaksono, Robert J. Hendley, Russell Beale. 2018. Does adding reinforcement of implementation intentions support behaviour change?. In Proceedings of the 32nd International BCS Human Computer Interaction Conference 32 (pp. 1-11). DOI: http://dx.doi.org/10.14236/ewic/HCI2018.38

Conference papers - WIP

Adhi Wicaksono, Robert J. Hendley, Russell Beale. 2019. Using reinforced implementation intentions to support habit formation. in CHI Conference on Human Factors in Computing Systems Extended Abstracts (CHI'19 Extended Abstracts). Association for Computing Machinery (ACM), ACM CHI Conference on Human Factors in Computing Systems (CHI 2019), Glasgow, United Kingdom, 4/05/19. https://doi.org/10.1145/3290607.3312985

CHAPTER 2

BACKGROUND AND RELATED WORKS

2.1 Overview

This thesis aims to investigate the impact of reinforced implementation intentions on mobile apps to support the development of daily mood reports as a habit. This chapter summarises underpinning theories and relevant works within mood tracking, habits, prospective memory, and smartphone apps. It starts with a discussion about mood tracking and why people need to track their mood regularly. Several benefits of regular mood tracking are discussed to justify the targeted behaviour. Habitual behaviours tend to be performed automatically when a cue triggering the response is encountered (Lally & Gardner, 2013). Making mood tracking a habitual behaviour will give long-term benefits, therefore the underlying mechanisms around habit formation are also discussed. When a behaviour such as mood tracking is not yet habitual, it relies on the strength of intentions to be performed (Ajzen, 1991). Therefore, we discuss the use of a simple technique called implementation intentions to turn intentions into actions (Gollwitzer, 1999). We also discuss prospective memory tasks since remembering to track mood regularly requires a person to remember the planned action in advance. Several factors around event-based vs time-based prospective memory are also discussed to show how implementation intentions can help increase the performance of prospective memory tasks. It is followed by a discussion around memory aids, which can be used to prevent forgetfulness when the intention to act has been planned. Finally, this chapter concludes by reviewing existing

work around smartphone apps to support habit formation by outlining their limitations and opportunities to improve their effectiveness in helping people to develop their habits.

2.2 Mood tracking

Psychological well-being has been regarded as an important aspect of mental-health (Ryff & Keyes, 1995). Positive emotions lead people to have better healthy habits, lower risk of cardiovascular disease, and better immune systems (Seligman, 2004). In addition, people with positive emotions are also found to be healthier, more successful, and socially engaged (Seligman, Steen, Park, & Peterson, 2005). Tracking mood regularly helps people to maintain their emotional well-being by increasing awareness of their mood patterns (Caldeira et al., 2017). Not only does it benefit healthy individuals, but mood tracking can also help individuals with mental health problems such as bipolar disorders (Nicholas et al., 2015). Mood tracking is also an important part of Cognitive Behavioural Therapy (CBT) (M. Matthews, Doherty, Sharry, & Fitzpatrick, 2008).

Mood is not the only component affecting mental health. In addition to mood, emotion and temperament are also important in our daily lives (Gray, Watson, Payne, & Cooper, 2001). Emotion is the most sensitive among those three, in which it changes frequently in response to external stimuli, making it highly adaptive (Gray et al., 2001). Conversely, mood cannot be linked to specific stimuli and does not change quickly (Gray et al., 2001). Instead, mood is a cumulative state of emotions over a period of time (Thayer, 1996). Mood has a strong influence on how people respond to events around them and can affect their cognition (Ekman & Davidson, 1994; Gray et al., 2001). Mood also affects judgement and the decision-making process, making it a pivotal aspect of our lives (Parkinson, Totterdell, Briner, & Reynolds, 1996; Thayer, 1996). Whereas emotion and mood are the reflections of the current state of mind which is temporary, temperament reflects the basic characteristic of trait and as a result more stable. Considering emotion and mood are more adaptive and they change more frequently, we will focus on these two aspects, especially mood due to its importance in

determining our response and decisions making towards various events in our lives.

Tracking mood regularly is beneficial for emotional well-being. Traditionally, Watson and Tellegen (1985) suggest that mood can be measured using a framework called Positive and Negative Affect Schedule (PANAS) which focuses on two dimensions of mood: positive affect and negative affect. However, the reliability and validity of the measurement method were criticised due to the nature of positive affect and negative effect (Russell & Carroll, 1999). Another criticism towards PANAS is that the two variables (positive affect and negative affect) are not sufficient to measure the mood (G. Matthews, Jones, & Chamberlain, 1990). As an alternative, a new model that measures three different dimensions of mood was proposed (Schimmack & Grob, 2000). The three dimensions of valance (ranging from unpleasant to pleasant), calmness (ranging from tense to relaxed), and energetic arousal (ranging from tired to awake) were argued to be the core structure of mood (Schimmack & Grob, 2000; Wilhelm & Schoebi, 2007). The aforementioned dimensions are closely correlated and as a result, when tracking mood, those three dimensions must be measured.

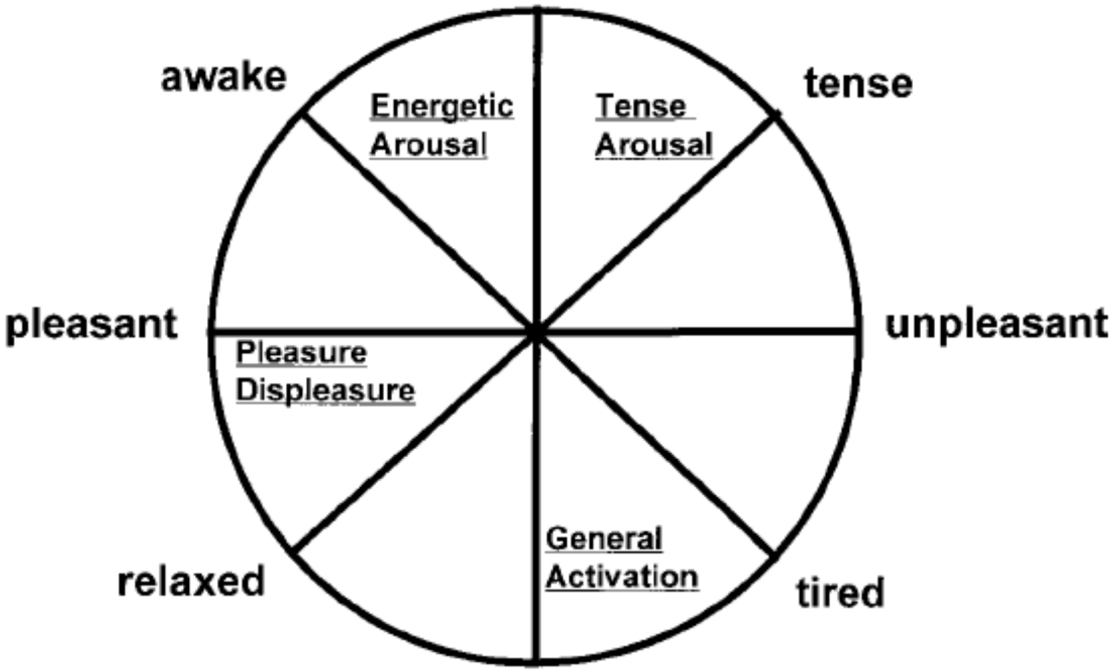


Figure 2.1: Three dimensions of mood (Schimmack & Grob, 2000)

Despite the proven benefits, mood tracking has not been part of habits for most people,

especially for healthy people. When a behaviour is not habitual, the execution relies on the strength of intentions (Gollwitzer, 1993). However, intentions are not stable and may change, making the intended behaviour not enacted (Orbell, Hodgkins, & Sheeran, 1997). Considering the importance of regularly tracking mood for mental health, mood tracking should be made a habitual behaviour.

2.3 Habits

Habits are defined as learned behaviours that have been repeated consistently, thereby performed automatically as a response to particular situations (Lally & Gardner, 2013; Verplanken & Aarts, 1999; Wood & Neal, 2007, 2009). Even though repetition is necessary during the formation of new habits, the frequency of the repetition does not necessarily lead to habits (Orbell & Verplanken, 2010). Behaviours can become habitual only if the repetition occurs in stable contexts (Gardner & Lally, 2018; Lally et al., 2010). Contexts in which habitual behaviours are repeated can be anything from locations, events, other people, or previous actions (Wood & Neal, 2007).

Habitual behaviours can be activated without much cognitive thought (Ouellette & Wood, 1998; Wood, Quinn, & Kashy, 2002). Orbell and Verplanken (2010) argue there are three important features of habits: repeated consistently, performed automatically, and triggered by stable contexts. Performing a behaviour creates an association between contexts as a cue and behaviour as a response (Lally & Gardner, 2013). Repetition of behaviour in stable contexts strengthens this association (Lally & Gardner, 2013). When the repetition reaches an asymptote state, the process becomes automatic (Lally et al., 2010). When behaviours reach automaticity, they can be triggered by contexts nonconsciously without the need for goals (Wood & Neal, 2007). Unlike non-habitual behaviours, habits are not dependent on the strength of intentions to perform such behaviour (Neal et al., 2012) and sometimes it may overpower intentions (Hall & Fong, 2007). Instead, it relies on the availability of the contexts as a cue (Wood & Neal, 2007). Therefore, habitual behaviours often persist and can

be difficult to change because they will be triggered automatically whenever the contexts are encountered (Verplanken & Aarts, 1999).

There are two different ways contexts cue habits: direct cuing and motivated cuing (Wood & Neal, 2007). Contexts can cue habits directly where the cue-response association is represented in the memory through consistent repetition, enabling the response to be automatically enacted when cues are present (Wood & Neal, 2007). Direct cuing works when cue-response associated is strong enough, making it overpower the intention to perform such behaviour. Therefore, direct cuing makes habitual behaviour difficult to change or even to break. On the other hand, motivated cuing works by associating habits with the reward of performing the behaviour (e.g., benefits from regular exercising) (Wood & Neal, 2007). In this case, the reward becomes a cue that triggers habits. Consistent with the definition of habits as learned behaviours, rewards can only cue habits when they have been acquired repeatedly, making them contiguous. However, motivated cuing works by enhancing context-response in direct cuing, instead of replacing such link Wood and Neal (2007). This concept is in concordance with habit loops coined by Duhigg (2012), where they define three components of habits: cue as a trigger, routine as a response, and reward as the benefit of performing the routine. Through repetitions, this loop of cue-response-reward becomes more automatic and creates a sense of anticipation and craving (Duhigg, 2012). In both motivated cuing and habit loops, the reward of performing habitual behaviour augments the associated cue-response link, heightening the chance of performing the behaviour when the cues are present.

Although it has been suggested that habits are automatically activated by contexts and not mediated by goals, there is an alternative argument suggesting goals as an important factor in habitual behaviours (Aarts & Dijksterhuis, 2000b; Verplanken & Aarts, 1999). Instead of being viewed as a context-response association, this alternate argument posits habits as a representation of goal-action links, thereby actions are performed only when the goal is activated (Aarts & Dijksterhuis, 2000b). Similar to the previous view of habit as a context-response association, the strength of goal-action association increases through consistent co-activation of the goal and its behavioural response (Aarts & Dijksterhuis, 2000a). This view

posits that habits cannot be enacted without relevant goals. However, there are criticisms of this view, mainly due to variability in responses to perform the intended behaviour, primarily found on nonconscious goals (Wood & Neal, 2007). This variability makes the automatic performance of habitual behaviour in goal-action setting difficult to predict. Additionally, goals are not stable for a longer time, thus the activation of intended action may fail (Wood & Neal, 2007). Therefore, compared to the goal-action association, using context-response association may yield better predictions for habits.

The underlying mechanism of habits is closely related to the concept of automaticity, where behaviours can be triggered automatically by contextual cues without deliberate effort. According to Bargh (1994), there are four features of automaticity: awareness, intention, efficiency, and control. Habits as a form of automaticity are performed with the absence of consciousness, intention, deliberate control, and mental effort (Bargh, 1994). When a behaviour is performed, an association between context as a cue and the performed behaviour as a response is created (Lally & Gardner, 2013). Repetition of behaviours strengthens the cue-response link that could lead to automaticity, making the behaviour be performed automatically when the cue is encountered (Wood & Neal, 2009).

However, during the early phase of habit development, planning is needed to specify when and how habits will be performed (Lally et al., 2010). A strong association between the contextual cue and its response are not present in newly performed behaviour. The activation of non-habitual behaviours often relies on the strength of intentions and the control over intended behaviours (Ajzen, 1991; Bandura, 1977). Therefore, strengthening the context-response association is important during the development of new habits (Lally & Gardner, 2013; Lally et al., 2010).

Forming habits can be effective in breaking unwanted behaviours. This is due to the nature of automatic activation in habits. Automaticity makes habits more powerful than intentions to perform an intended behaviour. In (Aarts, Paulussen, & Schaalma, 1997), Aarts argues that changing unhealthy habits using the attitude-intentions-behaviour route seems inefficient because intentions no longer guide the long-term behaviour. Another study investigates the re-

lationship between intentions and habits in using information systems, where the findings also suggest that intentions cannot predict the intended behaviour (Cheung & Limayem, 2005). They found that prior usage of information systems has a more significant role in predicting their use (Cheung & Limayem, 2005). The findings from (Aarts, Verplanken, & van Knippenberg, 1998) also suggest that frequently repeated behaviours such in the form of habits have a stronger effect in predicting future behaviours. Therefore, developing habits can play a pivotal role to help people change their behaviour.

Interventions targeting habit formation should strengthen the underlying mechanism of habits. Forming new habits should follow four stages (Lally & Gardner, 2013). Firstly, a decision to take action should be made in the form of intentions. Although intentions are not the only predictor of behavioural action, they still strongly affect the action initiation (Fishbein & Ajzen, 1975; Gollwitzer, 1993). Secondly, the intentions have to be translated into action. In their study, (Webb & Sheeran, 2006) argue that there is an intention-behaviour gap, and this gap could be bridged using self-regulatory or action planning (Gollwitzer, 1999; Schwarzer, 2008).By creating action planning, someone could also keep his/her intentions and prevent lapses during action initiation. It will also provide a clear pathway from the motivational phase (intention) to the volitional phase (post-intention). Thirdly, when the behaviour is performed, it needs to be repeated. To overcome the challenge of repeating behavioural actions, one should have self-regulatory methods (Abraham & Michie, 2008). And the fourth or final stage, the behavioural response, not only needs to be repeated, but it also has to be repeated consistently in the same contexts that could lead to automaticity. Repeating a particular behaviour in a stable context leads to a higher level of automaticity (Lally & Gardner, 2013; Lally et al., 2010). It means, that when the situation is encountered, a behavioural response will be performed automatically. When the behaviour has reached the asymptote of automaticity, the cognitive control to perform such behaviour becomes less needed. Interventions to support habit formation should focus on strengthening the cue-response link so the repetition of behaviour can reach the asymptote state quicker, and eventually become automatic.

2.4 Implementation intentions

Although the goal may not mediate habitual behaviours, it plays a pivotal role in the early stage of habit development. Goals are the desired outcomes of behaviour (Aarts & Dijksterhuis, 2000b). When behaviour is not habitual, its activation relies on the strength of intention to perform the behaviour (Ajzen & Madden, 1986). Goal desire is pervasive in the intention-behaviour relationship. Three studies from Prestwich, Perugini, and Hurling (2008) on fruit intake and alcohol consumption suggest that intentions to perform behaviours are linked to the strength of goal desires. Behaviours are more likely to be enacted when there is a strong desire to perform.

Goal is not the only determinant in intention formation. The theory of planned behaviour posits attitude, subjective norm, and perceived behavioural control as proximal determinants of intentions (Ajzen, 1991). Further, Ajzen (1991) also suggest that intentions can be a powerful tool to predict behaviour. However, the intention to perform certain behaviours can only be achieved if the intended behaviour is under volitional control (Ajzen, 1991). This volitional control can be a specific condition of whether the action is possible to be done or not.

Whilst the theory of planned behaviour suggests that forming a good intention is needed to achieve a particular goal, Gollwitzer (Gollwitzer, 1999) further investigated the relationship between intention and goal achievement. His findings suggest that successful goal achievement requires a strong commitment from a person to get started and perform the intended action until the goal is achieved. Gollwitzer (1999) also identify two reasons for how goal pursuit can be effectively achieved: 1) a person needs to frame his intention in achieving a particular goal by setting a specific goal rather than merely a vague goal, 2) self-regulatory skills in initiating goal-directed behaviour affect the goal attainment.

Goal intentions provide a better explanation of how intentions affect goal achievement (Gollwitzer, 1999). Goal intentions specify the detailed target of an action, for instance, having a goal to walk 10,000 steps every day. The structure of goal intentions usually follows the pattern: *"I intend to do X !"*, In which X is the intended goal (Gollwitzer, 1999). The result of performing goal intentions is that people are more likely to commit actions to achieve

their goals than just having the desire to pursue that goal. Therefore, it explains how goal intentions work. It sets a specific target for the goal and commits people to perform such action to realise the goal. In line with the theory of planned behaviour, goal intentions enable a person to have strong intentions in performing their intended behaviour.

However, it has also been suggested that having goal intentions may not be enough to motivate people into committing to long-term goals. This is due to the gap between people's intentions and their actual behaviour, (Sheeran & Orbell, 2000). Moreover, the intentions are not stable for a prolonged period, and they may change over time (Sutton, 1998). To overcome this issue, Gollwitzer (Gollwitzer, 1993) proposed a construct with a term *implementation intentions*.

Implementation intentions bridge the gap between intentions and goal-directed behaviour by providing a clear mechanism to move from a motivational phase where a decision to achieve a goal is made, to a volitional phase where the detailed plans are made to ensure the goal is achieved (Gollwitzer, 1999). Implementation intentions follow a pattern: *"If situation X happens, then I will do action Y"* (Gollwitzer, 1999). When an individual follows this pattern, a mental link will be created between the cue and its associated behaviour. By forming implementation intentions, an individual will commit to performing a particular action that has been planned whenever the situational cue is encountered. Compared to the goal intention, implementation intention furnishes the goal intentions with a more specific situational context, including when, where and how the intentions will be performed (Gollwitzer, 1999). When the contextual cues are encountered, they will activate the individual's consciousness and trigger their mental state to perform the intended behaviour.

Implementation intentions can contribute to increasing goal achievement, as found in several studies, including cervical cancer screening (Sheeran & Orbell, 2000), promoting exercise (Prestwich et al., 2003), drivers' compliance with speed limits (Elliott & Armitage, 2006), and fruit intake (Luszczynska, Tryburcy, & Schwarzer, 2007). There are two ways implementation intentions give a positive impact on goal achievement. First, the specified situation in the *if* component becomes more accessible, making it easier to identify (Sheeran et al., 2005).

Second, the associated response specified in the *then* condition can be activated automatically whenever the situation is encountered (Sheeran et al., 2005). Those two factors enable implementation intentions to have a better prediction on action initiation.

Existing studies suggest that implementation intentions can be used to break unwanted habits replacing with new habits. This is due to the similarity in the underlying processes between implementation intentions and habits, in which context-response association is key during action initiation (Holland et al., 2006). However, unlike habitual behaviours where automaticity is reached through consistent repetition (Lally & Gardner, 2013), implementation intentions activate automatic response through conscious planning (Gollwitzer, 1993). When formed, implementation intentions allow an individual to consciously associate contexts and behavioural responses from the beginning, without needing to repeat the behaviour to start having those associations in their mental state. The mechanism in which conscious planning such as implementation intentions can break existing habits is through replacing the associated behavioural response with an alternative response, as found in several studies such as recycling habit (Holland et al., 2006), snack consumption (Adriaanse, Gollwitzer, De Ridder, de Wit, & Kroese, 2011), healthier diet (Verplanken & Faes, 1999), and the use of online newspaper (Pahnila & Siponen, 2010). In their study, Adriaanse, Gollwitzer, et al. (2011) suggest that counter habitual implementation intentions can eliminate the cognitive advantage of habits, in this case, the mentally represented context-response association, allowing a person to choose the alternative response specified in the implementation intentions. These findings suggest that implementation intentions have the potential to support the formation of new habits.

Despite the promising results, when the intention to perform a behaviour is low, implementation intentions could have a weak effect (Prestwich et al., 2003; Sheeran et al., 2005). Considering implementation intentions require conscious planning, when the intention is weak, the context-response association can be forgotten in critical moments. Therefore, implementation intentions require reinforcement to strengthen their effects. One type of reinforcement is using plan reminders to heighten the accessibility of the contextual cue and its associated response.

2.5 Prospective memory

Remembering intended actions to be performed in the future is referred to as prospective memory (McDaniel, 1995). Prospective memory tasks are pervasive in daily life. According to previous literature, there are two types of prospective memory: time-based prospective memory and event-based prospective memory (Sellen, Louie, Harris, & Wilkins, 1997). Time-based prospective memory is a mechanism of remembering to perform an intended task at a specified time - for example, remembering to exercise every day at 7:00 in the morning. On the other hand, event-based prospective memory involves remembering to perform an intended task in a particular situation. Many activities in our daily lives commonly belong to this category. We often remember something that is not constrained by time but by situations. For example, when we pass a grocery store near our home, we remember to buy something. Event-based prospective memory helps people to remember things by associating the things with a certain situation.

A study from (Sellen et al., 1997) found that using event-based cues is better than time-based cues, even though people who use an event-based cue take more time to process the cues. It is related to how the association of cue and its associated response are formed. Associating an intended behaviour with specific cues will reduce the need to recall intentions since the control of performing the intended behaviour will be delegated to the accessibility of specified cues (Bargh & Gollwitzer, 1994).

Several factors could affect the performance of prospective memory. A prospective memory task can be successfully performed when a person remembers the situation when they should perform the intended task Einstein and McDaniel (1990). At the same time, the person needs to remember to actually perform the task when the situation is encountered Einstein and McDaniel (1990). In addition, intentions must be present in prospective memory tasks (McDaniel & Einstein, 2007). It implies prospective memory tasks can be activated through conscious planning. Another key characteristic of prospective memory tasks is that the intended tasks will not be performed immediately after formed (McDaniel & Einstein, 2007). The delayed realisation of the intended task could lead to forgetfulness due to the gap between the

time in which the task is intended and the actual time in which the task needs to be executed.

Reminders can prevent forgetfulness in event-based prospective memory, specifically reminders targeting both the event and its response. In their study, Guynn, Mcdaniel, and Einstein (1998) found the most effective reminders are the ones that target both the event and its associated action, compared to the reminders that only target the intended action. Further, Guynn et al. (1998) also suggest that reminders targeting the event do not improve the performance of prospective memory. Interestingly, in their study, Guynn et al. (1998) found that adding an instruction to imagine performing the intended task also does not have a positive effect on the prospective memory. This could be caused by the instructions that were not worded in an associative pattern similar to implementation intentions. Nonetheless, using reminders targeting the event and its response can improve the performance of prospective memory. Another benefit of using reminders on prospective memory is to offload the cognitive processes needed to continue monitoring the availability of the event and its linked response (F. T. Anderson, McDaniel, & Einstein, 2017).

On the other hand, implementation intentions could also be used to support prospective memory, especially for older adults (Burkard et al., 2014; Chasteen, Park, & Schwarz, 2001) and people who suffer from memory problems (T. Chen et al., 2019; X.-J. Chen et al., 2016; Khoyratty et al., 2015). As found in a study investigating the impact of implementation intentions on older adults, participants who formed implementation intentions performed better on performing the intended task (57% correct responses to the task), compared to participants who were only given instruction to perform the task or rehearsed the instruction without forming implementation intentions (22% correct responses to the task) (Chasteen et al., 2001). Implementation intentions are also found to benefit the performance of prospective memory in early psychosis patients (Khoyratty et al., 2015), and schizophrenia patients (T. Chen et al., 2019; X.-J. Chen et al., 2016). Implementation intentions improve the performance of prospective memory by strengthening the cue-response link, making the cue and its associated response more salient (McCrea, Penningroth, & Radakovich, 2015). Whereas reminders benefit prospective memory externally, implementation intentions reinforce the internal process of

prospective memory by targeting the cue-response association. Together, they help the cue-response link to be mentally presented in the memory, improving the chance to be recalled and activated in critical moments.

2.6 Memory aids

Forgetting happens when the encoded prospective memory cannot be retrieved in critical moments, making the planned intentions not being recalled (Nørby, 2018). Forgetting is more common in episodic or irregular behaviours due to the absence of automaticity in the context-response association. There are two distinct types of forgetting: intentional and unintentional (Collette, Germain, Hogge, & der Linden, 2009). Intentional forgetting can be beneficial to free up a cognitive load in memory from outdated or unwanted retrospective memory (M. C. Anderson, Bjork, & Bjork, 1994).

On the other hand, unintentional forgetting may cause problems. Even though cognitive control such as motivation affects the ability to remember prospective memory tasks (Meacham & Singer, 1977), it may not be able to prevent unintentional forgetting (Maxcey, Dezso, Megla, & Schneider, 2019). Unintentional forgetting happens when there are multiple items associated with the same cues (M. C. Anderson et al., 1994). The presence of multiple items linked to the same cues can make the remembered items compete with each other, and the one with a weaker association to the cue will be forgotten (M. C. Anderson et al., 1994). Regardless, both intentional and unintentional forgetting is common to happen because of interruptions in contexts cuing our routines (Lehman & Malmberg, 2009).

The ability to differentiate the contexts cuing prospective memory is important to counter forgetting. One way to increase contexts awareness is using memory aids. There are two different types of memory aids that can help people remember things: internal memory aids (e.g. mental rehearsal, mental imagery) and external memory aids (e.g. notes, writing on calendar, asking someone) (Intons-Peterson & Fournier, 1986). External memory aids are more often used by people in their daily life because they are perceived to be more accurate,

dependable, and easier to use compared to internal memory aids (Harris, 1980; Intons-Peterson & Fournier, 1986). Additionally, memory aids are also useful to offload cognitive processes, which in turn, increases the ability to remember prospective memory due to more cognitive resource that is available (Risko & Gilbert, 2016).

Even though external memory aids are used more frequently, internal memory aids have the benefit of portability. Considering internal memory aids only involve mental activities and do not need any external elements, they can be accessed in any situation (Intons-Peterson & Fournier, 1986). A strategy such as mental imagery can be used as internal memory aids by strengthening context-response association during the encoding stage of prospective memory. Differently, a technique such as mental rehearsal enables a person to remember prospective memory through constantly thinking about the task (DeWitt, 2007). In certain circumstances, internal memory aids such as mental rehearsal can be more effective compared to external memory aids such as note-taking (DeWitt, 2007). This happens when the tasks or things that need to be remembered are simple, allowing a person to have more time to think about it (DeWitt, 2007). Conversely, when the task is more complex, using external memory aids is better to support remembering.

External memory aids use external devices or mechanisms to facilitate the remembering of prospective memory. Even though external memory aids may not always be available in any situation compared to internal memory aids, they are thought to be more accurate and reliable (Intons-Peterson & Fournier, 1986). This is due to the limitation of our memory to process information. In addition, external memory aids help to offload the cognitive processes needed to remember prospective memory (Intons-Peterson & Newsome, 1992). There has been a body of works studying different strategies of external memory aids such as shopping lists, memos (Harris, 1980), writing notes (Intons-Peterson & Fournier, 1986; Schryer & Ross, 2013), and asking someone else (Intons-Peterson & Fournier, 1986).

More recently, technology such as smartphone apps is also common to be used as prospective memory aids. The ubiquity of smartphones has made them suitable tools for people to access memory aids in the form of reminders. Several commonly used reminder strategies

in smartphones are Short Message Service (SMS) (Prestwich et al., 2009; Stawarz et al., 2015; Wade & Troy, 2001), custom messages with personalised ringtone (Stapleton, Adams, & Atterton, 2007), and in-app push notifications (Lathia, Rachuri, Mascolo, & Roussos, 2013; Mehrotra, 2017; Omaki et al., 2017).

Reminders sent through push notifications can be effective due to the ability to customise the context in which the reminders are triggered. However, sending reminders via push notifications should consider the availability of the person. Otherwise, the notifications could cause interruptions and have a negative impact on the recipient (Mehrotra, 2017). Therefore, it is important to determine the opportune moment when delivering reinforcements. To predict the opportune moment, we can use context-aware capabilities from mobile phones by utilising different data.

The growth of smartphone ownership has opened a new avenue of research in context-aware computing by sensing human behaviour (Lathia, Pejovic, et al., 2013). Information such as time, location, activity, and connectivity can be easily gathered from a smartphone to understand the context of its user (Lathia, Rachuri, Mascolo, & Roussos, 2013), and by utilising this contextual information, we can tailor the notifications to be unobtrusively sent at an opportune moment when the recipient is available (Pejovic & Musolesi, 2014b).

Developing context-aware reminders can be challenging, especially in terms of technical implementation (Pinder, 2018). Physical data such as location and activity can be easily obtained using Bluetooth, cellular network, Wi-Fi, accelerometer, or GPS (Rachuri et al., 2010). However, complex data such as current mood, emotion, and cognitive state are more difficult to obtain. Prior studies suggest that inferring psychological state from smartphone data might lead to low accuracy (Burns et al., 2011; LiKamWa, Liu, Lane, & Zhong, 2013). There is no such sensor in our smartphone that can sense the current psychological state at the moment. Another challenge in designing context-aware reminders is determining which contextual data should be selected (Pinder, 2018). With multiple contexts to choose from, it is impossible to combine all of them into one model. Not only will it be challenging to implement, but it will also require a considerable amount of computing resources to process.

There is no general answer when it comes to selecting the best contexts. The selection has to be tailored according to the targeted prospective memory tasks.

Researchers have developed libraries to collect data from smartphone sensors. For example, (Lathia, Rachuri, Mascolo, & Rentfrow, 2013) have developed EmotionSense to capture mood from the users and compare the result with the sensor data on their phone to give the information about how the mood relates to their behaviour. Meanwhile, Pejovic and Musolesi (2014b) has investigated InterrupMe as a tool to deliver intelligent interruption for the user to a better response from the user. In a different way of using the sensor data, Mehrotra, Pejovic, and Musolesi (2014) have developed SenSocial as a middleware for integrating Online Social Networks (OSN) and mobile sensing data streams. Using the sensor data, SenSocial can deliver filtered information from two massive social media platforms (Twitter and Facebook) to the application.

Even though reminders can enhance the performance of prospective memory tasks, they could lead to dependency on the reminders (Renfree et al., 2016). This can happen for reminders targeting the intended actions because when repeated consistently, the activation of the intended actions will rely on the availability of the reminders (Renfree et al., 2016). Dependency on reminders has been found in the majority of habit formation apps (Renfree et al., 2016; Stawarz et al., 2015). To counter dependency, reminders targeting prospective memory, especially the ones designed to support habit formation should help the users to create a strong context-response association.

2.7 Smartphone apps for mood tracking

Smartphone apps are popular tools used by people to keep track of their emotional well-being. The ubiquity of smartphones has made them a tool for people to keep track of their moods regularly. Guided activities, helping to relax, and tracking health-related data are the most common features of smartphone apps targeting mental well-being (Stawarz et al., 2018). There have also been a number of research investigating the use of smartphone apps to collect

mood patterns. For example, M. Matthews et al. (2008) developed a Mood Diary app that allows participants to log daily data of energy, mood, sleep and textual thoughts or feelings. They found that the compliance mood report using Mood Diary app is significantly higher compared to the paper report. In another study, Church, Hoggan, and Oliver (2010) developed MobiMood, allowing people to track their mood using different colours, and share the results with their friends. They suggest that mood tracking apps should highlight the context when the mood is reported. Meanwhile, Gay, Pollak, Adams, and Leonard (2011) designed Aurora, a smartphone app that helps people to track their mood using photos representing their mood. The advanced features of smartphone apps allow researchers to experiment with various strategies in helping people to track their moods regularly. In another study, Kumar et al. (2020) developed Mood 24/7 as an electronic platform to collect mood data via SMS and email.

However, the majority of these apps do not help people to develop a habit of tracking their moods every day. Instead, they only focus on the activation of the behaviour itself (tracking their mood). For example, Mood Diary and Aurora do not have a reminder feature and rely on the ability of participants to report their mood (Gay et al., 2011; M. Matthews et al., 2008). Whereas in MobiMood, participants only received email and SMS whenever a participant submitted a mood, but no reminders of reporting the mood itself (Church et al., 2010). Considering that mood tracking is not habitual behaviour for the majority of people, there is a risk of forgetfulness to perform the intended task, as found in Mood Diary where the compliance of reporting their mood every day was only 50% (M. Matthews et al., 2008). As mood tracking was a new behaviour for participants in the study, there was no association of the task with the existing context, making participants rely on their intentions.

2.8 Towards better smartphone apps for mood tracking

Mood tracking is a prospective memory task because participants need to remember to track their moods every day. To get the full benefits of mood tracking, a person needs to turn

the task into a habit. However, there is a risk of forgetting in prospective memory tasks, even when motivation presents, especially for a new task such as mood tracking. Therefore, memory aids are needed to counter the risk of forgetting.

There are two distinct types of memory aids: both internal and external (Intons-Peterson & Fournier, 1986). Smartphones apps targeting mood tracking can utilise these memory aids to help turn the task into habitual behaviour. Reminders have been used as external memory aids to help remember various tasks in the majority of smartphone apps (Renfree et al., 2016; Stawarz et al., 2015), including the ones targeting mood tracking (Kumar et al., 2020). However, reminders could lead to dependency if they target the action (Renfree et al., 2016). Memory aids targeting prospective memory tasks should focus on strengthening the context-response association in the memory.

Therefore, we aim to investigate the effect of using a special type of reminder that we call *reinforcements*. More specifically, we use reinforcements on implementation intentions of tracking mood every day. Unlike reminders that target the enactment of mood tracking immediately, the reinforcements need to be sent in advance before the planned task is performed to avoid dependency. Reinforcements act as memory aids to help participants recall their implementation intention of tracking their mood regularly. In addition, since we do not want participants to associate the reinforcement with the planned task, we sent the reinforcements way in advance (in the afternoon, randomly between 12:00-14:00), for them to track their mood later on the day (in the evening or night). Tobias (2009) argue that the effect of a particular reminder is stronger when the intended task is performed close to the reminder, which can lead to dependency in which the execution of the planned task depends on the reminder. Therefore, by having a time gap between reinforcements and the execution of the task, we aim to minimise the risk of dependency. Also, the reinforcements should force participants to rely on their ability to recall the planned implementation intention of tracking their mood later during the day when they arrive at home.

Reinforcements also aim to strengthen the context-response association of mood tracking by targeting the underlying mechanism of implementation intentions. Reinforcements aim to

increase the accessibility of contextual cues, allowing the cues and their response to be mentally represented in the memory. The reinforcement framework applies the concept of prospective memory research and combines external memory aids such as push notifications with internal memory aids such as mental rehearsal and mental imagery. There are three different strategies of reinforcements that we propose. First, we call it passive reinforcements, where the reminders containing the planned implementation intentions were sent via push notifications. Passive reminders require a person to read the implementation intention, allowing them to recall the initially planned intentions of tracking their mood in a particular situation. The reinforcements help participants to associate mood tracking with their existing routines as the contextual cue. The second strategy is called active reinforcements. In this case, the reminders sent contain a mental imagery task to vividly imagine the situation when the specified cue is encountered, and to imagine to track their mood immediately. However, instead of being sent via push notifications, active reinforcements occupy the whole screen and will interrupt any existing activities on the smartphone. The third strategy is called context-aware reinforcements. The content is similar to active reinforcements, a message containing mental imagery task. Instead of being sent via push notifications at random times, context-aware reinforcements utilise a set of mechanisms allowing the app to predict opportune moments when delivering the reminders.

2.9 Summary

This chapter outlined the underpinning theories that set the foundation of this thesis, mainly around mood tracking, habit formation, implementation intentions, prospective memory, and memory aids. We discussed the potential benefits of mood tracking and why it is important to make it a habit. We argued that, since mood tracking is not habitual, it requires someone to remember the task in the future, hence, we have categorised mood tracking as a prospective memory task. Even though forming an implementation intention could improve the performance of prospective memory tasks, it is still prone to forgetfulness due to a lack of strength between the situation defined in the "if" condition, and the action defined in the "then" as

a response. We identified the gap that can be addressed by strengthening the underlying mechanisms of implementation intentions. We also discussed the problems within the existing habit formation apps that focus on task-tracking and reminders and that they could lead to dependency (Renfree et al., 2016). Therefore, in the next chapter, we propose a reinforcement framework aimed to enhance the performance of implementation intentions by drawing several key points from the theories that we have discussed above. We also outline how the reinforcement framework can be implemented in mobile apps and the results of testing the performance in several empirical studies.

CHAPTER 3

FRAMEWORK OF REINFORCEMENTS AND ITS APPLICATION

3.1 Overview

In this chapter, we will discuss the mechanism of reinforcements on the implementation intention task of daily mood tracking, with the aim of developing the task into a habit. Based on the literature review, we identify the gap within habit formation apps aimed to support regular mood tracking. The majority of existing apps focus on the use of reminders to prompt the intended action immediately, and do not help their users to associate mood tracking with existing contextual cues. As a result, instead of supporting the development of new habits, those apps create dependency towards the reminders sent on daily basis (Renfree et al., 2016) and hinder the automaticity as an important element of habit (Stawarz, 2017). We draw upon the existing works in the area of prospective memory and memory aids. Unlike reminders, reinforcement's goal is to strengthen the key element of implementation intentions: the mental link between the situational cue and its associated response, allowing to develop habits in the long-term through consistent repetition in stable context. We will also discuss the application of reinforcements in a mobile app. Finally, we outline how the proposed reinforcements framework is going to be used in several empirical studies.

3.2 Introduction

Forgetfulness can happen when there is an absence of proper information retrieval, specifically related to contextual cues (Nørby, 2015). Reminders act as an external memory aid to minimise forgetfulness by helping the memory recall a particular task when the cues triggering the task are encountered (Brewer, Morris, & Lindley, 2017). Reminders are common to prevent forgetfulness and they have been widely used in the majority of habit-formation apps to keep their users engaged and sticking to their habit (Stawarz et al., 2015). Even though reminders effectively support repetition of tasks, they could create dependency in the long-term where a person relies on the reminders to perform their habit, instead of relying on the situational cue that triggers the habit itself (Renfree et al., 2016). Relying on the reminders instead of the actual situation is bad because it hinders automaticity during the habit formation process. In their study, Stawarz et al. (2015) investigated the formation of habits, using daily lunch report as the task. They found that participants in the reminder groups had the lowest automaticity score in their 4-week study measured using SRBAI questionnaire (Gardner, Abraham, Lally, & de Bruijn, 2012).

Previous studies have investigated the use of reinforcements on implementation intentions (Prestwich et al., 2009, 2010). However, it remains unclear when the reinforcements were delivered in those two studies since participants were given a choice to decide on the reinforcements' delivery time. If the reinforcements were sent when the plan was supposed to be executed, they had the potential of causing dependency as well. Reinforcements targeting implementation intentions should strengthen the underlying mechanism of context-response association.

Therefore, we propose a framework of reinforcements on implementation intentions and highlight the key differences with the normal reminders:

- Reminders aim to prompt a planned task immediately. Whereas reinforcements aim to strengthen the mental link between a contextual cue and its associated response.
- Whilst reminders are usually sent when the intended action is supposed to happen,

reinforcements are sent in advance to minimise the risk of dependency.

- The construct between reminders and reinforcement is different. "Remember to do X" is a reminder, whereas "Remember, if X happens, then do Y" is a reinforcement.

- Reminders are external memory aids. On the other hand, reinforcements act as a combined internal & external memory aids. Internally, reinforcements help participant to visualise the context and response, allowing the connection to be mentally represented. Externally, reinforcements help participants to recall the planned intentions in advance.

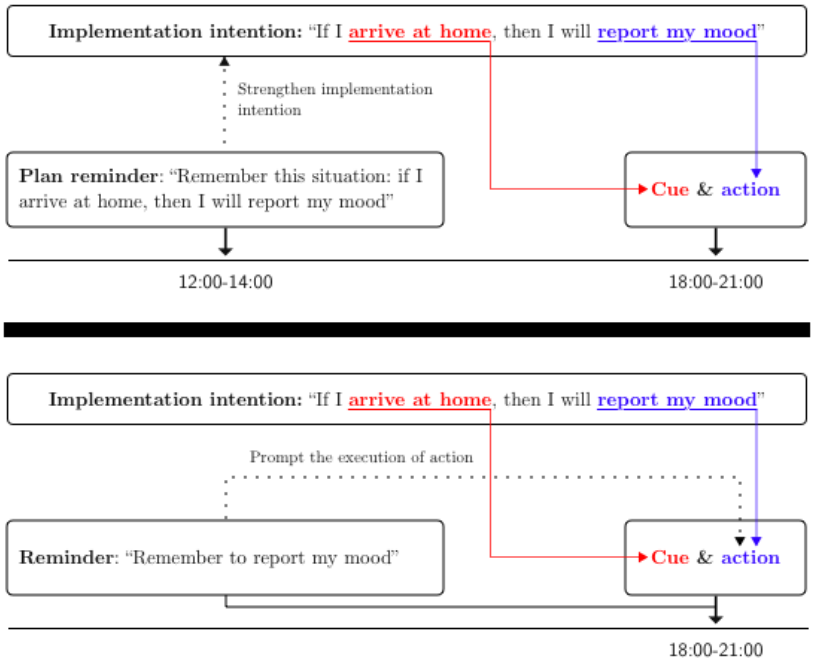


Figure 3.1: Different mechanism between reminder and reinforcement

As outlined in Figure 3.1, reinforcements work by nudging the implementation intentions in advance. reinforcements aim to improve the impact of implementation intention by targeting the two underlying processes of implementation intentions. Firstly, reinforcements make the contextual cue more salient (Prestwich & Kellar, 2014). Implementation intentions demand the attention of a person to take action when the specified cue is detected. Adding reinforcements heighten the accessibility of the cue and increase the awareness whenever the cue is encountered. Secondly, reinforcements strengthen the mental link between the cue and its

associated response (Prestwich & Kellar, 2014). When the context-response link is maintained in a stable context, it could make the intended behaviour become habitual.

3.3 Mechanism of reinforcements

Reinforcements to support implementation intentions can also enhance prospective memory of remembering the intended task, in this case mood tracking. Prospective memory is about remembering to execute an intended action at the future time (McDaniel, 1995). When it is not yet habitual, remembering to track mood every day is a prospective memory task. Ellis (1996) suggest there are five phases of prospective memory task as shown in Figure 3.2. We detail the mechanism of reinforcements on implementation intentions concerning each different phase of the prospective memory task.

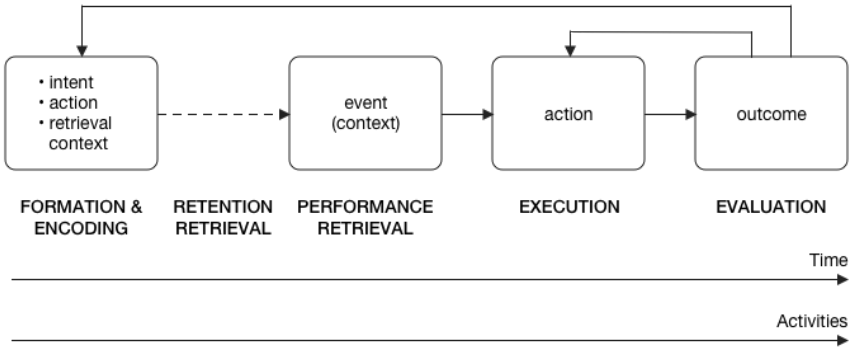


Figure 3.2: The five phases of prospective memory tasks (Ellis, 1996)

The first phase is *formation and encoding of intention and its associated action*. In this phase, when someone decides to form a prospective memory task, they need to specify intent, action, and a context in which the intent and action will be recalled (Ellis, 1996). An intent is related to the motivation of performing the action. When the intent is stronger, there is a higher opportunity for it to be executed. Meanwhile, for an action, it is related to either physical or mental activity that varies depending on whether it is a newly learned behaviour or a well-learned behaviour (habit). When the activity is new, it requires more attention during formation and encoding phase. On the other hand, a well-learned activity should be

easier to perform since it has become a part of existing routines. For the third element, the retrieval context is related to situations that trigger the recall of intended action. The retrieval context can be in different types, e.g., events, times, locations, activities, persons, and objects (Einstein & McDaniel, 1990). Existing studies suggest that using events as the retrieval context for prospective memory tasks yields better performance results than using times but requires more effort to be executed (Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). In the case of implementation intentions, the three elements (intent, action, and retrieval context) are present. Suppose there is no particular construct on how an action, an intent, and a context should be worded when forming a prospective memory task, in implementation intentions. In that case, the wording follows a construct: "If situation X happens (context), then I will do Y (action)". Together, the *if* and *then* part will form an intent. Gollwitzer (1993) argue that by following this construct, the control of intended action will be delegated to the contextual cues, reducing the cognitive load when retrieving the context, and as a result, increasing the chance of the intended action to be enacted. During the formation and encoding phase, reinforcements of implementation intentions work by rehearsing the elements of implementation intentions, including the intent, context, and intended action immediately after the intention has been formed. Mental rehearsal has been found to positively impact the performance of implementation intentions (Gollwitzer, 1999). Consistently rehearsing the implementation intention should enhance its effect.

The second *(retention interval)* and third phase *(performance interval)* of prospective memory task are closely related (Ellis, 1996). Retention interval is related to the delay between the formation of intention and the start of performance interval. On the other hand, the performance interval is related to when the intended action should be performed. Since retention interval is started when an intention is formed, it could have a longer duration, depending on when the action should be performed. In contrast, the performance interval is closer to the actual time of execution of the planned action. For an intended action to happen, it should be recalled during performance interval where the context is retrieved, and the subsequent action is performed. In implementation intentions, the two phases are important,

especially performance interval, where the specified condition is encountered. Reinforcements heighten the accessibility of the context and strengthen the presence of context in the memory, as a result improving the chance of retrieval during performance interval. When a person receives reinforcements, they will be reminded of the contextual cue and how the intended task should be performed when the cue is encountered. This will allow a person to associate the context and target behaviour. And since implementation intentions work by delegating the control of performing the intended task to the specified condition, heightening the accessibility of the cue should improve the chance of the intended plan to be executed.

The fourth *(initiation and execution of intended action)* and fifth phase *(evaluation of outcome)* of prospective memory task are related to the execution and evaluation of the intended action when the context is retrieved (Ellis, 1996). Similarly, in implementation intentions, for an intended action to happen, it should be performed immediately when the specified condition is encountered. The execution of intention is affected by the strength of the link between the contextual cue and its associated action as a response. Reinforcements should strengthen the link between those two critical elements through repetition. Even though forming implementation intentions will delegate the control of execution of planned action to the situational cue, it all depends on the strength of cue-response link. When the mental link between the cue and its response is weak, a person may forget to execute the intended action at a critical time when the cue is retrieved because they could not associate the cue with its response. Sometimes, interruptions in the context can also lead to forgetting because the presence of multiple things associated to the same context. Therefore, reinforcements aim to strengthen the cue-response link, making the specified plan difference with the others. In these two phases, reinforcements work by strengthening the link between the cue and its associated response through consistent repetition (rehearsal). Besides, reinforcements should also support a person to evaluate the performance.

From the above discussions, we focus on impact of reinforcements on the key factors that make a planned intention can be successfully executed, mainly the ability to remember the context in which a task should be performed, and the ability to execute the task whenever the

context is encountered (McDaniel, 1995).

3.4 Three reinforcement strategies

In the previous section, we detail how reinforcements work on different phases of prospective memory. This section outlines the different reinforcement strategies that we will be tested on various empirical studies, discussed in the next chapters.

3.4.1 Passive reinforcements

When a person forms an implementation intention, they need to specify the context (where, when, and how) in which the planned action should be performed. Since the type of action varies from a newly planned behaviour to a habit, executing the implementation intentions requires different attention levels. Habitual behaviours are often automatically performed whenever the situation that triggers the particular behaviour is encountered (Aarts et al., 1998; Lally & Gardner, 2013; Lally et al., 2010). However, for a new behaviour that is just started, it requires a high level of cognitive effort to remember performing the intended behaviour when the cue is retrieved (Nørby, 2015). The cue responsible for prompting the intended action should be monitored so it can be retrieved later after the intention has been encoded.

After forming an implementation intention, rehearsal is needed because the accessibility of performing a planned intention decreases over time (Tobias, 2009). Rehearsal helps to heighten the accessibility of such a plan, allowing the memory to remember the retrieval cue and act when the cue is encountered. As a result, rehearsal also reduces the risk of forgetfulness in executing the planned intention by strengthening the link between the situational cues and the associated response. Since the goal of reinforcements is to make the planned intention into habitual behaviour in a long-term, the rehearsal help to recall the planned intention repeatedly. The rehearsal only contains message to remember the planned implementation intentions, therefore we call this as "passive reinforcements". We will investigate the impact of passive

reinforcements on implementation intentions by measuring compliance and automaticity in tracking mood every day.

3.4.2 Active reinforcements

Mental imagery has been suggested to improve the performance of implementation intentions (Knäuper et al., 2011; Knäuper, Roseman, Johnson, & Krantz, 2009). Therefore, the reinforcements should also employ a mental imagery task by requiring participants to recall the implementation intention in their mind, and to vividly imagine the situation in which they would track their mood. Mental imagery targeting implementation intentions planning should help to strengthen context-response association in the memory and as a result, easier to recall in critical moments. Considering mental imagery task require participants to take a moment to recall their encoded implementation intentions and to vividly imagine the if-then condition, we call this as "active reinforcements". Unlike passive reinforcements, active reinforcements requires a person to respond and perform the mental imagery task immediately. Similarly with passive reinforcements, we will measure the impact of passive reinforcements on implementation intentions using compliance and automaticity of tracking mood every day.

3.4.3 Context-aware reinforcements

Reinforcements of implementation intentions demand attention from a recipient through rehearsing the planned intentions. Therefore, a person needs to be able to acknowledge the content of reinforcements. Otherwise, there is a risk of the reinforcements being dismissed.

Currently, the majority of habit formation apps deliver reminders at the same time every day, regardless of the availability of a person receiving those reminders. As a result, many of reminders are dismissed quickly. Moreover, there is also a risk of disrupting the ongoing task if the reminders are delivered at inopportune moments (Mehrotra, 2017).

In the case of reinforcements, especially for more demanding tasks such as mental imagery task, we need to predict the opportune moment for delivering the task to maximise its effect

and minimise interruptions. Allowing the reinforcements to be sent at opportune moments will help a person acknowledge the message and perform the mental-imagery task to strengthen the underlying process of implementation intentions that they have planned. Therefore we call this as "context-aware reinforcements".

The table below outlines the key differences between the three different reinforcements strategies, mainly in terms of delivery mode, delivery time, and the content of reinforcements. In the next following chapters, we examine the performance of each strategy. Considering both active and context-aware reinforcements add mental imagery to enhance the implementation intentions, we predict that they will perform better compared to passive reinforcements.

Table 3.1: Different reinforcement strategies

	Passive reinforcement	**Active reinforcement**	**Context-aware reinforcement**
Delivery mode	Push notifications	Fullscreen activity	Fullscreen activity
Delivery time	Randomly between 12:00-14:00	Randomly between 12:00-14:00	At opportune moments between 12:00-14:00
Content	Figure 3.7 - part a	Figure 3.7 - part b	Figure 3.7 - part c

3.5 Mood Journal app

To test the effectiveness of reinforcements on implementation intentions of daily mood tracking, I designed and developed an app called as Mood Journal. The app was developed on Android platform and published on Google Play Store. Android had been selected as the platform for Mood Journal app because it is the leading mobile operating system worldwide with around 73% of share (Statista, 2021). Mood Journal app was able to collect various smartphone's sensor data by utilising a set of library developed by Mehrotra (2017). The library was responsible to collect data such as notifications, network status, location, activity, ringer volume, read & write data, and accessibility (when users touch the screen). The app would explicitly ask permission when users open the app for the first time.

Meanwhile, apart from the library, I was responsible in designing and developing other parts of the app, including the consent & registration screen, implementation intentions setup, goal motivation measurement, mood report questionnaire, SRBAI (Self-Report Behavioural

Automaticity Index) questionnaire Gardner et al. (2012), and also responsible for developing a secure data collection and transfer process into our server.

In the following sections, I will outline the design rationale and technical details related to Mood Journal app.

3.5.1 Registration and initial setup

When participants opened the Mood Journal app for the first time after installation, the first thing they saw was the consent screen as shown in Figure 3.3. The screen explained about the nature of experiment and required participants to give their consent in order to continue participating and using the app. Without giving the consent, participants would not able to continue to the next steps.

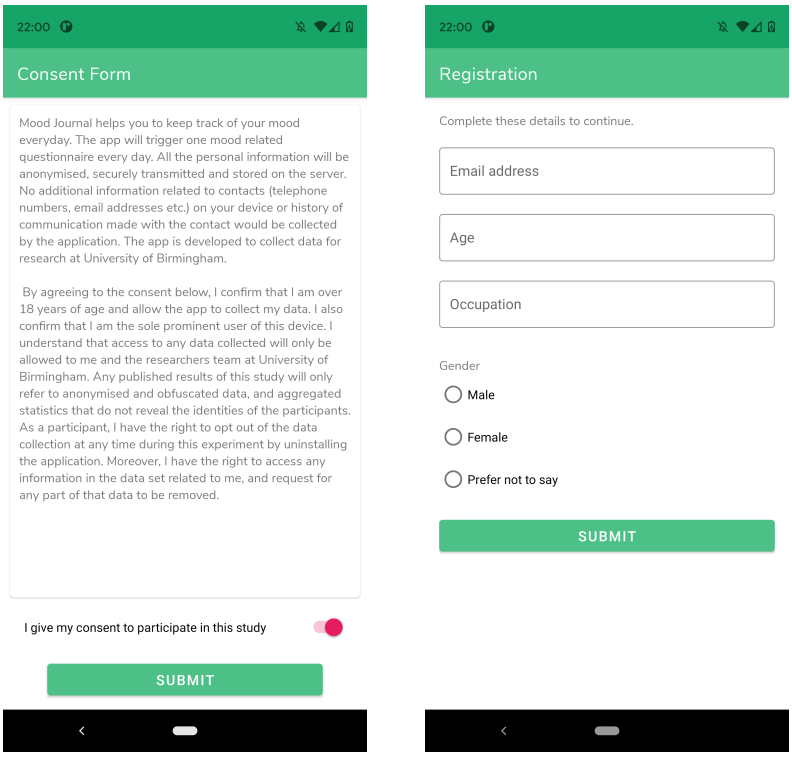


Figure 3.3: Consent and registration screen

In the registration screen, participants had to complete demographic questionnaire including email address, age, occupation, and gender. All forms are compulsory before continuing

to the next step. When participants submitted the data, they would be assigned a randomised ID so their personal information was anonymised.

3.5.2 Implementation intentions setup

After successfully registered, the app would ask participants to go through a process of setting up implementation intentions plan of tracking mood, and rehearsing the encoded plan as shown in Figure 3.4. At the beginning, the app present the benefits of tracking mood regularly and how using implementation intentions could help to turn mood tracking into habit.

In the next screen, participants were shown an instruction to form implementation intention. The 'if' and 'then' component of the implementation intention were set by default, so all participants had the same implementation intentions plan. Both context and response were also highlighted.

The selection of context in the Mood Journal app were arbitrary and designed to have a long delay between the time reinforcements were sent to the actual context (5-6 hours delay). This was to avoid participants reporting their mood straight away after receiving the reinforcements. We also want to investigate whether the delay could diminish the effect of reinforcements or not.

When encoding the implementation intention plan, participants were also asked to perform a mental imagery task to vividly imagine the situation specified in the implementation intention task.

Upon finishing with setting up an implementation intention plan, participants were required to rehearse their newly formed plan. The rehearsal task involved writing down the specified condition as context that would trigger tracking the mood. Participants would then be shown whether their typed context were correct or wrong.

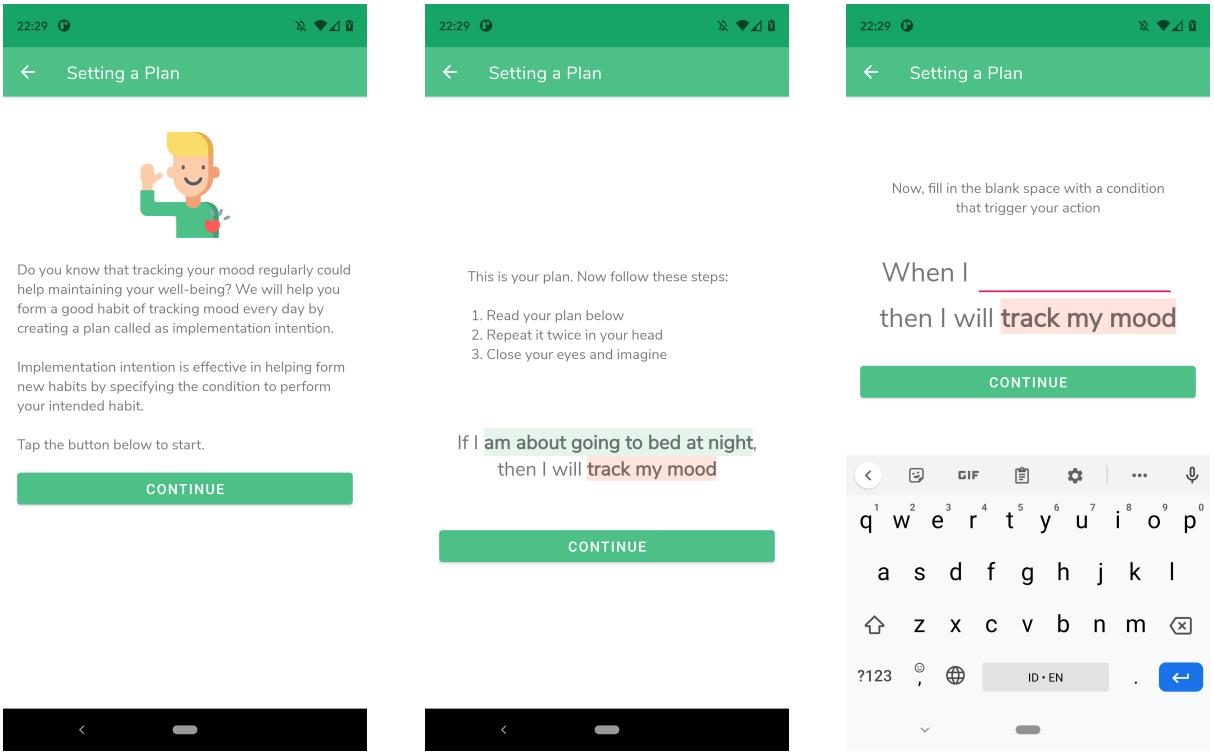


Figure 3.4: The flow of setting up implementation intentions and rehearsing the plan

3.5.3 Measuring goal commitment

The Mood Journal app would also measure the goal commitment from participants to track their mood regularly.

Goal commitment was measured using HWK scale (Klein, Wesson, Hollenbeck, Wright, & DeShon, 2001), consisting of five-scale questions as follow:

1. It's hard to take this goal seriously. (R)
2. Quite frankly, I don't care if I achieve this goal or not. (R)
3. I am strongly committed to pursuing this goal.
4. It wouldn't take much to make me abandon this goal. (R)
5. I think this is a good goal to aim for.

*) Items followed by "R" indicate that the item needs to be reverse-scored before analysis.

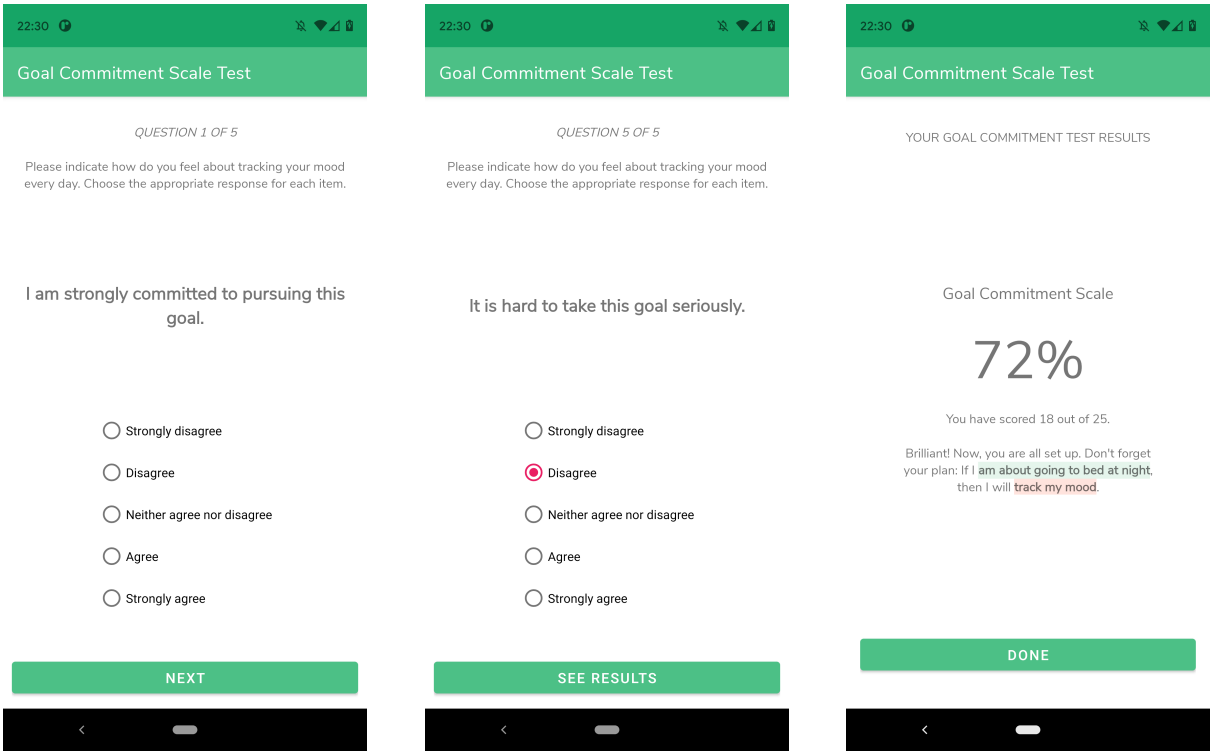


Figure 3.5: Goal commitment questionnaire flow

Upon completing the goal commitment questionnaire, participants would be shown their commitment score, ranging from 1-100%, with the raw score was also shown below. Figure 3.5 illustrates the process from filling up questionnaires to seeing the results. When participants tap the "Done" button in the results screen, the app would close and run the background. At this stage, participants in the test group would receive reinforcements of their planned implementation intentions every day.

3.5.4 Mood questionnaire

The content of mood questionnaire within Mood Journal app was designed based on the literature around mood measurement. It has been argued that using three dimensions of mood: valance (ranging from unpleasant to pleasant), calmness (ranging from tense to relaxed), and energetic arousal (ranging from tired to awake), is the best way to measure mood (Schimmack & Grob, 2000; Wilhelm & Schoebi, 2007). Based on the previous research, Mood Journal

would ask participants to measure those three dimensions using a 5-point Likert scale on each item. The design of the mood questionnaire screen is shown in Figure 3.6. After completing the mood questionnaire, participants would be redirected to the homepage, where they could access their mood history and patterns.

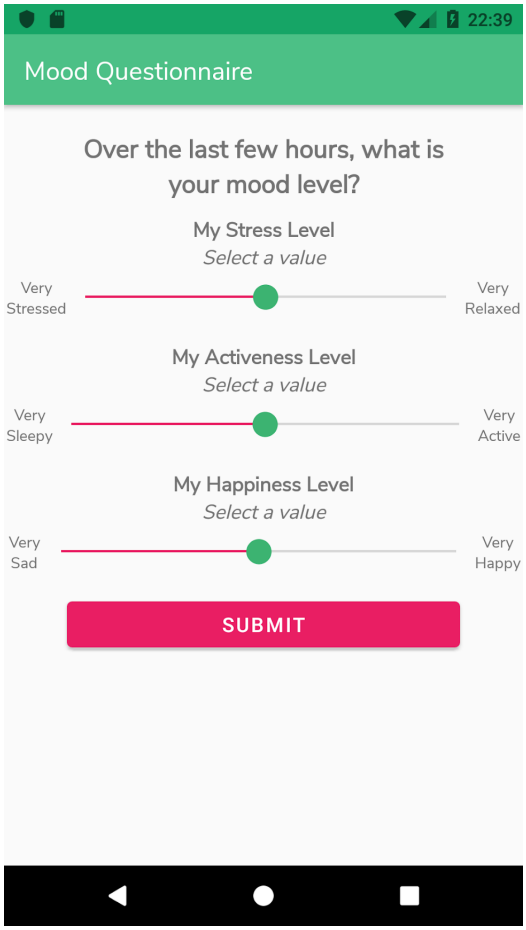
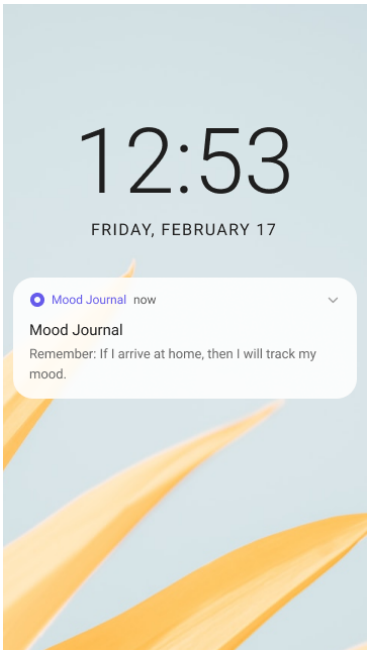


Figure 3.6: Mood questionnaire screen

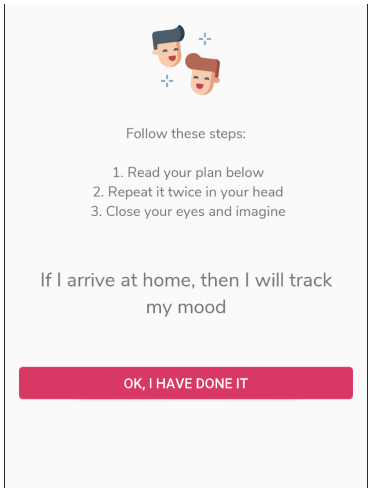
3.5.5 Notification and reinforcements

Mood Journal app was capable in delivering reinforcements through push notifications and prompting full screen activity, determined by participants group number. I developed a mechanism that would allow this group number to be configured remotely. This allowed us to divide participants into control and test groups based on their goal commitment score, and set the group number when the score was known (see Figure 3.7 for different reinforcements mode).

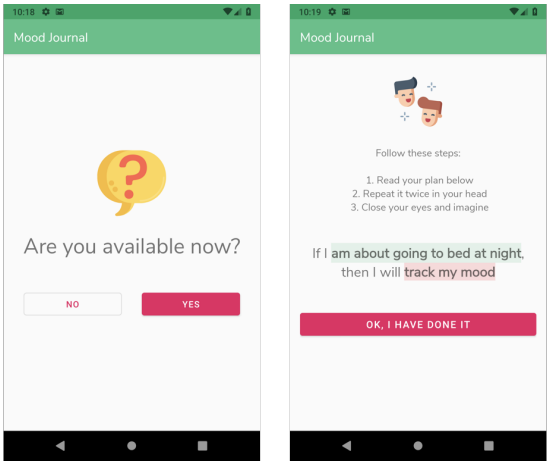
The notification module is responsible to determine the logic of the push notifications and full screen activity (for active and context-aware reinforcements). The module runs on the background and utilise background service, allowing the Mood Journal app to be able to send notifications even though the app is minimised or exited.



(a) Passive reinforcement



(b) Active reinforcement



(c) Context-aware reinforcement

Figure 3.7: Different mode of reinforcements

3.6 Summary

In this chapter, we proposed a reinforcement framework which aims to strengthen the underlying processes of implementation intentions. The framework facilitates the formation and encoding of implementation intentions at the beginning, and rehearses the planned intentions through consistent repetitions. The reinforcement framework targets two important aspects of implementation intentions: the specified cue and its associated response. Strengthening the cue-response association will eventually lead the intended behaviour to become habitual. We also outline 3 different strategies in which the reinforcement framework will be applied in mobile apps: passive, active, and context-aware. For passive reinforcements, push notifications will be used as the mode for delivery. For active reinforcements, full-screen activity with a mental imagery task will be used to prompt the recipients to perform the mental imagery task immediately upon receiving the message. Whereas for context-aware reinforcements, the same message for active reinforcements will be delivered at opportune moments by sensing the context around the recipients. The following chapters will discuss in more detail the implementation of each reinforcement strategy through a series of empirical studies. In each study, the effect of reinforcements on a daily mood tracking task will be analysed.

CHAPTER 4

USING PASSIVE REINFORCEMENT TO SUPPORT IMPLEMENTATION INTENTIONS

4.1 Overview

In this chapter, we investigate the use of passive reinforcements on implementation intentions. Passive reinforcements aim to strengthen implementation intentions by targeting the two underlying processes: firstly, heighten the accessibility of the cue, allowing a person to identify the specified cue, and secondly, strengthen the cue-response association, making a person to act immediately when the cue is encountered (Prestwich & Kellar, 2014). Unlike reminders used in previous studies that were sent via SMS, in this study, reinforcements were sent via push notifications, allowing us to investigate when and how participants reacted to the reinforcements. Based on the discussion in the previous chapter, passive reinforcements should help a person to rehearse and recall their planned intentions, making them to be aware when the cues are encountered and to response immediately. Finally, The effect of the adding reinforcements will be assessed and the findings will be discussed.

4.2 Method

Previous research investigating how implementation intentions could be enhanced limited to adding reminders via SMS and they sent the reminders when the actual action happens (Prest-

wich et al., 2009, 2010; Stawarz et al., 2015). Hence, we applied a different approach in this study by sending the reminders of one's plan as a reinforcement and sent the reinforcement 5-6 hours before the actual action happens. We asked participants to form an implementation intention of reporting their mood every day for 28 days. Mood report was selected as a task because it is a prospective memory task, easy to do, and not part of any existing routine. Implementation intention as support for habit formation should be executed automatically and immediately when the cues are encountered, and it is also repeated in a stable context. By adding reinforcement, implementation intentions should be strengthened. So, our hypotheses of this study are:

- Participants who receive reinforcement will have a higher compliance compared to participants who do not receive reinforcement.
- Participants who receive reinforcement will have a higher level of automaticity compared to participants who do not receive reinforcement.

4.2.1 Participants

We recruited participants using email, social messaging apps, and meeting them face-to-face without offering any financial incentives. We conducted pre-screening via an online questionnaire to only recruit participants who used Android phones. Overall, 58 participants signed up to the study, consisting of 18 males (mean age: 28 years old, SD=5.61) and 39 females (mean age: 30 years old, SD=8.92). One participant preferred not to specify their gender. The majority of participants are students (undergraduate, master, and doctorate level). We measured participants' motivation in tracking their mood regularly using goal commitment questionnaire as proposed by (Klein et al., 2001). Participants were then divided into two different groups (test and control group), balanced by their age and goal commitment score.

4.2.2 Design

The study used a between-subject design with two different groups:

- Passive reinforcement group. Participants in this group were asked to form the same implementation intention. They were given an option to choose their routine as the cue. Additionally, we sent them reinforcements that reminded them of their implementation intentions. The reinforcements were sent at lunchtime via push notifications, way in advance of the actual action to report their mood in the evening.

- Control group. Participants in this group were asked to form an implementation intention of reporting their mood every day. They had to select their existing routine as the cue (IF condition). No reinforcement was given to this group.

This study used two dependent variables to measure the differences between the reinforcement and control groups: compliance and automaticity. We measured compliance using the consistency in reporting the daily mood. Whereas automaticity was measured using the Self-Report Behavioural Automaticity Index (SRBAI) questionnaire.

4.2.3 Materials

We developed an Android app called Mood Journal for both groups. When opening the app for the first time, the Mood Journal app gave participants step-by-step guidance to create an implementation intention of reporting their mood in the evening of each day. Participants had to specify their evening routine event as the cue for reporting their mood, for example: when arriving at home, commuting, or after taking a shower. For the reinforcement group, they received a reinforcement of their implementation intentions at lunchtime. The reinforcement consisted of the specified routine event selected as a cue (if condition) alongside its associated response (to report their mood). Whereas for the control group, they did not receive any reinforcement. The app recorded their daily mood data and transferred the data securely to our server.

We use Self-Report Behavioural Automaticity Index questionnaire (SRBAI) (Gardner et al. 2012) to measure the automaticity. The SRBAI questionnaire consists of 4 items, asking that *"Behaviour X is something ..."*:

- "I do automatically",
- "I do without having to consciously remember",
- "I do without thinking", and
- "I start doing before I realise I'm doing it".

Each of the items has a 7-point Likert scale, and the score of SRBAI is from 4-28 points, where the higher points mean a higher level of automaticity. The SRBAI questionnaire was available online, and we sent the link to access the questionnaire to participants in the second week and fourth week (last day of the study).

4.2.4 Procedure

At the start of the study, we asked participants to complete a consent form and pre-test questionnaire. Upon completion, we allocated participants into two groups based on their goal commitment score: a control group and a reinforcement group. Both groups were asked to install an Android app called Mood Journal. The app guided participants to form a plan (implementation intention) to report their mood. In the plan, participants had to choose one existing routine that they usually do in the evening, for example arriving at home or taking a shower. The routine event was used as the cue for reporting mood. Upon completion of setting implementation intentions, each participant was presented with an if-then plan inside the Mood Journal app.

In the reinforcement group, a daily reinforcement will be sent at lunchtime, consisting of the implementation intention (routine event as the cue and reporting mood as the response). For example: "Remember, if I arrive at home, then I will report my mood". The timing was selected to minimise dependency by allowing the reinforcements to be sent in advance, further from the time of reporting the mood.

Daily mood reports were recorded, as well as the time when the reports were received. On the second week and fourth week (14th and 28th day respectively), a link to access the

SRBAI questionnaire was sent to participants. The SRBAI score was used to measure the automaticity in reporting their mood. At the end of the study, participants received a debrief of the study via email.

4.3 Findings

From 58 participants who signed up to this study, 41 of them (74%) downloaded and installed the Mood Journal app. We then divided our participants into two different groups: control and reinforcement group, with 20 participants in the control group, and 21 participants in the reinforcement group. The groups were balanced by participants' goal commitment, measured using the HWK Scale (Klein et al., 2001). However, from 41 participants who downloaded the app, only 24 reported their mood at least once using the app, where 14 came from the reinforcement group, and 10 came from the control group respectively. We only included participants who reported their mood in the analysis.

Levene's test was conducted to compare the equality of variance in term of age and goal commitment score between the two groups. The test indicates there is no significance difference in term age ($F(1) = 1.901$, $p = .181$) and goal commitment score ($F(1) = 0.109$, $p = .744$) between active reinforcement and control group

Table 4.1: Mean and SD of age and goal commitment score from both groups

Group	Age		GCS	
	Mean	SD	Mean	SD
passive reinforcement	32.2	8.91	15.5	1.65
control	27.6	4.72	15.8	1.46

4.3.1 Level of compliance

We used compliance to measure the consistency of participants in reporting their mood every day. Over the duration of 4 weeks, 241 mood reports were received. We found a noticeable dif-

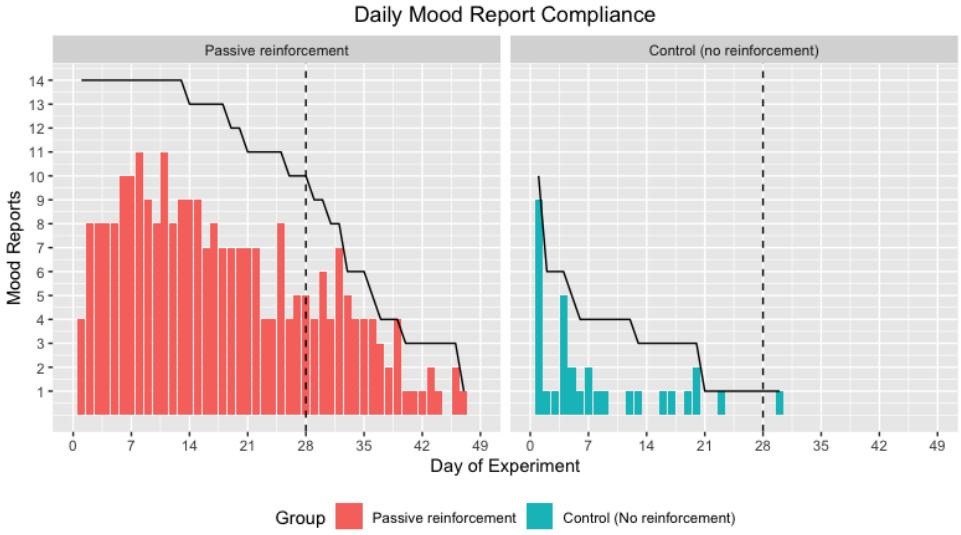


Figure 4.1: The changes of compliance between two groups, measured using mood report counts

ference between the two groups with 212 mood reports from participants in the reinforcement group, compared to only 29 mood reports from within the control group.

A Kruskal-Wallis test suggests that participants in the reinforcement group had a significantly higher ($X^2(1) = 37.508$, $p<.001$) compliance rate ($M = 5.78$, $SD = 2.91$) compared to participants in the control group ($M = 1.10$, $SD = 1.84$) . Although the overall compliance level was not as expected. Participants in the reinforcement group had a 54.08% compliance rate compared to 10.36% of those in the control group. We then looked into the compliance changes and found that an interesting pattern has emerged from the mood report data. Participants in the control group dropped off significantly after the first day of the study and remained low in compliance throughout the study's remaining duration. Meanwhile, participants who received reinforcement had their compliance level relatively stable, although it started to decrease in the fourth week. Figure 4.1 shows that even though both groups had a high drop-off rate, participants in the reinforcement group lasted longer than the control group.

Whilst the overall mood reports were low; we were interested to understand how many participants were active (who were still using the app) throughout the study. Our results indicated that the number of participants who were still active was higher than the reports

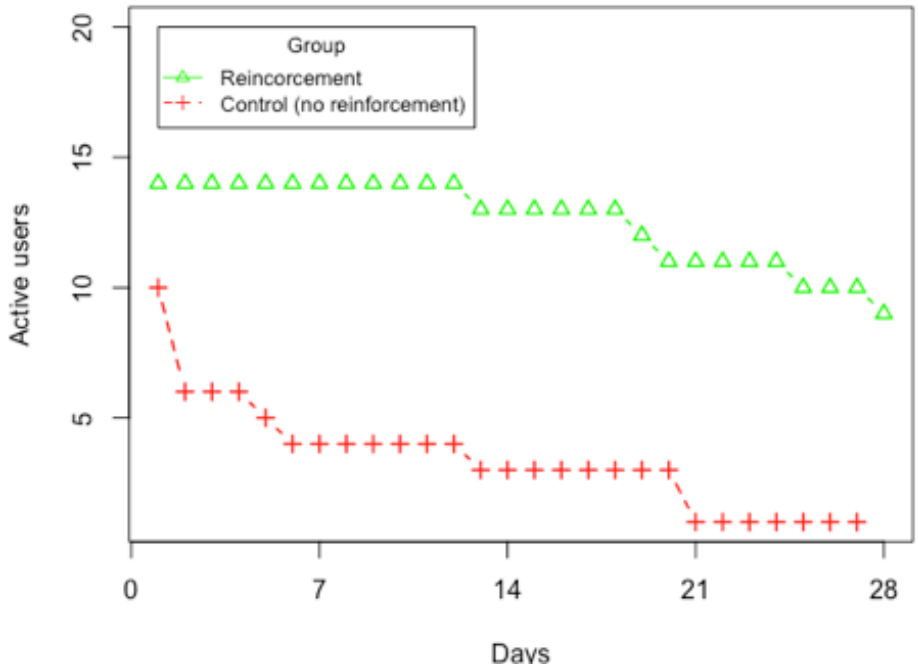


Figure 4.2: Active users from the beginning until the end of the study

since many would miss completing some reports (Fig. 4.2). Participants were considered as active if they still sent at least 1 mood report over 7 days. For example, if a person sent a mood report on the 1st day and went missing, and then reported again on the 7th day, this person was still considered as active throughout a week. Similar to the pattern of compliance, the number of active users from the control group declined significantly from 10 active users on the first day of the study, down to 6 on the second day, and remained low during the remainder of the study. The number of active users from the control group even went to only 1 in the fourth week.

We are also interested to see how participants' commitment compared against the actual mood reports. At the beginning of the study, we measured their commitment using the HWK scale. Both groups had a similar score of their goal commitment with the mean score of 76%. This means that the participants in both groups had a similar level of commitment and intentions in reporting their mood every day. The low level of compliance suggests that the majority of participants failed to act upon their intention, as shown by the significant drop-off rate, especially in the control group. In the reinforcement group, the decrease of compliance

as measured using mood report counts was slower than the control group. Interestingly, two weeks after the study ended, eight participants from the reinforcement group were still reported their mood. Conversely, all control group participants stopped reporting their mood after the 27th day of the study.

4.3.2 Time distribution of mood reports

We sent reinforcements of the implementation intention in advance before the actual action was supposed to happen. When using the Mood Journal app for the first time, participants had to choose one of the following routines as a cue for their mood report: on the train going home, arriving at home, going to bed, or after having dinner. These cues for reporting the mood were supposed to happen in the evening, whereas the reinforcements were sent at a random time during lunchtime (12:00-14:00). We are interested to understand how the gap between the reinforcements affected the actual mood report.

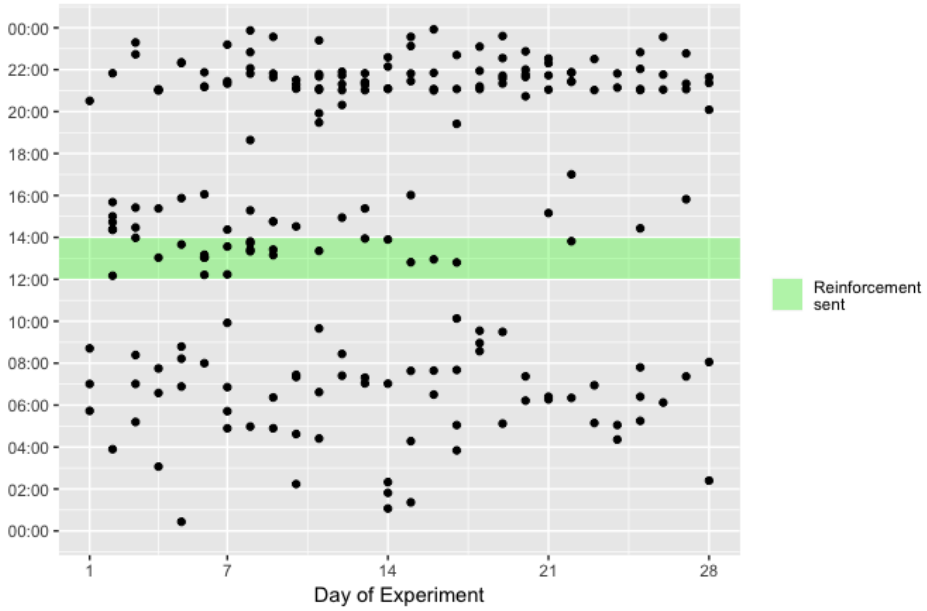


Figure 4.3: Time distribution of mood reports

Therefore, we visualised the time distribution in which mood reports were received (Fig. 4.3) to see whether participants followed their implementation intentions (to report their mood in the evening) or not. Our data showed 57 reports (27%) were sent in the morning (4:00 -

11:59), 50 reports (23%) were sent in the afternoon (12:00 - 19:59), and 103 (49%) others were sent in the evening (20:00-3:59). Of those numbers, only 24 reports (11%) were sent in the window of reinforcements sent (12:00 - 14:00).

The results indicate that majority of participants complied with their implementation intentions of reporting their mood in the evening. Also, with only 11% of mood reports sent at around the time reinforcements were sent, it is a good indicator that the reinforcements worked. However, we found some of them reported their mood early in the morning. At the moment, we cannot conclude why some participants chose to report their mood in the morning as we did not have any supporting data to answer this question. Indeed, a more rigorous investigation needs to be conducted to understand this situation.

4.3.3 Change of automaticity

SRBAI was used to measure the strength of automaticity in reporting mood every day. We asked participants to complete the SRBAI questionnaire at the beginning of the study, second week, and at the end of the study (fourth week). We were interested in the changes of the automaticity score between the two groups. Unfortunately, the number of SRBAI responses that we received was insufficient for further analysis.

On the second week of our study, only 6 participants responded to the SRBAI questionnaire (5 from the reinforcement group, 1 from the control group). The same number of participants responded to the SRBAI questionnaire at the end of the study (fourth week). The SRBAI score from the reinforcement group increased from the second week to the fourth week. However, when we looked at the data closely, the two reports from the control group, came from different participants. Therefore, changes of automaticity in the control group from week-2 to week-4 cannot be interpreted. Due to the small sample size, we cannot run an inferential statistical analysis on SRBAI.

Table 4.2: Recall of routine events as the cue in the implementation intentions to report daily mood

Participant ID	Group	Original cue	Recall of the cue	
			Week 2	Week 4
P1	1	Arriving at home	Teaching and its stuff	Teaching and its preparation
P2	1	Arriving at home	Arrived at home	Arrived at home
P3	2	Arriving at home	My routine event is study	-
P4	1	Going to bed	I chose night sleep, but my app keeps ringing on the middle of afternoon, so I just report my mood on that time	Night sleep
P5	1	Going to bed	Work	-
P6	2	Arriving at home	-	Watching movie
P7	1	Going to bed	Every morning	Every morning start of activity
P8	1	Commuting	-	After commuting

4.3.4 Recall of Implementation Intention

We also investigated how the participants recalled their original cues in their implementation intentions. We sent them a questionnaire asking about their routine as the cue on the second week, and again on the fourth week of the study. Eight participants answered the questionnaire either on the second or the fourth week. We then compared the routine events recalled by each participant in Table 4.2.

Overall, only 60% of participants in the reinforcement group recalled their cues correctly, whereas, of the control group, none of them gave the correct answer when remembering their cues. One of the participants in the reinforcement group also mentioned that initially, he/she chose to go to bed/sleep at night for the routine events. However, because the app sent the reinforcement at lunchtime, he/she reported his/her mood immediately after receiving the reinforcement.

4.4 Discussion

Previous studies have suggested that adding reminders of implementation intentions could enhance its effect (Prestwich & Kellar, 2014). In our study, we found that the participants who received reminders of their plan in the form reinforcements had better compliance in reporting their mood than participants without reinforcements. As measured using the daily mood reports, the compliance has been shown to decay from the beginning towards the end of the study. However, adding reinforcements has been shown to slow down the decay of compliance. Even after the study ended, there were still 8 participants in the reinforcements group who reported their mood. Considering that the mood report is a prospective memory task that has not been part of our participants' existing routine, this finding suggests that adding a reinforcement of implementation intention can indeed be used to support action initiation.

It has been argued that intentions alone cannot be relied upon when committing to perform a behaviour (Scholz, Schüz, Ziegelmann, Lippke, & Schwarzer, 2008). In this study, we found similar results where both groups had a notably high drop-off rate even though they had a good intention of reporting their mood every day, as measured using the HWK scale at the beginning of the study. It is indeed common that people fail to act upon their good intention. However, in our case, the intention might not be the only factor that determines behavioural action. In our study, we suspect the drop-off might also be affected by the type of behaviour itself. As we mentioned earlier, the mood report is a prospective memory task that does not belong to our participants' existing routine. Most people might not intend to report their mood every day unless they are forced to do it. Therefore, the intention to record their everyday mood may not be strong enough to make the task consistently performed daily. When the behaviour is not habitual, the attitude and intentions to perform such behaviour still play an important role to determine the execution of the intended behaviour (Ajzen, 1991; Fishbein & Ajzen, 1975). However, even though the intention is still needed to perform a behaviour, it is not sustainable for forming new habits. Intention to perform behaviour will decay over time, as our findings have shown decreased mood reports throughout the study.

The aim of adding reinforcement is to help the participants perform their intended task repeatedly in a stable context, even when their intention is weak, in line with the concept of habit where behaviour needs to be repeated consistently in the same context to make it habitual (Lally & Gardner, 2013; Lally et al., 2010; Ouellette & Wood, 1998). According to Tobias (2009), reminding someone to perform a behaviour can use three different strategies: reminding by events, reminding by executing the behaviour itself, and reminding by situational cues. Existing studies that use reminders focus on situational cues, asking people to perform the intended action when the actual cues were encountered. However, a reminder does not necessarily need to be sent at the actual time when the cues happen because the effect of situational cues does not depend on time (Tobias, 2009). Additionally, reminders decay over time and the effect becomes less significant. Thus, our approach of giving reinforcement 5-6 hours in advance should also affect promoting behaviour as suggested by our findings on the compliance of mood report, without making participants dependant towards the reinforcement. We argue that sending a reminder at the actual time could lead to dependency where people will associate the intended behaviour with the reminder. The study from Renfree et al. (2016) suggests that even though habit formation apps that use reminders could support the repetition of new behaviours, it makes their users dependent on the reminder for remembering to perform the behaviour. Instead, we utilise prospective memory by sending the reinforcement of one's plan way in advance, so they can recall their original plan and help them to strengthen their cue-response link.

According to previous literature, there are two types of prospective memory: time-based and event-based (Brewer et al., 2017; Sellen et al., 1997). Time-based prospective memory is a mechanism of remembering to perform a behaviour at a specific time. For example, remember to submit an assignment at noon. Unlike time-based, event-based prospective memory involves remembering to perform a particular behaviour when a specific situation or cue is encountered. Many activities in our daily lives fall into this category. We often have to remember something that is not constrained by time but by other situations. For example, when we pass a gym near our home, we remember to exercise. Event-based prospective memory will help people to

remember something by associating the intended behaviour with specific cues. A study from Sellen et al. (1997) found that using event-based cues are better than time-based cues, even though people who use an event-based cue take more time to process the cue. It is related to how the association of cue and its associated response are formed. In implementation intentions, forming a specific if-then plan takes time to consistently perform the intended plan. In the beginning, forming implementation intentions requires deliberate effort and sufficient intention to perform the intended behaviour. Otherwise, people will forget about their plan. As our findings have suggested, participants in the control group who formed implementation intentions failed to act upon their plan. Conversely, participants who received reinforcement could execute their plan more consistently.

Accessibility also has a vital role in predicting behaviour performance. According to Tobias (2009), accessibility to perform a behaviour decays over time. He argues that remembering to perform a behaviour becomes more difficult as time passes. Our findings show a similar trend where the compliance of mood report decreases over time. However, adding the reinforcement slows the decay, making people remember their intended task.

Nevertheless, accessibility could also be affected by other factors. In our case, we found that there was a high drop-off rate after the first day of the study. Some of our participants complained about privacy concerning permissions, requested by the Mood Journal app, including location, mood data, access to phone storage, and internet. Those permissions might become a concern for some participants, and thus it reduces their accessibility, and then they decided to stop using the app.

Another interesting finding is the change of automaticity. According to the previous research, repeating a particular behaviour consistently in a stable context could lead to a higher automaticity level. Although our results show that the reinforcement group's automaticity score increased from the beginning until the end of the study, in contrast, the automaticity score from the control group decreased significantly after the second week. However, as we mentioned earlier, only one participant responded to the SRBAI questionnaire from the control group in each of week 2 and week 4. So, the result of the control group cannot be interpreted.

The small sample size in this study also makes it impossible to run inferential statistics.

In terms of recalling the routine event as a part of the implementation intention, our results suggest that the participants had difficulty remembering their routine events as the cue for reporting their mood. This might be due to the reinforcements sent at lunchtime (around 12-2 pm), whereas their goal of reporting their mood should be done in the evening. Initially, we argue that by sending the reinforcement in advance from the actual action, we can minimise the dependency towards the reinforcement for reporting a mood. Yet, it seems that the participants expected to receive the reinforcement based on the routine event that they chose. For example, when they chose "going to bed" as the cue, they expected to receive a reinforcement about their implementation intentions at night when they are about going to sleep. Our reinforcements were not context-aware, and they were sent at approximately the same time every day. This might also be the cause of participants having difficulty in recalling their routine as a cue. Moreover, sending the reinforcement at an inopportune moment might be annoying for some of them, which might lead to some adverse effects (Mehrotra, Musolesi, Hendley, & Pejovic, 2015).

Future work should investigate how different strategies and timing of the reinforcement could affect the implementation intention itself. To minimise the dependency towards the reinforcement, we might be able to phase out the reinforcement if the participants start committing to their intended plan. The reinforcement could also be made context-aware, for example, adapting to the situation of an individual. In the following parts, we discuss recommendations for future work in the area of reinforcement to support habit formation.

In our study, we sent the reinforcements in the form of push notification, containing the instruction to remember the implementation intention that participants have formed. When the notification is clicked, it will then open a page that has an instruction to repeat the plan in the participants' head and highlight the *if* and *then* part of the implementation intention. The aim was to make sure that participants remember the plan and stick it to their mind. The current design has a weakness where the reinforcement of the implementation intention is a passive mode that requires participants to remember their plan to be executed later, as

seen in Figure 4.4.

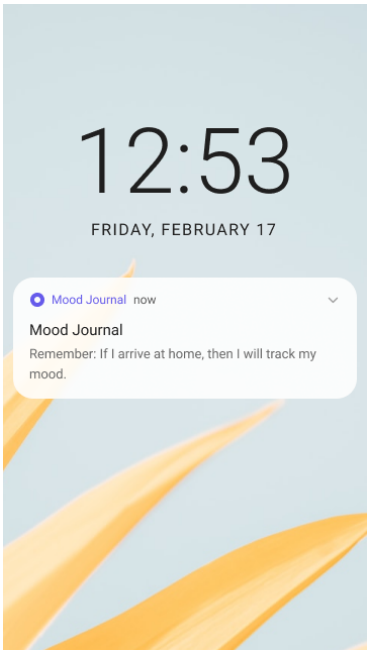


Figure 4.4: Reinforcement of implementation intention in Mood Journal app sent via push notification

Use mental-imagery task and make reinforcements active

Tobias (2009) argues that accessibility to perform an intended behaviour decays over time, and that as a result, it will become more challenging to remember to perform a behaviour when the cue is encountered. Delivering reinforcements with passive instruction is prone to being forgotten or overlooked. It also requires more cognitive effort to remember the content within the reinforcement. Therefore, instead of using passive instruction sent via push notifications, the second strategy for implementing the reinforcement framework is to use active reinforcements. The key differences between passive and active reinforcements are the mode of delivery and the required response. Passive reinforcements are sent via push notifications and do not force an immediate response, active reinforcements are sent via full-screen activity on the phone, filling the phone screen by showing the reinforcement in the front and requiring immediate response from the recipients. Active reinforcements use a technique called mental imagery that has been suggested to improve the performance of implementation intentions

(Knäuper et al., 2011, 2009). The idea is to ask recipients to vividly imagine the situation in which they want to track their mood, and to imagine performing the task immediately in that situation. Mental imagery can help the implementation intentions to be represented better in the memory, helping a person to recall their planned intentions when the situational cue is encountered.

4.5 Summary

This chapter investigates how implementation intentions can be enhanced by adding passive reinforcement. Unlike prior studies that tried to enhance implementation intentions by sending reminders at around the intended action's actual times, we investigated a different approach by sending the reminder of one's plan (reinforcement), way in advance before the actual action should happen. We tested whether the reinforcement has a positive impact on the implementation intentions or not. We measured the changes in compliance and automaticity of a daily mood report task.

Even though our initial findings suggest that giving passive reinforcements improves compliance, it is difficult to draw reliable conclusions due to the small sample size. A similar finding was found for the automaticity where there was only one participant from the control group who answered the SRBAI questionnaire in both of week-2 and week-4 of the study. The type of behaviour and reinforcement might be the factors. Mood report as the task in this study is a prospective memory task that does not belong to our participants' existing routines. Therefore, the task might not be interesting for some of them.

Concerning the intention to perform a behaviour, even though the intention is not suitable for predicting habitual behaviour, it still has a vital role in determining the execution of behaviour. In our findings, participants failed to act upon their good intentions, including the reinforcement group, even when we already gave them passive reinforcements. The role of intention cannot be undermined when we intend to perform a behaviour. With the addition of reinforcements, it is argued that the intention will be strengthened. More importantly, the

behaviour that aims to be a habit can be consistently executed until it becomes habitual.

Implementation intentions require a firm commitment from an individual who wants to use them. Additionally, when people start forming an implementation intention, they still need reinforcements because they tend to forget about their plan, as our findings confirm. People had difficulty recalling their plans. Therefore, reinforcements of one's plan are needed to strengthen the implementation intention. We used passive reinforcements sent via push notifications to help participants associate the mood report task, with their existing routine as a cue. As the passive reinforcements were sent way in advance of the actual action, we hoped that the participants would remember their implementation intentions and not rely on the reinforcement to report their mood. Participants who received passive reinforcement did have a better recall performance compared to the others without reinforcements. However, passive reinforcements could be ignored since they are sent via push notifications. Also, the wording makes them non-urgent for the recipients. In the next chapter, we will discuss the use of different reinforcement strategies. In this case using a mental-imagery task that requires participants to vividly imagine the situation of their planned intention, and to imagine tracking their mood when the situation happens. The reinforcements will be delivered via full-screen activity, forcing participants to see it when they open their phones. Because this type of reinforcement requires immediate attention and response, we call it "active reinforcement".

CHAPTER 5

USING ACTIVE REINFORCEMENT TO SUPPORT IMPLEMENTATION INTENTIONS

5.1 Overview

Based on the findings discussed in the previous chapter, adding reinforcements can enhance implementation intentions. We sent the reinforcements using push notifications on smartphones. Despite participants in the intervention group who received reinforcements had a significantly higher compliance rate than the control group, their overall compliance level was low throughout the study, averaging 5.78 reports in 4 weeks.

Therefore, we investigated the effect of making reinforcements active by adding a mental imagery task. As we previously outlined, the reinforcements sent via push notifications only contain the planned implementation intentions, e.g. "Remember, if I arrive at home, then I will report my mood". Also, the reinforcements were easy to dismiss, thus increasing the risk of being ignored. Therefore, by making the reinforcements active, we aim to increase its effect.

In this chapter, we investigated the impact of making reinforcements active by changing the format into a mental imagery task. In addition, the task should require a person to take action immediately and cannot be dismissed. We are interested in studying whether adding mental imagery tasks will improve reinforcements' performance on implementation intentions.

5.2 Method

In our previous studies discussed in Chapter 4, we investigated the use of passive reinforcements to support an implementation intention task of reporting mood every day. In this study, we changed the reinforcements of implementation intentions to become active by using mental imagery to improve the impact of reinforcements on implementation intentions. The proposed hypotheses for this study are:

- Participants who receive active reinforcements will have higher compliance compared to participants who do not receive reinforcements.
- Participants who receive active reinforcements will have a higher level of automaticity compared to participants who do not receive reinforcements.

5.2.1 Participants

We recruited participants using email, social messaging apps, and meeting them face-to-face without offering any financial incentives. Overall, 59 participants signed up to the study, but only 29 completed the screening questionnaires, which we included in the final analysis. Of those, we put participants in two different groups: active reinforcement and control group, balanced by their age and goal commitment score. The demographic of participants were majority students (undergraduate, master, and doctorate). Participants' main motivation to join this study was also assessed using goal commitment questionnaire. To avoid including the same participants from our previous study, we sent the recruitment to different set of groups of people.

5.2.2 Design

The study used a between-subject design with two distinct groups:

- Active reinforcement group. Participants in this group were asked to form an implementation intention of reporting their mood every day. In addition, we also sent them

active reinforcements where participants had to perform a mental imagery task, imagining the actual situation in which their planned intention is supposed to be performed, and perform the intended plan.

- Control group. Participants in this group were asked to form the same implementation intention of reporting their mood every day. No reinforcement was given to this group.

This study used two dependent variables to measure the difference between the two groups: compliance and automaticity. Compliance was measured by the consistency of reporting mood. Whereas automaticity was measured using the Self-Report Behavioural Automaticity Index (SRBAI) questionnaire.

We also measured the response time from participants in the active reinforcement group to understand whether participants ignored the reinforcements (when they dismissed the instruction within 10 seconds) or acknowledged and performed the mental imagery task. In addition, we also measured the actual time in which participants reported their mood to understand whether participants committed to their plan of reporting their mood in the evening where they arrive at home or reported their mood immediately upon receiving the reinforcements.

5.2.3 Materials

We modified the Mood Journal app used in the previous study. The main change was the form of reinforcements, where we made them into a mental imagery task. In our previous study, reinforcements were sent using Android push notification system where participants could easily dismiss. Whereas in this version, when the reinforcements were sent, participants would see a full-screen page, showing an instruction to perform mental imagery task where participants were asked to imagine the actual condition in which their intention of reporting mood should be performed subsequently performed the planned intention. They could not dismiss this page, unless they tap a button, acknowledging the message. Since the instructions asked participants to perform the mental imagery task, we called this "active reinforcement".

Another change in the app was the addition of a consent form and screening questionnaire,

allowing participants to complete all questionnaires within the app, ensuring the data to be stored securely in our server. Additionally, the SRBAI questionnaire was also included in the app. It was triggered automatically on the 7th, 14th, 21st, and 28th of the study, allowing participants to complete the SRBAI questionnaire directly from the app. We did this to improve the questionnaire's number of responses since we found in the previous study that only 6 of participants who completed the SRBAI questionnaire sent on a separate document. Other parts of the app remain the same, including the condition in which they had to report their mood, and the time of delivery for the reinforcements (every day between 12:00 - 14:00). Every time participants received reinforcements; the app will log information, including how reinforcements were sent and response time from participants. The app recorded participants' daily mood data and transferred the data securely to our server.

For the SRBAI questionnaire, we used the same version (Gardner et al. 2012) to measure the automaticity. The SRBAI questionnaire consists of 4 items, asking that *"Behaviour X is something ..."*:

- "I do automatically",
- "I do without having to consciously remember",
- "I do without thinking", and
- "I start doing before I realise I'm doing it".

Each of the items has a 7-point Likert scale, and the score of SRBAI is from 4-28 points, where the higher points mean a higher level of automaticity. The SRBAI questionnaire was triggered automatically within the app.

We used a goal commitment score to balance the group, measured using the HWK scale (Klein et al., 2001). Goal commitment is one of the most prominent moderators of how behaviour could happen, and it can be used to measure the strength of intention.

5.2.4 Procedure

At the beginning of the study, participants were asked to download Mood Journal app from Google Play Store. When opening the app for the first time, participants were asked to agree with the consent form to continue their participation in this study. On the next step, participants were asked to fill demographic questions. Upon completion, participants were allocated in two groups based on their goal commitment score: active reinforcement and control group. The app then guided participants to form a plan (implementation intention) to report their mood every day. All participants were given the same implementation intentions of reporting their mood when they arrive at home, so they had the following plan: "If I arrive at home, then I will track my mood". The condition is selected to allow reinforcements to be sent way before the planned action is performed, so it minimises the risk of dependency.

In the active reinforcement group, participants received a mental imagery task in their phone, asking them to imagine the situation of their planned implementation intention vividly and to act immediately when such a situation is encountered. The mental imagery task, acted as reinforcement for their implementation intentions, was sent automatically via the Mood Journal app, every day between 12:00-14:00. The task itself could not be dismissed unless participants decided to tap the button in the app. Daily mood reports were recorded, as well as the time when the reports were received. Every week (7^{tth}, 14^{th}, 21^{st} and 28^{th} day respectively), a SRBAI questionnaire was opened automatically in the Mood Journal app. The SRBAI score was used to measure the automaticity in reporting their mood. At the end of the study, participants received a debrief of the study via email.

5.3 Findings

In our study, 56 participants downloaded the Mood Journal app from Google Play Store. Of those, 29 people (52%) completed the screening questionnaire and formed the implementation intention of tracking their mood every day. Participants were divided into two different groups, balanced by their goal commitment score, measured using the HWK scale (Klein et al., 2001).

Table 5.1: Mean and SD of age and goal commitment score from both groups

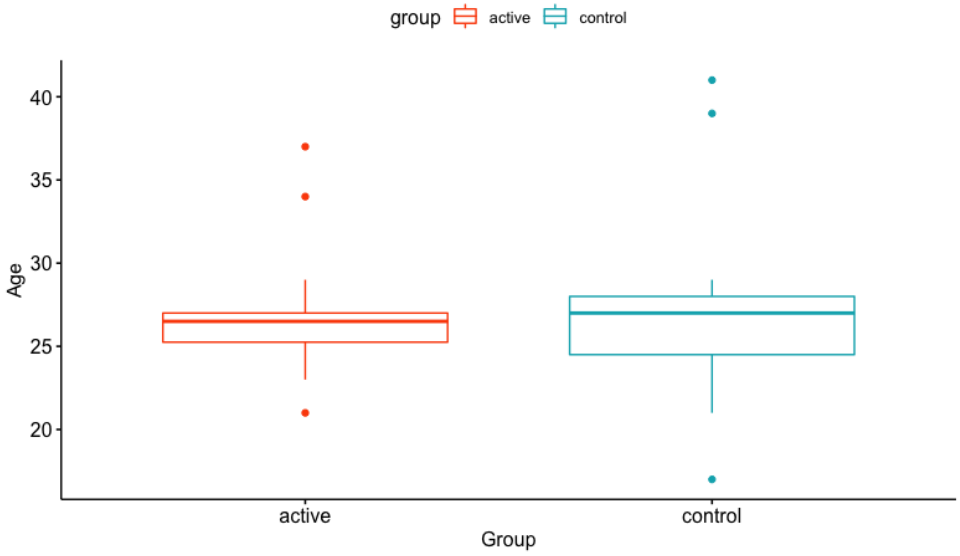
Group	Age		GCS	
	Mean	SD	Mean	SD
active	26.1	3.98	17.9	3.38
control	28.1	6.09	17.1	2.00

There were 14 participants in the active reinforcement group with a mean age of 26.1 (SD = 3.98) and a mean goal commitment score of 17.9 (SD = 3.38). Meanwhile, there were 15 participants in the control group with a mean age of 28.1 (SD = 6.09) and a mean goal commitment score of 17.1 (SD = 2.00). Levene's test was conducted to compare the equality of variance in term of of age and goal commitment score between the two groups. The test suggested there was no significance difference in term age ($F(1) = 0.975$, $p = 0.332$) and goal commitment score ($F(1) = 2.817$, $p = 0.105$) between active reinforcement and control group. Further, we only included participants who formed and completed the first rehearsal of implementation intention in the analysis.

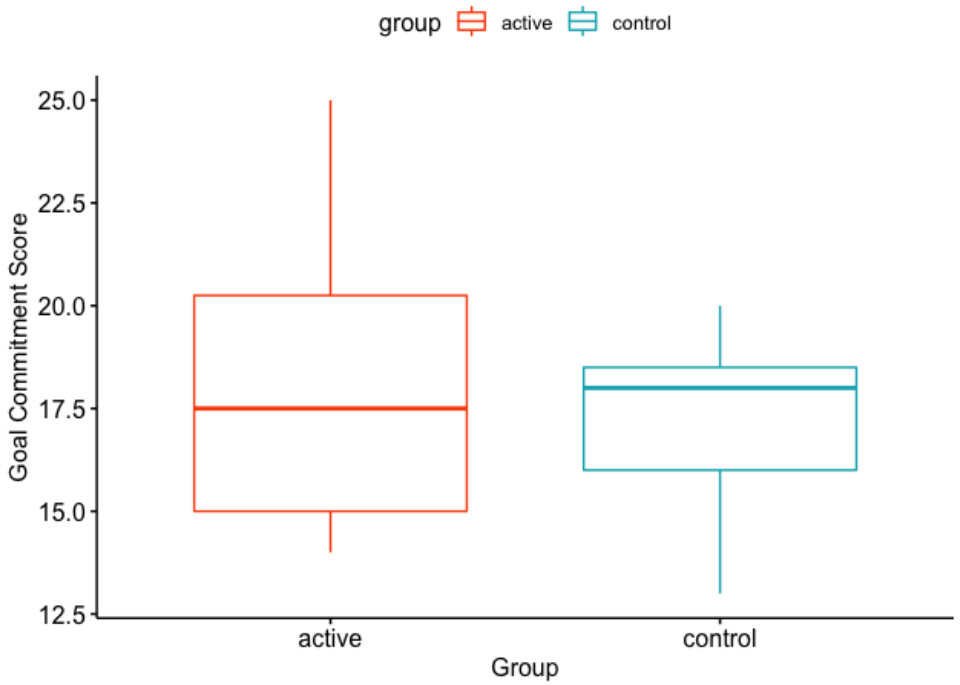
5.3.1 Level of compliance

We used compliance to measure the consistency of participants in reporting their mood every day. Over 4 weeks, 41 mood reports were received. A Kruskal-Wallis test suggested there was a significance difference of compliance ($X^2(1) = 35.207$, $p<.001$) between active reinforcement ($M = 1.29$, $SD = 1.80$) and control group ($M = 0.179$, $SD = 0.476$). However, the overall compliance level from both groups was low. In the active reinforcement group, the compliance level was only 9.18%, whereas the control group was significantly worse with only 1.19% of compliance. When we looked at the number of mood reports throughout the study, we noticed similar patterns with our previous studies.

The data indicate that the compliance of reporting mood from both groups dropped significantly after the first week of the study, even for the active reinforcement group, where we sent mental imagery tasks to rehearse their implementation intentions. On the first day of the study, there were 8 mood reports from 11 participants in the active reinforcement group.



(a) Age



(b) Goal commitment score

Figure 5.1: Age and goal commitment score between two groups

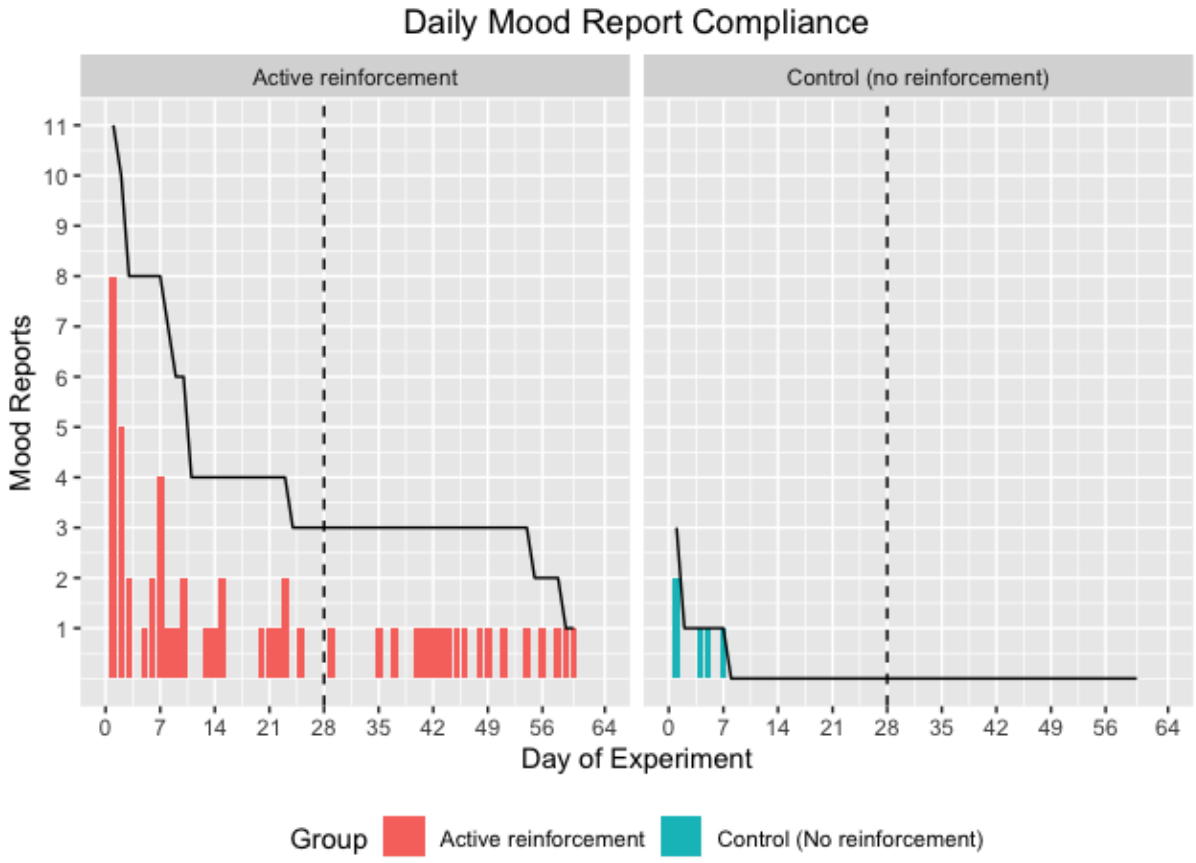


Figure 5.2: The changes of compliance between active reinforcement and control group

However, we only received 2 mood reports from 15 participants in the control group. The number of mood reports decreased significantly, and after the first week, there were only 2 or fewer mood reports received every day.

However, when we looked at the data beyond 28 days, 3 participants from the active reinforcement group still reported their mood at least once after the study period has ended. After 4 weeks, we still received further 18 mood reports from those 3 participants. Participants who consistently reported their mood at least once in two consecutive weeks tend to be more complied and last longer. However, only 1 participant was consistent in reporting their mood at least once every week. Besides, we also noticed that only 4 participants reported their mood in two consecutive days at least once, whereas other participants reported their mood inconsistently (See Fig. 5.3). Nonetheless, overall compliance remains low in both groups.

The overall mood reports were low; we were also interested in understanding how many

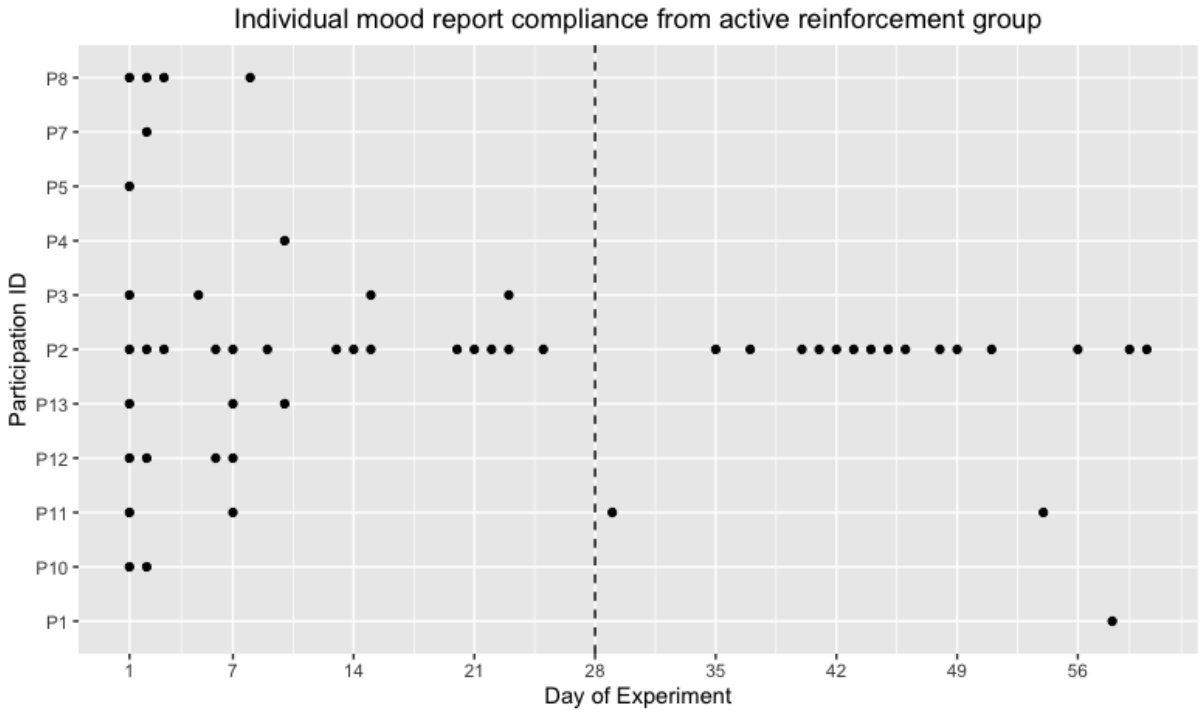


Figure 5.3: Individual compliance from active reinforcement group

participants were active (who were still using the app) throughout the study. Participants were considered active if they still had the Mood Journal app installed, and kept sending mood reports at least once in two consecutive weeks. Similar in the findings discussed in the previous chapter, our results indicated that the number of participants who were still active was higher than the reports since many would miss completing some reports (See the line in the Fig. 5.2). Similar to the pattern of compliance, the number of active users from the control group declined significantly from 11 active users on the first day of the study, down to 8 on the second day, and 3 at the end of the study. The number of active users from the control group even went to only 1 after the first week of the study, and none of them was active anymore after the second week of the study.

We were also interested to see how participants' commitment compared to the actual mood reports. At the beginning of the study, we measured their commitment using the HWK scale. Both groups had a similar score of their goal commitment with the mean score of 72% for the active reinforcement group and 68% for the control group, respectively. As shown in Figure 5.2, the low level of compliance suggests that the majority of participants failed to act

upon their intention, as shown by the significant drop-off rate. Interestingly, 4 weeks after the study ended, 3 participants from the reinforcement group were still reported their mood. However, only 1 of them was consistent in reporting their mood beyond the 28 days duration of the study. Conversely, all control group participants stopped reporting their mood after the 10^{th} day of the study.

5.3.2 Time distribution of mood reports

Since active reinforcements aimed to strengthen implementation intentions through mental imagery task and minimise the dependency towards the reinforcements itself, all reinforcements were sent hours in advance. Participants received active reinforcements between 12:00-14:00 for an intended task that has to be performed later in the evening. We recorded the actual times of mood reports sent by participants.

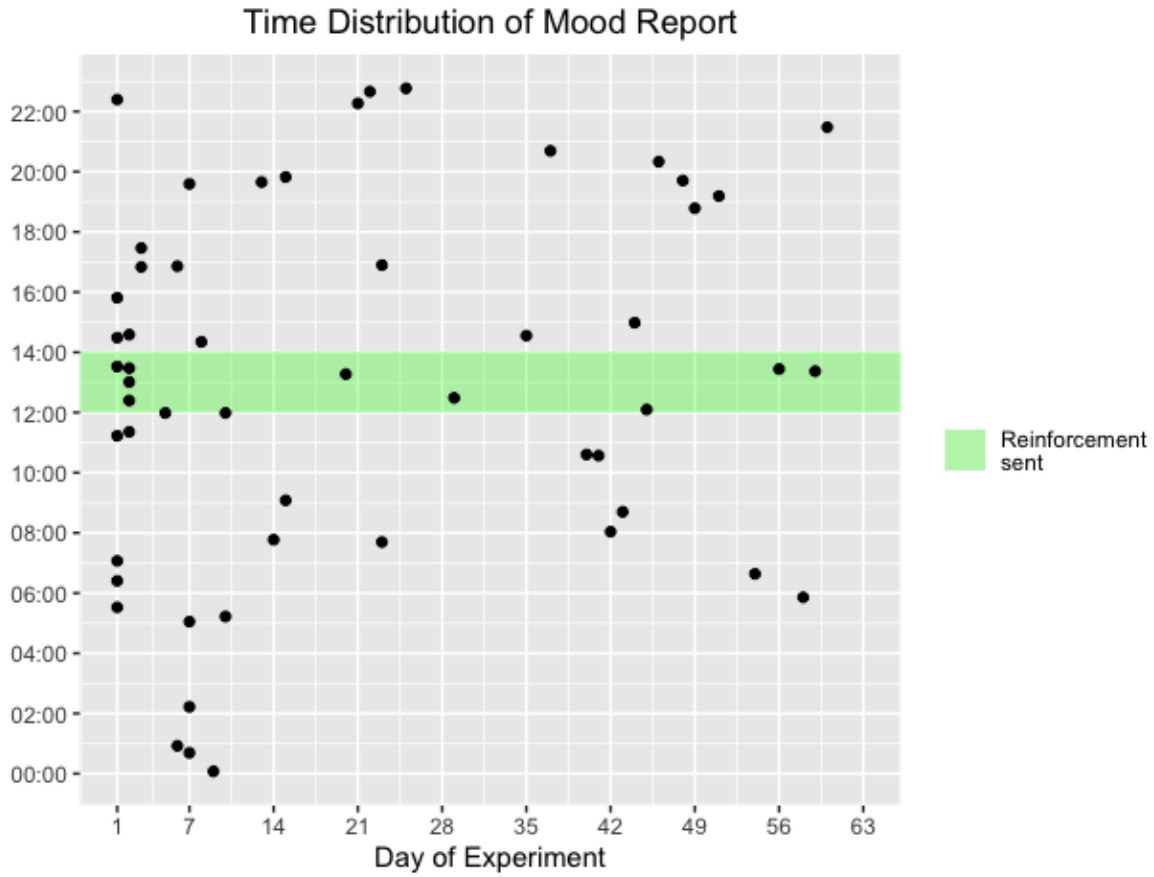


Figure 5.4: Time distribution of mood reports

When the mood reports were sent, the distribution of time was visualised to see whether participants followed their implementation intentions (to report their mood in the evening) or not. The graph shown in Figure 5.4) shows that only mood reports from the active reinforcement group were included since only participants in this group received reinforcements. We found some interesting results from this data.

Of 36 mood reports received within 28 days from the active reinforcement group, 15 were reported between 14:00-23:59 (afternoon until evening), 4 were reported between 0:00-4:59 (midnight until early morning), 12 were reported between 5:00-11:59 (morning until late morning), and 5 were reported between 12:00-13:59 (when the reinforcements sent). Although only 4 of them were reported when reinforcements were sent, 12 mood reports were received in the morning before reinforcements were sent. We cannot conclude the reason behind this since we did not ask why participants reported their mood at that time. Nonetheless, it was still interesting findings since not majority of participants committed to their implementation intentions. Instead, some of them reported their moods at their own specified time (in the morning).

5.3.3 Elapsed time between reinforcements and mood reports

We define elapsed time as the time difference between receiving the reinforcements and sending mood reports. Because we wanted the reinforcements to strengthen the implementation intentions, participants were expected to execute their planned intention of reporting their mood a few hours later after receiving reinforcements.

During the 4 weeks duration of the study, 129 reinforcements were triggered and sent to participants in the intervention group. Of these, only 27 reinforcements were followed by mood reports, indicating that the majority of reinforcements were ignored. Based on the reinforcements with follow up mood reports, we plot the elapsed time needed to report the mood.

The graph in Figure 5.5 shows that the elapsed time increases within 4 weeks. The mean elapsed time is 5.50 hours. However, the number of reinforcements with subsequent reports

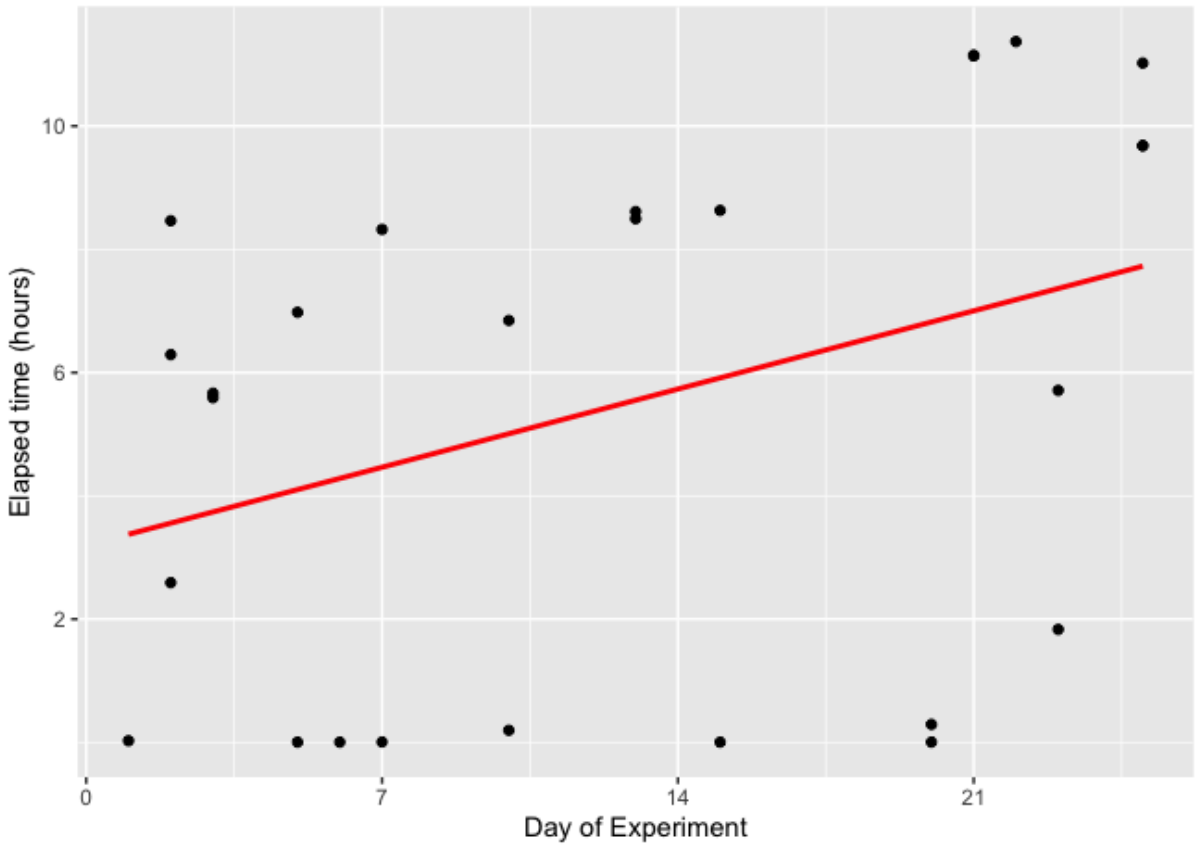


Figure 5.5: Elapsed time between receiving reinforcements and sending mood reports

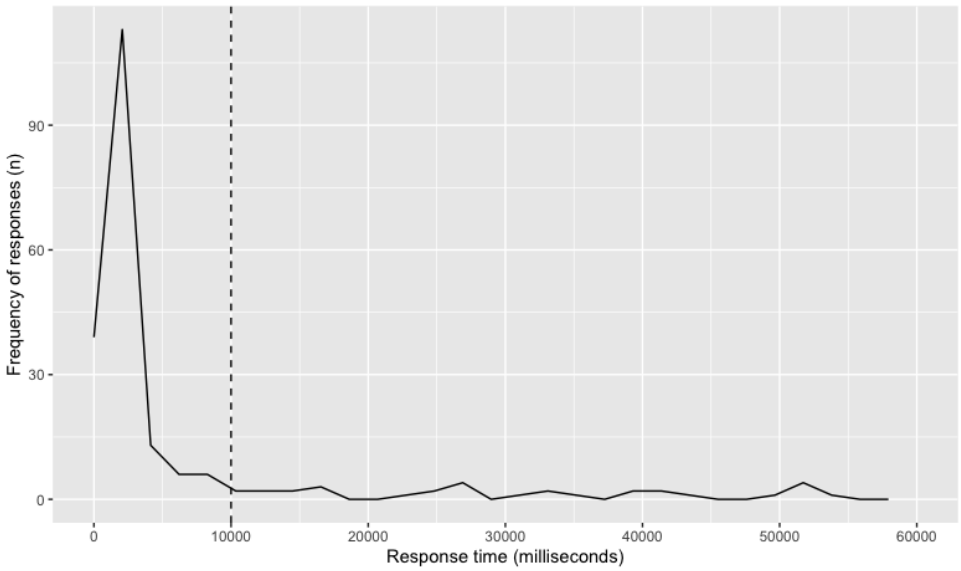
is relatively small; therefore, it is difficult to draw any significant conclusions.

5.3.4 Response towards reinforcements

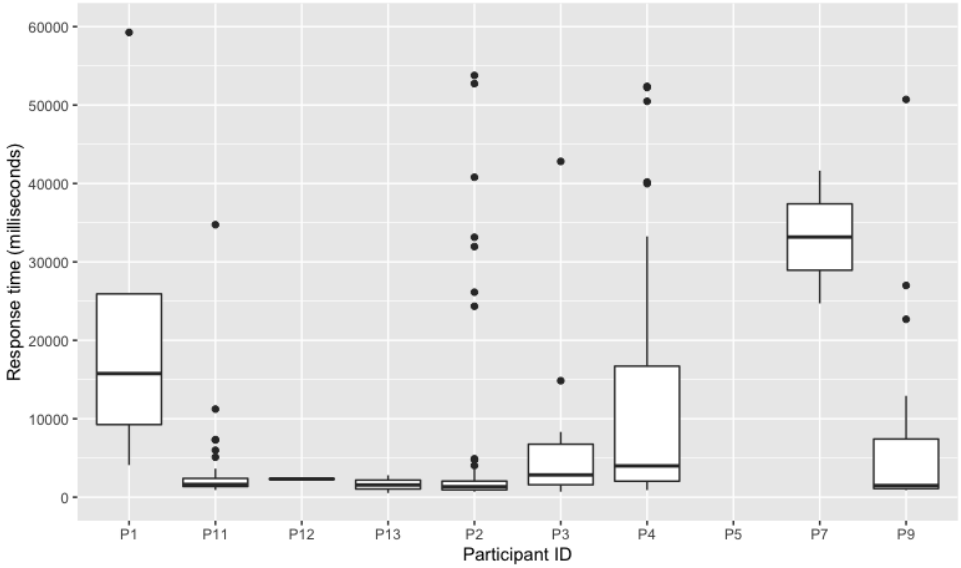
We measured response time towards reinforcements to determine if participants acknowledged the mental imagery task or ignored the message when they received it. Based on the instruction's text length to perform mental imagery task, we set 10 seconds (10,000 milliseconds) time limit before participants dismissed the reinforcements by tapping the button.

Our findings indicate that the majority of reinforcements were dismissed within 1 hour with a mean response of 667,441 milliseconds (11 minutes 7 seconds). However, when we looked at the data more closely, 40% of reinforcements were dismissed within 10 seconds. Meanwhile, the median response time is 93,135 milliseconds (1 minute 33 seconds).

We were also interested to understand individual response times from each participant.



(a) 1 second scale within 1 minute time-frame (60,000 milliseconds)



(b) Individual response time from each participant (1 minute scale within 15 minutes)

Figure 5.6: Response time towards active reinforcements

We set a cut-off time of 900,000 milliseconds (15 minutes) to visualise the data since the mean and median of response times fall within that time. Note that only 10 participants were included in the graph since 1 participant only received reinforcement once, and the response time was 2,423,979 milliseconds (40 minutes 24 seconds).

A Kruskal-Wallis test indicates there was a significance difference of response time between participants ($X^2(9) = 67.26$, $p<.001$). The individual response time graph as shown in Figure 5.6 suggests that among participants, majority of them would response to the reinforcements within 1 minute after receiving. We also noticed that there was no clear pattern of the response time, meaning participants would response in different time whenever they received the reinforcements.

5.3.5 Change of automaticity

SRBAI was used to measure the strength of automaticity in reporting mood every day. We asked participants to complete SRBAI questionnaire at the 7^{th}, 14^{th}, 21^{st}, 28^{th} day of the study. We were interested in the changes of the automaticity score between the two groups. However, even though we have automated the SRBAI questionnaire within the app, the number of responses we received was still insufficient for further analysis.

Overall, we only received SRBAI responses from 6 different participants (5 from active reinforcement group, and 1 from the control group). Interestingly, even though participants in the control group stopped sending mood reports after the first week of the study, one of the participants still responded to the SRBAI questionnaire every week. This might be due to the mechanism of the questionnaire that will be opened automatically within the app. We notice that the active reinforcement group's automaticity score decreased from the end of the first week until the third week and slightly increased at the end of the fourth week. Meanwhile, the automaticity score from the control group remained the same throughout the study. Since the control group's response only came from 1 person, it is not easy to draw any conclusions in term of automaticity.

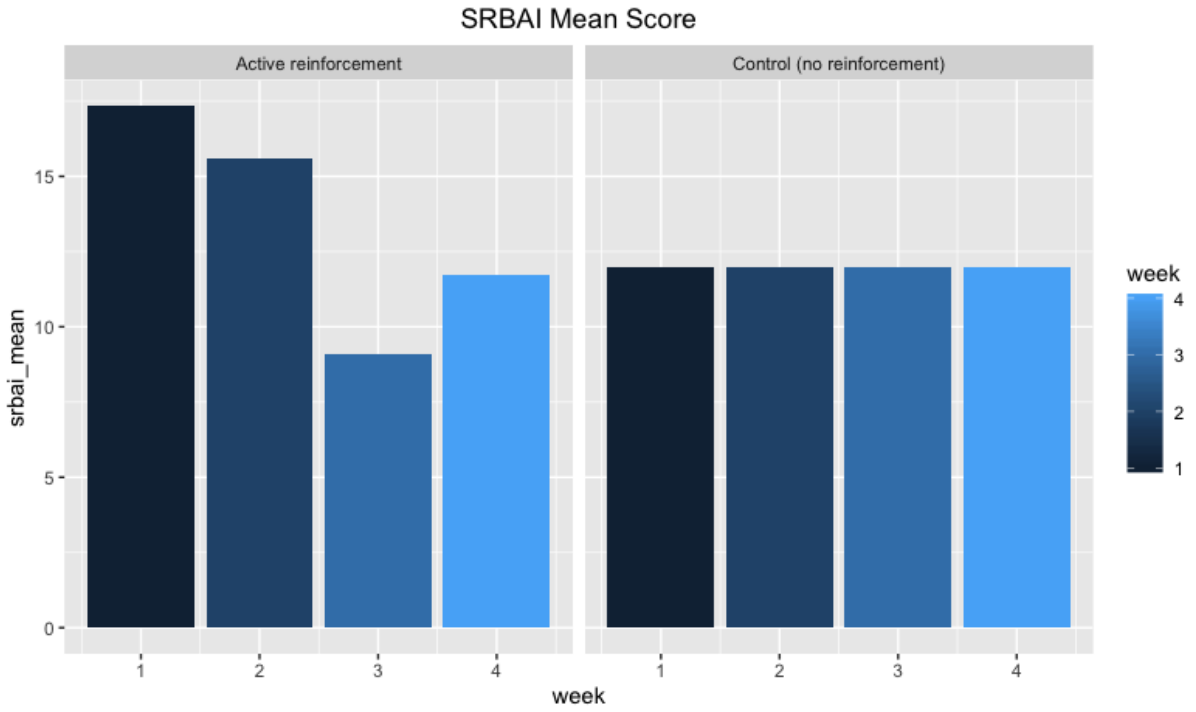


Figure 5.7: SRBAI score from both groups

5.4 Discussion

Previous studies suggest that adding mental imagery task can enhance implementation intentions, even on mundane tasks (Knäuper et al., 2011, 2009). Based on our study discussed in the previous chapter, we investigated the impact of making reinforcements active by adding mental imagery task. The task required participants to vividly imagine the situation in which the condition of their implementation intentions would be encountered, and subsequently, to imagine reporting their mood immediately when the situation happens. The mental imagery task, as a part of active reinforcements, was sent every day.

We measured the impact of adding active reinforcements on two dependent variables that can measure habit formation: compliance of mood report and automaticity in reporting the mood. Our findings indicate participants with active reinforcements had a significantly higher compliance rate than participants who only formed implementation intentions (without any reinforcements). However, the overall compliance level from both groups throughout the study remained low. Even though we have added active reinforcements by sending mental imagery

tasks every day, we found that the reinforcements did not help participants comply with their planned intentions. Among 14 participants in the active reinforcement group, only 1 of them consistently reported their mood at least once every week. In addition, we found only 4 participants who reported their mood in two consecutive weeks. Also, the number of mood reports dropped significantly after the first week of the study.

Since the number of mood reports was low throughout the study, we investigated the effect of active reinforcements on the time of mood reports. Considering the active reinforcements would require immediate attention from participants, we analysed whether participants reported their mood immediately after receiving the reinforcements in the afternoon, or committed to their implementation intentions by reporting their mood later in the evening. Our findings suggest only 5 mood reports (14%) were recorded when reinforcements were sent. Meanwhile, 15 mood reports (42%) were sent between 14:00-23:59, which indicate that almost half of them were sent according to the planned intentions. However, we found an interesting pattern where there were mood reports logged at odd times, for instance, 12 mood reports were sent (33%) from early in the morning to around midday (12:00).

In addition to the pattern in which mood reports were sent, we also analysed the participants' response time when receiving the active reinforcements. Since the reinforcements contained a mental imagery task that would require participants' time to reflect on their goal, acknowledging the task should be important.

By measuring the time needed to read the task, we set a 10 seconds limit to determine whether the reinforcements were either acknowledged or dismissed. The results have shown that 40% of reinforcements were dismissed within 10 seconds. Nonetheless, many participants missed the reports even though they received active reinforcements, prompting us about the reinforcements' effectiveness. Predicting the opportune moments when delivering the reinforcements should increase its effect. This is due to the nature of mental imagery task as part of the active reinforcements that would require immediate attention from participants.

Our study found that adding active reinforcements did not necessarily make participants comply with their implementation intentions since only one of them consistently reported their

mood at least once every week, making it difficult to support habit formation that requires consistent repetition. When compared to our previous study which used passive reinforcements, adding active reinforcements have yielded poorer results in which the compliance level was even lower (54.08% compliance rate in the passive reinforcements vs 9% in the active reinforcements). Although participants in our study had good intentions to report their mood every day (72% goal commitment score for the active reinforcement group and 68% goal commitment score for the control group), they failed to act upon their intentions. This finding is consistent with existing studies which suggest that intention cannot be relied on for long-term action initiation since it changes over time (Sutton, 1998). Also, for the implementation intention task, the accessibility of performing the planned intention will decrease (Tobias, 2009). This is why the majority of participants forget to send their mood even though they have formed an implementation intention at the beginning of the study. However, our findings contradicts previous studies that suggest mental imagery task can enhance the performance of implementation intentions (Knäuper et al., 2011, 2009). This could be because the active reinforcements in our case were sent at inopportune moments, since 40% of reinforcements were dismissed within 10 seconds after being received.

In term of automaticity, only 6 participants responded to the SRBAI questionnaire, even though the questionnaire was triggered automatically at the end of the week. As a result, we cannot run inferential statistics due to the small sample for the SRBAI.

Using context-aware reinforcement

In our study, the reinforcements were sent at lunchtime to perform the mood report task in the evening. Despite better results for participants in the reinforcement group, we need a better approach for the reinforcements. Sending the reinforcements at around the same time every day without considering the recipients' context could cause adverse effects when the reinforcements are received at inopportune moments, making the recipient ignore the reinforcements.

To avoid this potential issue, we should make the reinforcements context-aware by sensing

the recipients' situation and adjusting the delivery time of reinforcement to opportune moments. The growing amount of smartphones ownership has opened a new avenue of research in context-aware computing by sensing human behaviour (Lathia, Pejovic, et al., 2013). Modern smartphones can sense their surroundings using various sensors. Information such as time, location, activity, and connectivity can be easily gathered from a smartphone to understand the context of its user (Lathia, Rachuri, Mascolo, & Roussos, 2013). By utilising this contextual information, we can tailor the notifications to be unobtrusively sent at an opportune moment, when the recipient is available (Pejovic & Musolesi, 2014b). For example, when a person is in the middle of a meeting, we should delay the delivery of reinforcements. Otherwise, the reinforcements will be ignored.

However, developing context-aware systems to support behaviour intervention is challenging, especially in terms of technical implementation (Pinder, 2018). Physical data such as location and activity can be easily obtained using Bluetooth, cellular network, Wi-Fi, accelerometer, or GPS (Rachuri et al., 2010). However, complex data such as mood, emotion, and cognitive state are more difficult to obtain. Prior studies suggest that inferring psychological state from smartphone data might lead to low accuracy (Burns et al., 2011; LiKamWa et al., 2013). There is no such sensor in our smartphone that can sense the current psychological state at the moment. To gather information about the psychological state such as mood and emotion, researchers and developers have to build their own solutions, usually in a machine learning model. These models aim to predict the psychological state by processing information gathered from multiple data sources (Pejovic & Musolesi, 2014a).

The problem with predicting psychological states by inferring different data sources is the low level of accuracy. In their study, Burns et al. (2011) developed a machine learning model to predict mood, emotion, and cognitive state by using at least 38 concurrent smartphone sensor data (e.g., global positioning system, ambient light, recent calls). Even though their model has promising accuracy on predicting physical data such as location, it is a different case when predicting affective state such as mood where the result was poor (Burns et al., 2011). The poor accuracy of mood detection using smartphone data can be solved by giving

the model enough time to train the data. LiKamWa et al. (2013) developed a model to infer daily mood data and has 93% accuracy after a two-month training period. However, waiting for two months to infer, the psychological state is not a measurements for apps helping to track health related data.

Due to the difficulties of inferring psychological states from multiple sensor data, researchers opt to use an alternative method, i.e., Experience Sampling Method (ESM). ESM has been widely used to gather information by asking participants to send self-reports at random times every day (Larson & Csikszentmihalyi, 1983). ESM aims to get a sample of data on multiple occasions, hoping to get the most accurate representation of participants when they send the self-reports (Csikszentmihalyi & Larson, 2014). ESM is beneficial to obtain data that cannot be collected using sensor data. This data is often related to psychological states, such as emotional and cognitive states, and other personal data such as thoughts and opinions (Csikszentmihalyi & Larson, 2014).

Another challenge in designing context-aware reinforcements is determining which contextual data should be selected (Pinder, 2018). With multiple contexts to choose from, it is impossible to combine all of them into one model. Not only it will be challenging to implement, but it will also require a massive amount of computing resources to process. There is no general answer when it comes to selecting the best context. The selection has to be tailored according to the targeted behaviour. At the moment, there is no satisfactory answer to the question of how to select the best context. For now, picking the appropriate context when delivering reinforcements remains an open question that must be investigated further.

5.5 Limitations

One of the main limitations of this study is the small size of the sample. Even though we managed to get 59 people to sign up, only 29 of them completed the screening questionnaires and task so that they were eligible to be included for data analysis. Increasing the sample size should allow for better analysis, especially in term of automaticity score where we only

received a few responses.

We also used a between-subject design with only two distinct groups: active reinforcement as the intervention and the control group. The findings suggest that there was a significant difference between the two groups, which was expected. Adding more intervention groups should allow us to get more insightful findings, such as adding passive reinforcement groups to compare passive and active reinforcements.

In terms of the reinforcement mechanism, the instruction to perform the mental imagery task comprised a long text requiring immediate attention from the participants. This has resulted in many participants who ignored the reinforcements and did not send their mood report. Making the instruction more concise should help participants to acknowledge the message faster.

5.6 Summary

In this chapter, we investigate the effect of making reinforcements active by adding a mental-imagery task as part of reinforcements. We used the same task in this study: mood report. Our findings indicate that active reinforcements helped participants to have better compliance in reporting their mood every day, compared to participants without any reinforcements. However, we found that the compliance level was low even for active reinforcement group. Considering that the mental imagery task should enhance the effect of reinforcements on implementation intentions, the results were surprising. However, when we looked at the data of response towards active reinforcements, we noticed that 40% of reinforcements were dismissed within 10 seconds, which could be the cause. Future work should look into a better mechanism when delivering the reinforcements so that participants could acknowledge the instruction and perform the mental-imagery task immediately.

In terms of automaticity, we still could not make a firm conclusion due to the small number of participants' responses, even though we have automated the questionnaire within the app. Throughout the study, we only received responses from 6 participants, making it difficult to

run any inferential statistics.

CHAPTER 6

USING CONTEXT-AWARE REINFORCEMENTS TO SUPPORT IMPLEMENTATION INTENTIONS

6.1 Overview

Based on our previous study (see Chapter 5), we found that making reinforcements active by adding mental imagery task did not make the performance of implementation intentions better, compared to using passive reinforcement (see Chapter 4). We argued that this is due to the demand for immediate attention to perform the mental imagery task. Making the active reinforcements context-aware, by delivering the task at opportune moments, should improve its performance. In this chapter, we discuss the effect of using context-aware reinforcements on implementation intentions. We still used the same target behaviour in this study: mood report. Understanding the impact of making reinforcements context-aware can help us to determine whether sending the reinforcements at opportune moments can lead to better performance or not.

To understand the impact of making reinforcements context-aware, we also run a pilot study targeting the reinforcements of implementation intentions on daily study report. This study was conducted as a collaboration with Ben Chen as part of his MSc summer project in 2019. Ben was responsible for designing and running the experiment, including ethics application, giving out the consent form, and recruiting participants. Whereas I was responsible for designing and developing an Android app called Task Journal to collect the data and perform the data

analysis. Daily study report was chosen as the task because we wanted to investigate the impact of reinforcements on a more meaningful task. Considering that studying is part of existing daily routines for university students, we wanted to measure how reinforcements on implementation intentions help students to record their daily study activities.

6.2 Mood report with context-aware reinforcement

6.2.1 Overview

In this study, we investigated the impact of making the reinforcements context-aware. We applied a similar method from the previous studies discussed in Chapter 4 & 5. The key difference is the mechanism in which reinforcements were sent. Instead of sending the reinforcements at random times, we used a context-aware mechanism to predict the opportune moments. In term of the target behaviour used in this study, we still chose mood report.

6.2.2 Method

In general, the method used in this study is similar to studies discussed in the previous chapters. Our hypotheses were still centred around two key elements of habit formation: compliance and automaticity. We proposed the following hypotheses for this study:

- Participants who receive context-aware reinforcements will have higher compliance compared to participants who do not receive reinforcements.
- Participants who receive context-aware reinforcements will have a higher level of automaticity compared to participants who do not receive reinforcements.

Participants

We used email, social messaging apps, and face-to-face meeting to recruit participants without offering any financial incentives. While 58 people registered to this study, only 57 of them

completed the screening questions and preliminary tasks. Only participants who completed those two tasks were included in the final analysis. Among participants who were eligible to be analysed, we put them in two different groups: context-aware reinforcement and control group, balanced by their goal commitment score & age. The demographic of participants were majority professionals working on startup, so they were quite familiar with smartphone apps, especially the ones helping to form habits. Participants' main motivation to join this study was also assessed using goal commitment questionnaire. To avoid including the same participants from our previous study, we sent the recruitment to different set of groups of people.

Design

The study used a between-subject design with two independent groups:

- **Context-aware reinforcement group**. Participants in this group were asked to form an implementation intention of reporting their mood every day. In addition, they were also given a mental imagery task to rehearse their implementation intentions. While the task was similar to the one within our previous study, the delivery time was different. Instead of sending the reinforcements at random times, we predicted the opportune moments for delivery.
- **Control group**. Participants in this group were asked to form the same implementation intention of reporting their mood every day. No reinforcement was given to this group.

This study used two dependent variables to measure the difference between the two groups: compliance and automaticity. Compliance was measured by the consistency of reporting mood. Whereas automaticity was measured using the Self-Report Behavioural Automaticity Index (SRBAI) questionnaire.

We also measured the response time from participants in the context-aware reinforcement group to determine whether participants acknowledged the task when they receive it or ignored it. In addition, we also logged the actual time in which participants reported their mood to

understand whether participants committed to their plan of reporting their mood at night or reported their mood immediately after receiving the reinforcements.

Materials

To collect the data, we used Mood Journal app that has been designed and developed as part of our previous study. While the app would still send mental imagery task as part of the reinforcements, we modified the mechanism in which reinforcements were sent. Instead of randomly sending the reinforcements between 12:00-14:00, we implemented context-aware capabilities within the app that would predict opportune moments of the receiver using Android sensors data. Considering the app would predict the opportune moments, the window for delivering the reinforcements was also extended to be 12:00-17:00. We considered a moment as opportune in these conditions:

- When the device is picked up, and the screen is ON (reading accelerometer & gyroscope)
- When a person is still and accessing Social Networking Services (SNS)
- When a person's activity changes, e.g. from walking to still
- When a person switches between tasks (by reading app usage)
- When a person is on the train, and phone screen is on (detect when on the train by reading the WiFi SSID)

In term of collecting automaticity data, we used the SRBAI questionnaire, triggered automatically within the Mood Journal app, starting on the 7^{th} day of study, and repeated every week. This mechanism allowed participants to complete the SRBAI questionnaire directly from the app. We made the SRBAI questionnaire to be opened automatically to improve the number of responses for the questionnaire. When participants received reinforcements, the app would log additional information, including how reinforcements were sent and response time from participants. The app recorded participants' daily mood data and transferred the data securely to our server.

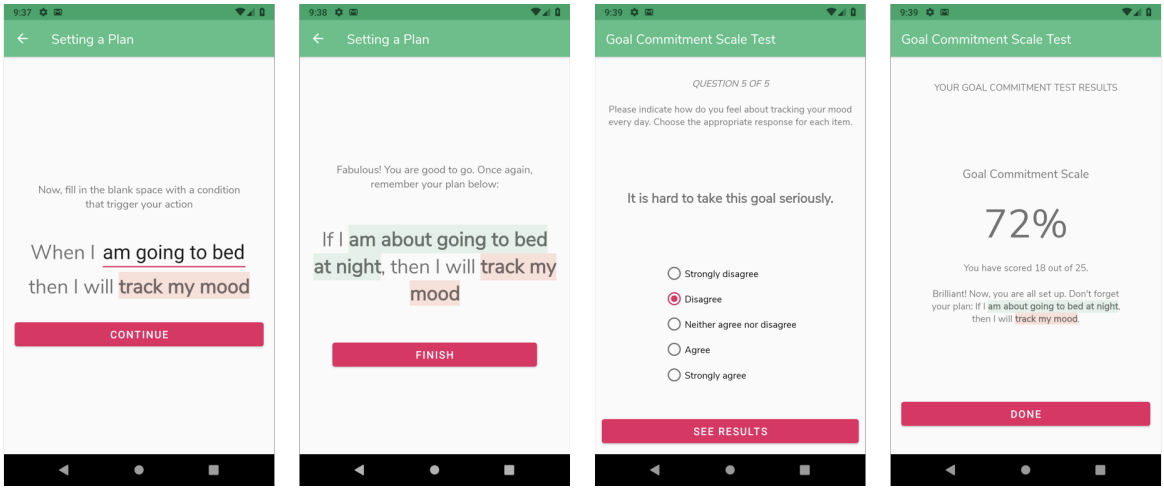


Figure 6.1: Setting an implementation intention and measuring goal commitment score.

For the SRBAI questionnaire, we used the same version (Gardner et al. 2012) to measure the automaticity. The SRBAI questionnaire consists of 4 items, asking that *"Behaviour X is something ..."*:

- "I do automatically",
- "I do without having to consciously remember",
- "I do without thinking", and
- "I start doing before I realise I'm doing it".

Each of the items has a 7-point Likert scale, and the score of SRBAI is from 4-28 points, where the higher points mean a higher level of automaticity. The SRBAI questionnaire was triggered automatically within the app.

We used participants' age and their goal commitment score to balance the group, measured using the HWK scale (Klein et al., 2001). It has been argued that goal commitment is one of the most prominent moderators of how behaviour could happen, and it can be used to measure the strength of intention.

Procedure

At the beginning of the study, participants were given a link to download Mood Journal app from Google Play Store. When opening the app for the first time, participants were asked to agree with the consent form to continue with their participation in this study. On the next step, participants were asked to fill demographic questions. Upon completion, participants were allocated in two groups based on their goal commitment score: active reinforcement and control group. The app then guided participants to form a plan (implementation intention) to report their mood every day. In addition, they were also asked to complete a rehearsal of their implementation intention. When participants rehearsed their implementation intentions at the beginning, they were asked to explicitly write down the condition of both "if" and "then" part of their implementation intentions. The rehearsal applied to both the intervention and control group. All participants were given the same implementation intention of reporting their mood at night, so they had the following plan: "If I am about going to bed, then I will track my mood". The timing was selected so participants did not associate the reinforcements with the mood report. After setting up the implementation intention and completing the HWK questionnaire, the app would close and run in the background.

For the context-aware reinforcement group, participants would receive a mental imagery task in their phone, asking them to vividly imagine the situation of their planned implementation intention and to act immediately when such a situation is encountered. The mental imagery task, acted as active reinforcement for their implementation intentions, was sent automatically via the Mood Journal app, every day between 12:00-17:00. The app would determine whether the moment is opportune within that time-frame. When the app detected an opportune moment, it would ask whether participants were available or not. Answering "yes" would open the instruction to perform a mental imagery task, whereas answering "no" would postpone the reinforcements to be sent again later. The task itself could not be dismissed unless participants decided to tap the button in the app. Daily mood reports were recorded, as well as the time when the reports were received. Every week, starting from day 7 of the study, an SRBAI questionnaire was opened automatically in the Mood Journal app. The SRBAI

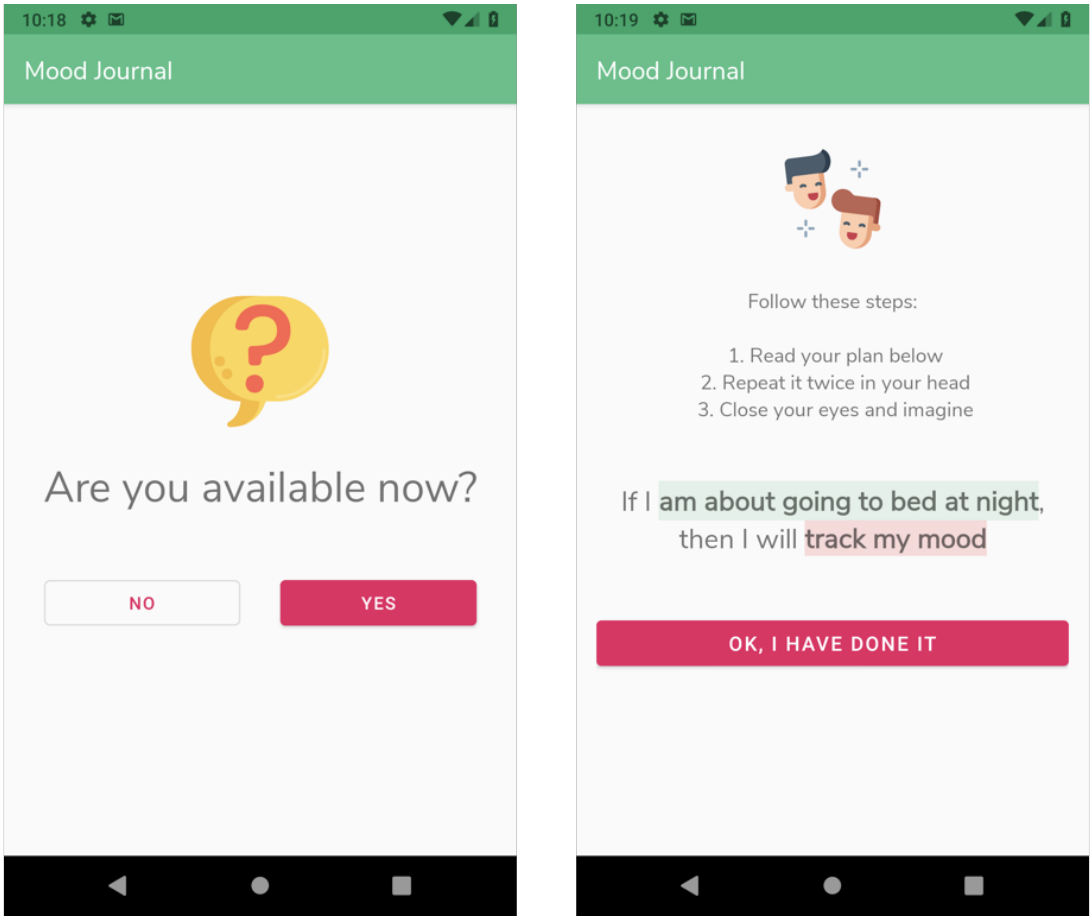


Figure 6.2: Reinforcements within Mood Journal app.

score was used to measure the automaticity in reporting their mood. At the end of the study, participants received a debrief of the study via email.

6.2.3 Findings

In our study, 58 participants signed up to the study and downloaded the Mood Journal app from Google Play Store. Of those, 57 people completed the screening questionnaire and formed the implementation intention of tracking their mood every day. Participants were divided into two different groups, balanced by their age and goal commitment score (GCS), measured using the HWK scale (Klein et al., 2001).

There were 38 participants in the context-aware reinforcement group with a mean age of 27.6 ($SD = 3.85$) and a mean goal commitment score of 18.40 ($SD = 1.66$). Meanwhile,

Table 6.1: Mean and SD of age and goal commitment score from both groups

Group	Age		GCS	
	Mean	SD	Mean	SD
context	27.60	3.85	18.40	1.66
control	28.60	4.38	19.10	1.93

there were 19 participants in the control group with a mean age of 28.6 ($SD = 4.38$) and a mean goal commitment score of 19.10 ($SD = 1.93$).

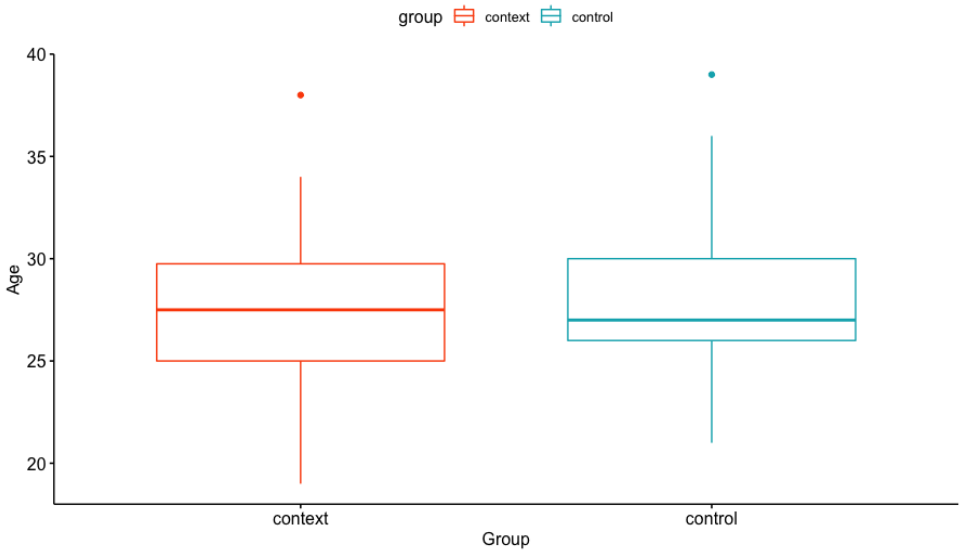
Levene's test was conducted to compare the equality of variance in term of of age and goal commitment score between the two groups. The test indicated there was no significance difference in term age ($F(1) = 0.018$, $p = 0.894$) and goal commitment score ($F(1) = 0.227$, $p = 0.636$).

Level of compliance

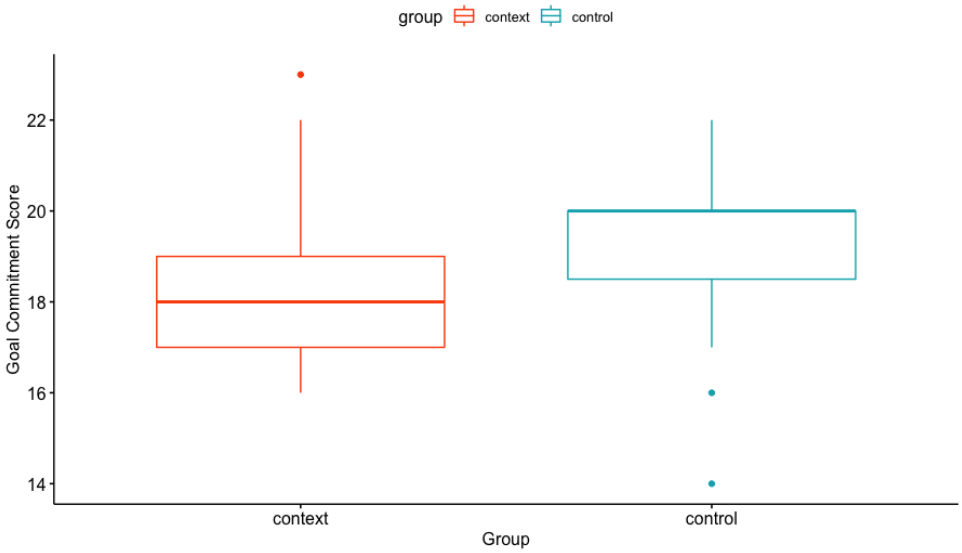
We used compliance to measure the consistency of participants in reporting their mood every day. For 4 weeks, 683 mood reports were received from both groups, with 506 reports sent by the context-aware group and 175 others from the control group. A Kruskal-Wallis test suggested there was a significant difference of compliance ($X^2(1) = 36.98$, $p<.001$) between context-aware reinforcement ($M = 18.10$, $SD = 4.83$) and control group ($M = 6.25$, $SD = 4.34$). Throughout the study, we found that participants in the context-aware group had a significantly higher compliance level (47.56%) compared to the control group (32.89%). When we looked at the change of compliance throughout the study, we noticed similar patterns with our previous studies.

Our data indicates that the compliance of reporting mood from both groups dropped after the first week of the study. However, the drop in compliance was slower on the context-aware group. On the first day of the study, 30 mood reports were received from participants in the context-aware group. Although the number of mood reports fluctuates throughout the study, there is a decreasing trend, especially towards the end of the study.

Meanwhile, we received 16 mood reports on the first day of the study on the control



(a) Age



(b) Goal commitment score

Figure 6.3: Age and goal commitment score between two groups

group. Similar to the context-aware group, the numbers are decreasing throughout the study. The findings indicate that the control group's drop in compliance is steeper compared to the context-aware group.

Despite the low compliance from both groups, we found 20 participants from the context-aware group who still sent their mood report after the study has ended (4 weeks). We also noticed that participants who regularly reported their mood on several consecutive days tend to have higher compliance level. A Spearman's correlation test suggests that the regularity of

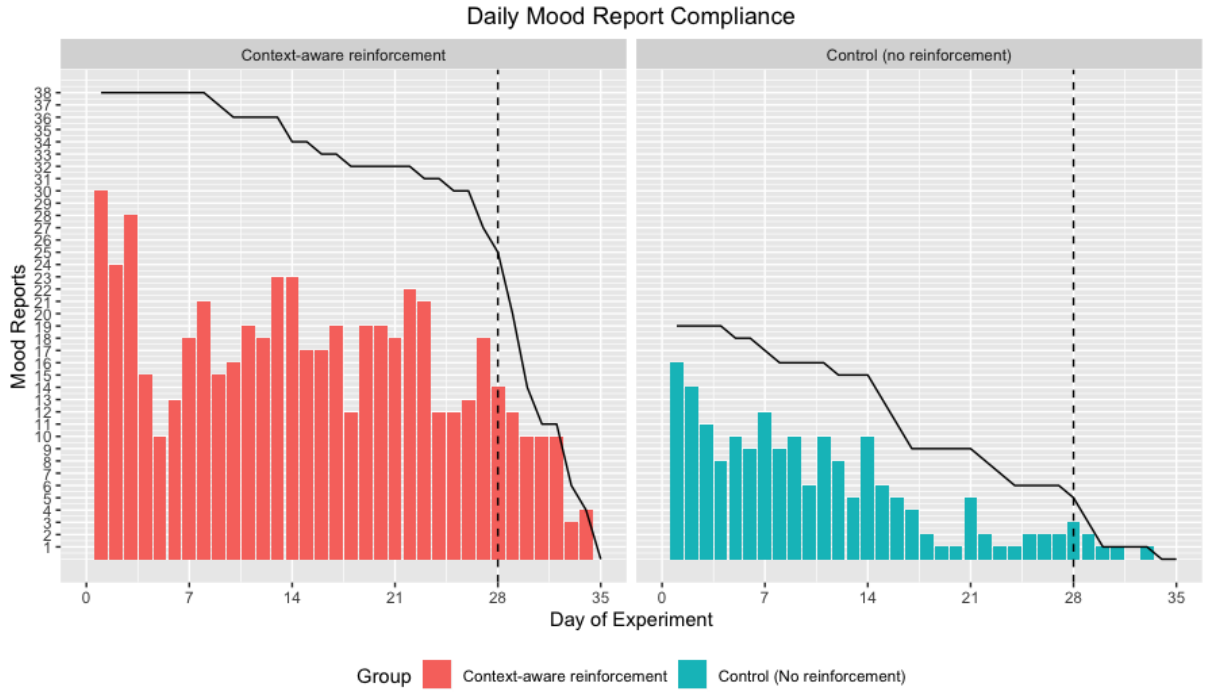


Figure 6.4: The changes of compliance between context-aware reinforcement and control group. The line indicates the number of participants who completed the mood report at least once in two consecutive weeks.

reporting the mood significantly correlated with the compliance level (r=.708, p<.001). As shown in Figure 6.5, participants with longer day streak had higher compliance than the ones with lower streak, meaning reporting their mood irregularly.

The overall mood reports were low; we also analysed the number of active participants throughout the study. Participants were considered active if they still had the Mood Journal app installed, and kept sending mood reports at least once in two consecutive weeks. Consistent with the results from our previous studies (see Chapter 4 & 5), we found that the number of participants who were still active was higher than the reports that we received. The data indicated that many participants would miss completing some reports (see the solid line in Figure 6.4). In line with the pattern of compliance, the number of active users from both groups dropped significantly after the study's first day. While the drop of number from participants in the control group was apparent, the drop of active participants in the context-aware group relatively slower. We found 20 participants in the context-aware group were still active, even beyond the sixth weeks.

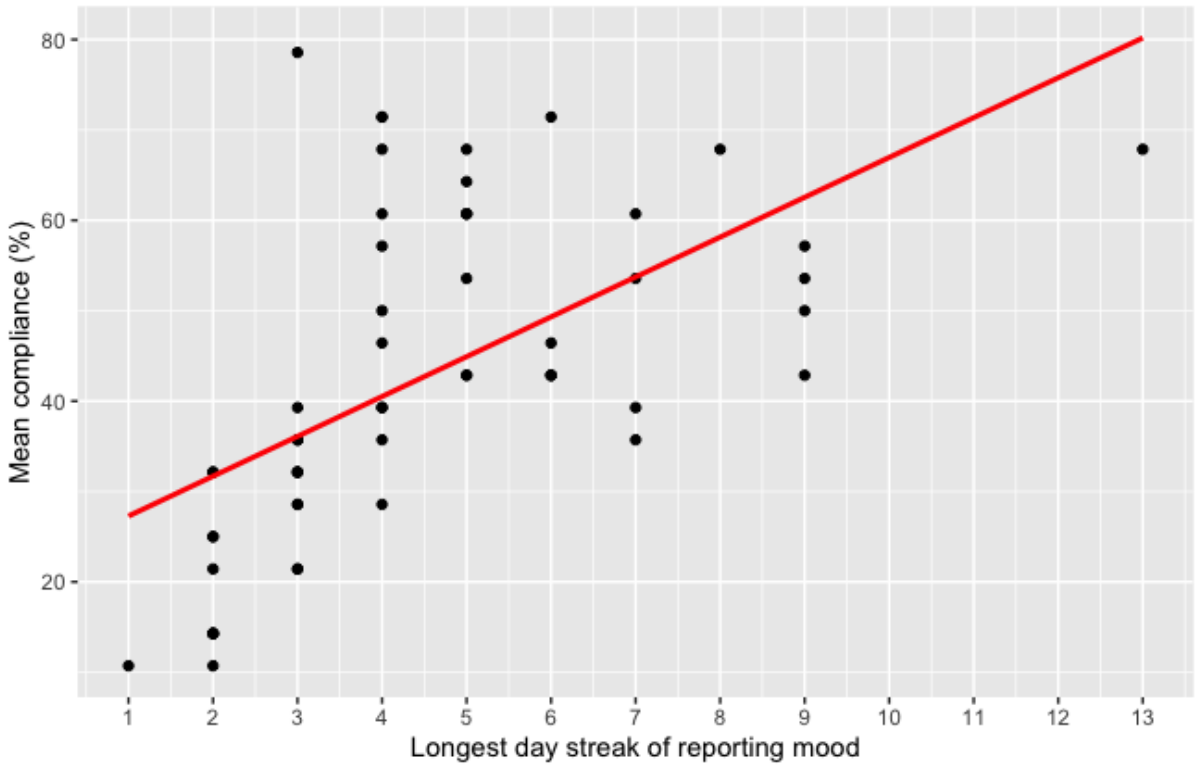


Figure 6.5: The correlation between longest day streak of reporting mood and the mean compliance

In addition to the compliance level and number of active participants, We were also interested to see how participants' commitment compared against the actual mood reports. At the beginning of the study, we measured their commitment using the HWK scale. Both groups had a similar score of their goal commitment with the mean score of 74% for the active reinforcement group and 76% for the control group, respectively. As shown in Figure 6.4, the low level of compliance suggests that the majority of participants failed to act upon their intention, as shown by the significant drop-off rate.

Time distribution of mood reports

Since the aim of using context-aware reinforcements was to strengthen implementation intentions and minimise the dependency towards the reinforcements itself, all reinforcements were sent hours in advance by predicting opportune moments. Participants received the reinforcements between 12:00-17:00 for the planned intention that has to be performed at night. Every

time participants report their mood; we logged the actual time of each report.

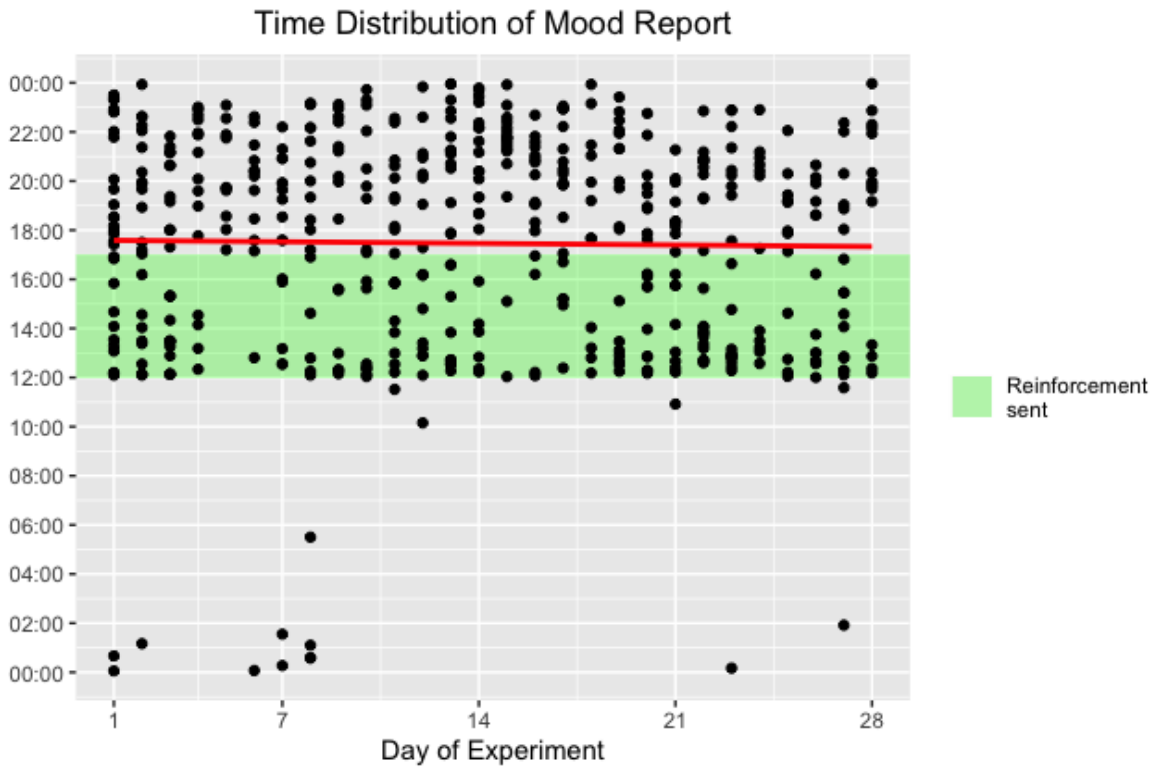


Figure 6.6: Time distribution of mood reports

When the mood reports were sent, the distribution of time was visualised to see whether participants followed their implementation intentions (to report their mood at night) or not. On the graph shown in Figure 6.6), only mood reports received from the active reinforcement group were included since only participants in this group received reinforcements. We found some interesting findings from this data.

From the 506 reports received within 28 days from the context-aware group, 186 of them (37%) were sent during the afternoon window of reinforcement (12:00-16:59). In comparison, 304 of them (60%) were sent in the evening and night (17:00-23:59). Furthermore, the other 16 reports (3%) were sent in the morning (00:00-11:59). Even though the majority of mood reports were sent in the evening and night according to the condition specified in their implementation intention, one-third of reports were still sent in the afternoon during the reinforcement window. As for the mood reports sent at early times in the morning, we cannot draw a firm conclusion since we did not follow up with qualitative questions.

Elapsed time between reinforcements and mood report

We measured the elapsed time between responding to reinforcements to sending the mood report. As participants have set the implementation intentions to report their mood later at night, we wanted to see whether they committed to their plan or sending the mood report immediately upon receiving the reinforcements. If they send the mood reports straight away, it means the reinforcements act as a reminder, and do not support the originally planned intention. As we discussed in the previous section where 37% of mood reports were sent in the window of reinforcements, we wanted to see the elapsed time in detail.

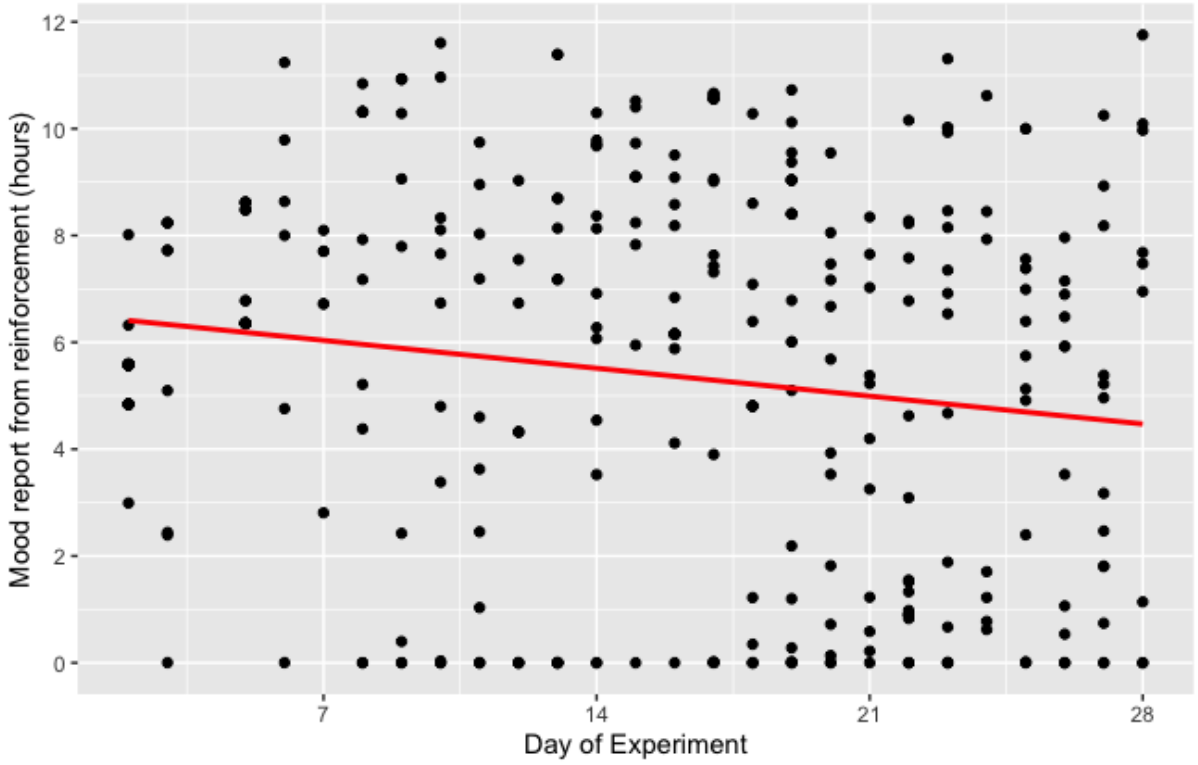


Figure 6.7: Elapsed time between receiving reinforcements and sending mood reports

From 427 reinforcements received, only 59 (13.82%) of them had elapsed time from reinforcements to mood report in less than 1 minute. The mean of elapsed time throughout the study was 5.31 hours. A Spearman's correlation test suggests that the days of experiment and the elapsed time to report the mood were negatively correlated (r=-.167, p<.001). Even though the mean of elapsed time was down from 6.17 hours on the 1st week of the experiment to 4.43 hours on the 4th week, we did not find a pattern in which elapsed time decreases

consistently. Majority of participants would report their mood at a different time every day, making the elapsed time changes throughout the study. This result indicates that even though 37% of mood reports were sent within the window of reinforcements, only 13.82% of them were sent in less than 1 minute after receiving the reinforcements. It suggests that the majority of the reinforcements were not treated as a reminder that prompts the planned action immediately. Instead, they helped the majority of participants to commit to their planned intention of reporting their mood later.

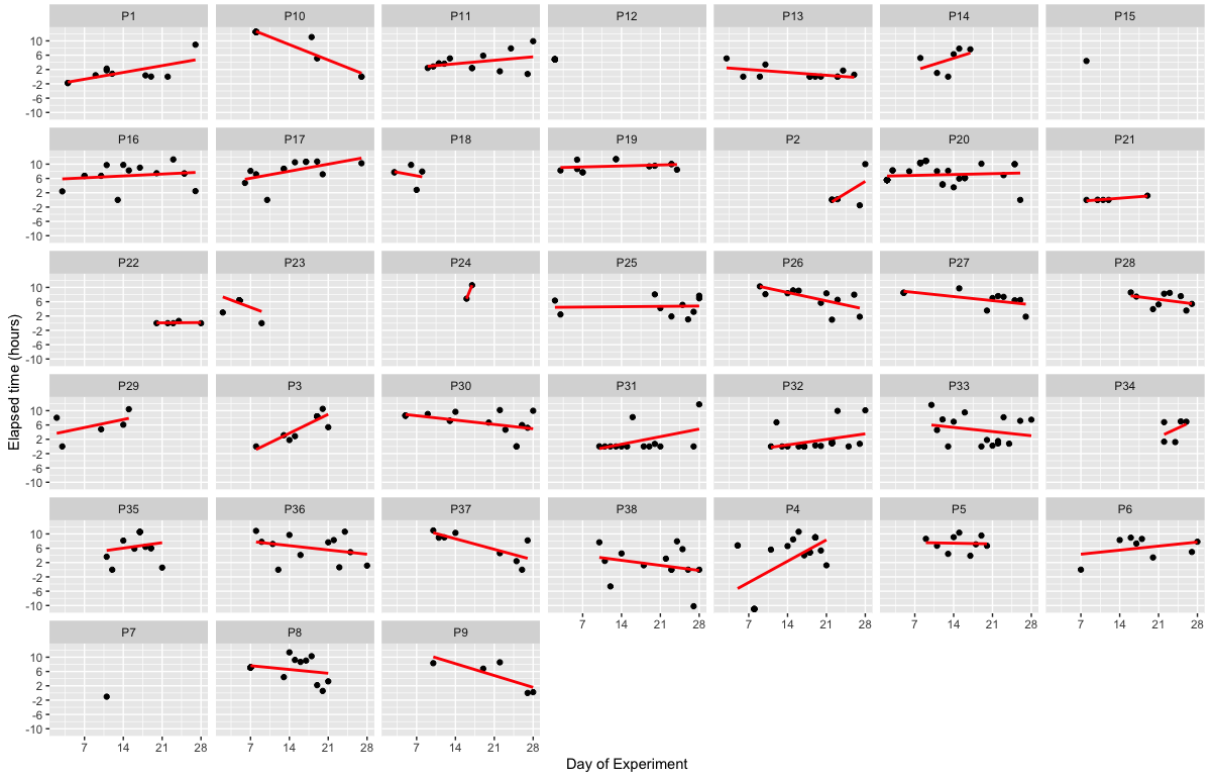


Figure 6.8: Individual's elapsed time between receiving reinforcements and sending mood reports

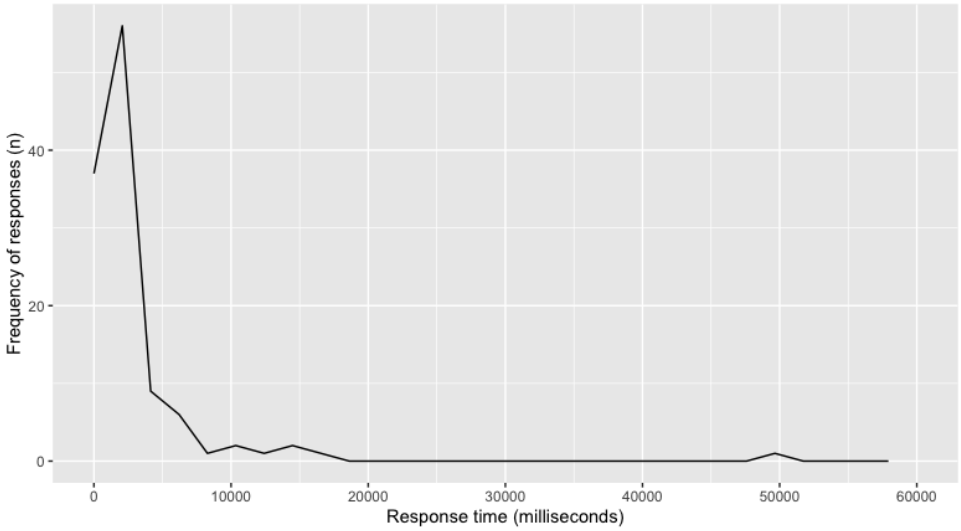
We also plot the data from participants in the intervention group to see if the negative correlation between days of experiment and elapsed time is consistent across different individuals. Among 38 participants in the intervention group, 16 of them had their elapsed time decreased throughout the study. Conversely, 19 had their elapsed time increased. While the 3 others only had 1 mood report, we cannot see the elapsed time. We also found that some individuals reported their mood even though they did not receive reinforcements. The reinforcements

were not always triggered every day, depending on whether the app was able to infer the context or not. Likewise, in some cases, individuals did not report their mood even though they received the reinforcements. The graph in Figure 6.8 only represents the data of individuals who reported their mood after receiving the reinforcements. Our analysis excluded the data with an elapsed time less than 0, which indicates some individuals reported their mood early in the morning, before receiving the reinforcement on that day. We also run a Kruskal-wallis test to compare the variances of elapsed time between each individual. The test suggests there was a significant difference in term of elapsed time ($X^2(37) = 162.76$, $p < .001$) between each individual in the intervention group. It indicates that participants chose their own time when reporting their mood and this was different everyday throughout the study. No participants that had consistent time in reporting their mood as the timing varied everyday.

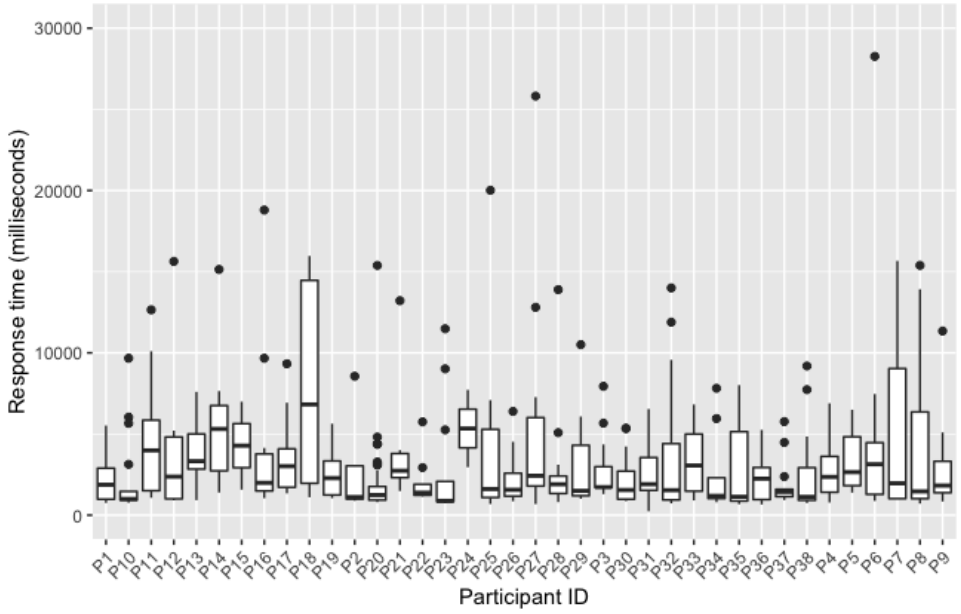
Response towards reinforcements

We measured response time towards reinforcements to determine whether participants acknowledged the mental imagery task or ignored the message when they received it. Based on the instruction's text length to perform the task, we set 10 seconds (10,000 milliseconds) time limit before participants dismissed the reinforcements by tapping the button.

The mean response time was 51,033 milliseconds or 51.03 seconds. At the same time, the median is 1,727 milliseconds or 1.73 seconds. These mean and median response time were lower than the response time from participants with active reinforcements in the previous study (see Chapter 5, Section 5.3.3). When we looked at the data, 599 responses (95%) were recorded within the 10 seconds limit. Individual data for response time also indicates that the majority of participants responded to the reinforcement within 10 seconds. A Kruskal-Wallis test suggests there was a significance difference in term of response time between each participant ($X^2(57) = 113.13$, $p < .001$). However, the quick response time in the context-aware reinforcements compared to active reinforcements has to lead to higher compliance of mood report and better compliance with the planned intention of reporting the mood later.



(a) 1 second scale within 1 minute time-frame (60,000 milliseconds)



(b) Individual response time from each participant (1 minute scale within 15 minutes)

Figure 6.9: Response time towards active reinforcements

Change of automaticity

SRBAI questionnaire was used to measure the strength of automaticity in reporting mood every day. The questionnaires were sent weekly, starting from the end of the first week until the end of the fourth week. We were interested in the changes of the SRBAI scores throughout the study. Figure 6.10 shows how the SRBAI scores from both groups change each week.

All participants (38) from the context-aware group completed the SRBAI questionnaire, whereas only 10 participants completed the questionnaire from the control group. Our findings indicate that the SRBAI score from the context-aware group increases from Week 1 to Week 2. Conversely, the SRBAI score from the control group decreases throughout the study. When we compare the mean difference of SRBAI score from the context-aware and control groups, we found there was no significance difference ($X^2(1) = 1.689$, $p = 0.194$). Unlike our previous findings which suggest the SRBAI score decreases in the intervention group, we found that when making reinforcements context-aware, it increases the automaticity.

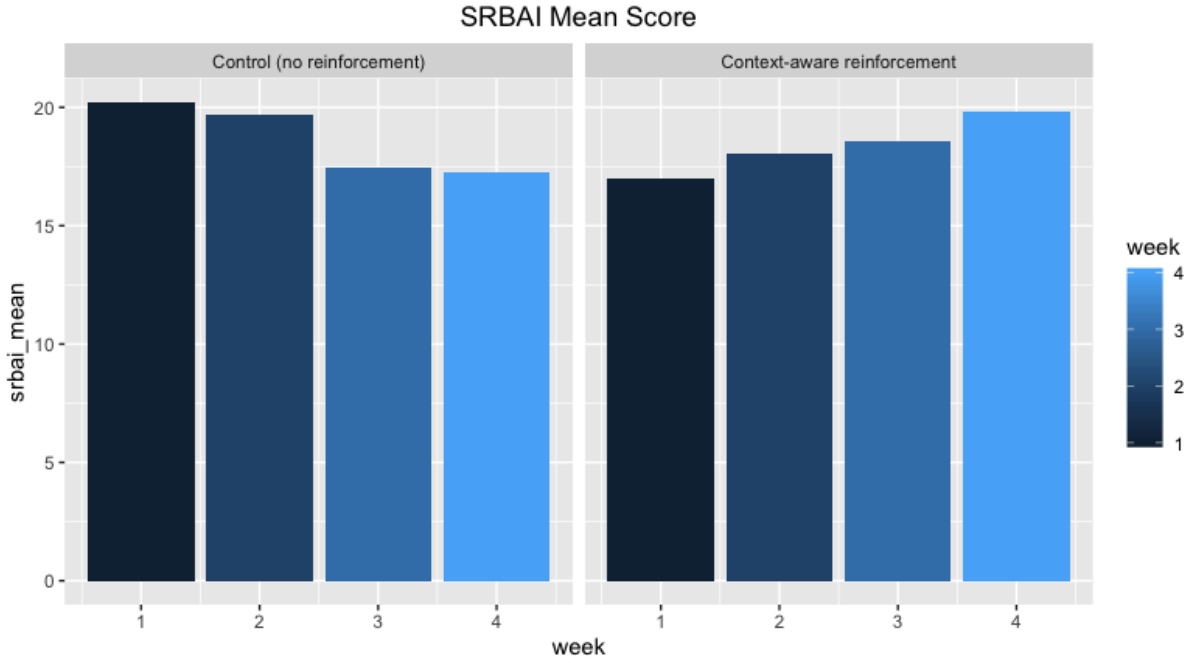


Figure 6.10: SRBAI score from both groups

6.2.4 Discussion

Our findings suggest that making active reinforcement context-aware increase its effect. The overall compliance level from participants in the context-aware group was significantly higher than the control group. When we compare the findings from our previous study (see Chapter 5), we found that the context-aware group's compliance level was also higher compared to active reinforcement group. In term of automaticity, it still difficult to conclude due to the small number size, even though we have attempted to automate the questionnaire.

In terms of individual level, making the reinforcement context-aware has also positively impacted individual compliance with more participants reported their mood on several consecutive days. Interestingly, 20 participants went beyond 28 days of study.

However, even though both groups had a similar goal commitment score, none had a compliance level above 50%. Even for the context-aware group that had a mean goal commitment score at 18.40 (73.60%), only had 47.56% compliance level, averaging 18.10 mood reports, compared with the control group who had a mean score of goal commitment at 19.10 (76.40%), with significantly lower compliance level at 32.89%, averaging only 6.25 mood reports. Nonetheless, we noticed different behaviour of the control group from our other studies where they had a higher compliance compared to the control group in our previous studies. This can be caused by the difference in term of rehearsal where participants were asked to explicitly write down their implementation intention at the beginning, right after forming it.

The discrepancy between goal commitment score and actual compliance support the findings from previous studies which suggest that intention cannot be relied on for long-term behaviour, since intention may change over time (Sutton, 1998). Instead of intention, the consistency of reporting the mood every day is the crucial factor that contributes towards compliance. We noticed that participants who did not miss sending mood reports on several consecutive days tend to have higher level of compliance and last longer than participants who sent their mood irregularly. Repetition is essential during the early development of new habits (Lally & Gardner, 2013; Lally et al., 2010). However, repetition alone is not enough to form new habits; also, the repetition should be performed in a stable context. When we look at the

actual mood reports, we found that majority of reports were sent according to the specified implementation intention (60% mood reports were sent at night), even though participants received reinforcements at the afternoon. This finding is encouraging since reinforcements were sent in advance to reinforce the implementation intention as prospective memory.

Another finding that we found interesting is the response time towards reinforcements itself. After making the reinforcements context-aware, we noticed that reinforcements were dismissed quicker. On average, the reinforcements were dismissed within 51 seconds, considerably quicker than our previous study (see Chapter 5), where the mean of response time was 11 minutes 7 seconds. Although the reinforcements were dismissed faster, it performed better, with higher compliance levels and a higher number of mood reports sent at the planned time.

6.2.5 Limitations

The main limitation of this study is the small number of sample size. Due to the study requirement that would ask participants to keep the Mood Journal app installed for at least 4 weeks without offering any financial incentives, many people refused to join. And for those who signed up to this study, many would miss sending their reports, especially participants in the control group.

Another limitation is the low number of SRBAI questionnaire that we received. Despite the SRBAI questionnaire being automatically triggered every week, we still did not receive a sufficient number of responses. What we could do better is to send a follow-up questionnaire that includes SRBAI.

In terms of experiment design, we used between-subject design with two different groups in this study: context-aware and control groups, where the difference of results was expected. Adding more intervention groups should give more insightful findings, such as adding active reinforcement and passive reinforcement groups as interventions.

In the experiment, we did not stop the reinforcements after the duration of the study. Instead, participants in the intervention group would still receive reinforcements beyond the 4 weeks of the experiment. Taking off the reinforcements would allow us to see if the reinforce-

ments have created dependency or not.

For the context-aware mechanism, the rules set for determining opportune moments were strict, resulting in fewer reinforcements being sent. While it can be useful to only send the reinforcements at an opportune moment, the rule could be made better by adapting to participants response.

6.3 Daily study report with context-aware reinforcements

6.3.1 Overview

While our previous studies focused on mood report as the target behaviour and found encouraging results for a prospective memory task, we wanted to investigate the impact of adding reinforcements of implementation intentions on different behaviour. Therefore, in this study, we selected a daily study report as the target behaviour. The task itself would require participants to write down their academic tasks on a daily basis. Since the target participants were students, we expected a higher level of compliance & automaticity score. In this study, I collaborated with Ben Chen, a MSc student at Human-Computer Interaction programme. My responsibility was to design and develop the app called as Task Journal. I was also responsible for the data analysis used in this thesis. Whereas Ben's responsibility was to design the experiment, and recruit the participants.

6.3.2 Method

We conducted a quantitative study and measured the impact of adding context-aware reinforcements on the daily study report's implementation intention. We also wanted to analyse the effect of changing the target behaviour to become more meaningful: daily study report. We propose these two hypotheses for this study:

- Participants who receive context-aware reinforcements will have higher compliance in

reporting their daily study compared to participants who do not receive reinforcements.

- Participants who receive context-aware reinforcements will have a higher level of automaticity in reporting their daily study compared to participants who do not receive reinforcements.

Participants

We recruited participants using email, social messaging apps, and private messages. The participants who completed the study were given £5 compensation. Participants were students in undergraduate and master level. Overall, 31 people signed up to the study, but only 19 of them completed the screening questionnaires, which we included in the final analysis. Of those, we put participants in two different groups: context-aware reinforcement and control group, balanced by their age and goal commitment score. To avoid including the same participants from our previous study, we sent the recruitment to different set of groups of people.

Design

The study used a between-subject design with two distinct groups:

- Context-aware reinforcement group. Participants in this group were asked to form an implementation intention of reporting their daily study activities at night before going to bed. In addition, we also sent them active reinforcements where participants had to perform a mental imagery task, imagining the actual situation in which their planned intention is supposed to be performed, and performed the intended plan.

- Control group. Participants in this group were asked to form the same implementation intention of reporting their daily study activities every day. No reinforcement was given to this group.

This study used two dependent variables to measure the difference between the two groups: compliance and automaticity. Compliance was measured by the consistency of reporting mood.

Whereas automaticity was measured using the Self-Report Behavioural Automaticity Index (SRBAI) questionnaire.

We also measured the response time from participants in the active reinforcement group to understand whether participants ignored the reinforcements (when they dismissed the instruction within 10 seconds) or acknowledged and performed the mental imagery task. In addition, we also measured the actual time in which participants reported their mood to understand whether participants committed to their plan of reporting their mood in the evening where they arrive at home or reported their mood immediately upon receiving the reinforcements.

Materials

We designed and developed an Android app called Task Journal. The app would allow participants to set an implementation intention of sending a daily report of their study and complete a journal of what they have studied everyday. In addition, similar to our previous studies, the app also helped participants complete screening questionnaires, goal commitment questionnaire (Klein et al., 2001), and SRBAI questionnaire (Gardner et al., 2012). In addition, for the context-aware group, the app would send daily reinforcements containing a mental imagery task to rehearse their implementation intention. When the reinforcement was sent, it could not be dismissed unless tapping the button. The app used context-aware sensing to predict the opportune moments for delivering the reinforcements. No sensitive data were collected, and all data were transmitted securely to our server.

Procedure

At the beginning of the study, participants were asked to fill a consent form. Upon completion, participants were given a link to download Task Journal app from the Google Play Store. However, since some of the participants were living in China and did not have access to Google Play Store, we provided them with a URL to download the app from our server. After finishing the demographic questionnaire, participants completed the HWK questionnaire to measure their goal commitment. Participants were then divided into two different groups

balanced by their age and goal commitment score: context-aware reinforcement and control group.

After completing the questionnaires, participants were required to form a plan (implementation intention) to report their study every day. Also, participants in both groups were guided to rehearse their implementation intention immediately after forming it. All participants were given the same implementation intentions of completing self-report diary of their study at night before going to bed, so they had the following plan: "If I am about going to bed at night, then I will complete self-report diary".

In the context-aware reinforcement group, participants received a mental imagery task in their phone, asking them to vividly imagine the situation of their planned implementation intention and to act immediately when such a situation is encountered. The mental imagery task, acted as reinforcement for their implementation intentions, was sent automatically via the Task Journal app, every day between 12:00-17:00. We predict the opportune for delivering the reinforcements during this time-frame. The task itself could not be dismissed unless participants decided to tap the button in the app. Daily mood reports were recorded, as well as the time when the reports were received. Every week (7^{th} and 14^{th}), an SRBAI questionnaire was opened automatically in the Mood Journal app. The SRBAI score was used to measure the automaticity in reporting their mood. At the end of the study, participants received a debrief of the study via email.

6.3.3 Findings

In our study, 31 participants signed up and downloaded the Mood Journal app. Of those, 19 people (61%) completed the screening questionnaire and formed the implementation intention of tracking their mood every day. Participants were divided into two different groups, balanced by their goal commitment score, measured using the HWK scale (Klein et al., 2001).

There were 9 participants in the active reinforcement group with a mean age of 22.9 ($SD = 2.76$) and a mean goal commitment score of 18 ($SD = 2.60$). Meanwhile, there were 10 participants in the control group with a mean age of 20.3 ($SD = 7.57$) and a mean

Table 6.2: Mean and SD of age and goal commitment score from both groups

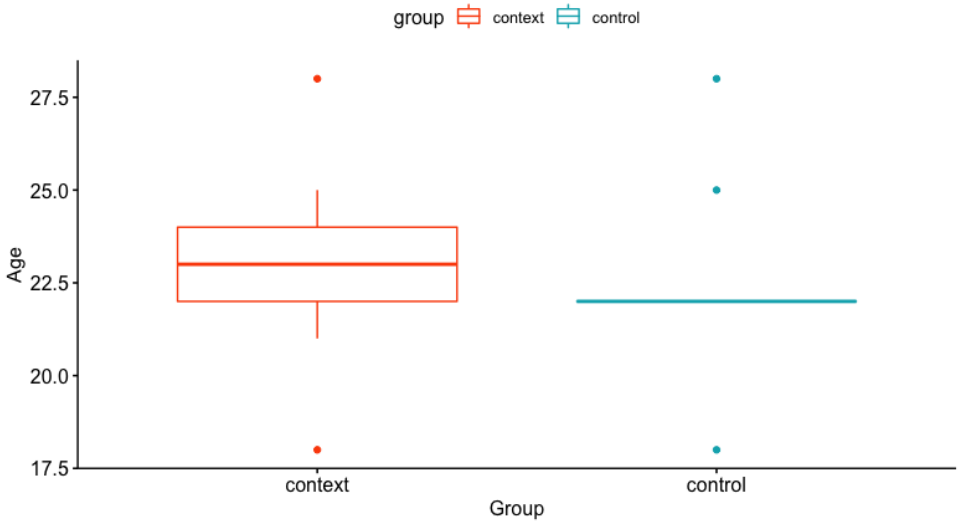
Group	Age		GCS	
	Mean	SD	Mean	SD
context	22.9	2.76	18.00	2.60
control	20.3	7.57	15.90	2.51

goal commitment score of 15.9 ($SD = 2.51$). Levene's test was conducted to compare the equality of variance in term of of age and goal commitment score of the two groups. The test suggested there was no significance difference in term age ($F(1) = 0.463$, $p = 0.505$) and goal commitment score ($F(1) = 0.125$, $p = 0.728$) between active reinforcement and control group. Further, we only included participants who formed and completed the first rehearsal of implementation intention in the analysis.

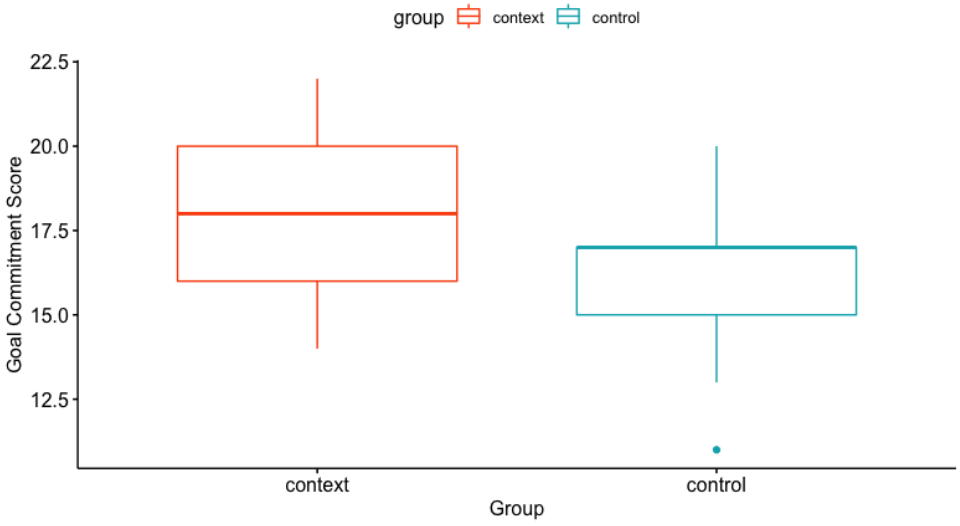
Level of compliance

We used compliance to measure the consistency of participants in completing their self-report study diary. Over the duration of 2 weeks, 79 daily study reports were received from participants in both groups. A Kruskal-Wallis test suggested there was a significance difference of compliance ($X^2(1) = 21.271$, $p<.001$) between context-aware reinforcement ($M = 5.21$, $SD = 1.12$) and control group ($M = 0.429$, $SD = 0.646$). Within 2 weeks of the study, participants in the context-aware group sent 73 daily study reports (57%) compared to 6 in the control group (4%). We noticed a significant difference in compliance compared to our previous studies, where we used mood reports and did not offer any financial incentives.

Our findings indicate that the context-aware group's compliance was relatively stable throughout the study, averaging 5.21 reports per day from 9 participants. In contrast, the control group's compliance was low and remained the same until the study ended, averaging only 0.646 reports per day from 10 participants. When we looked at the data beyond 14 days (the duration of the study), we still received 14 reports; all were coming from the context-aware group. Meanwhile, participants in the control group stopped sending reports on the 12nd day of the study.



(a) Age



(b) Goal commitment score

Figure 6.11: Age and goal commitment score between two groups

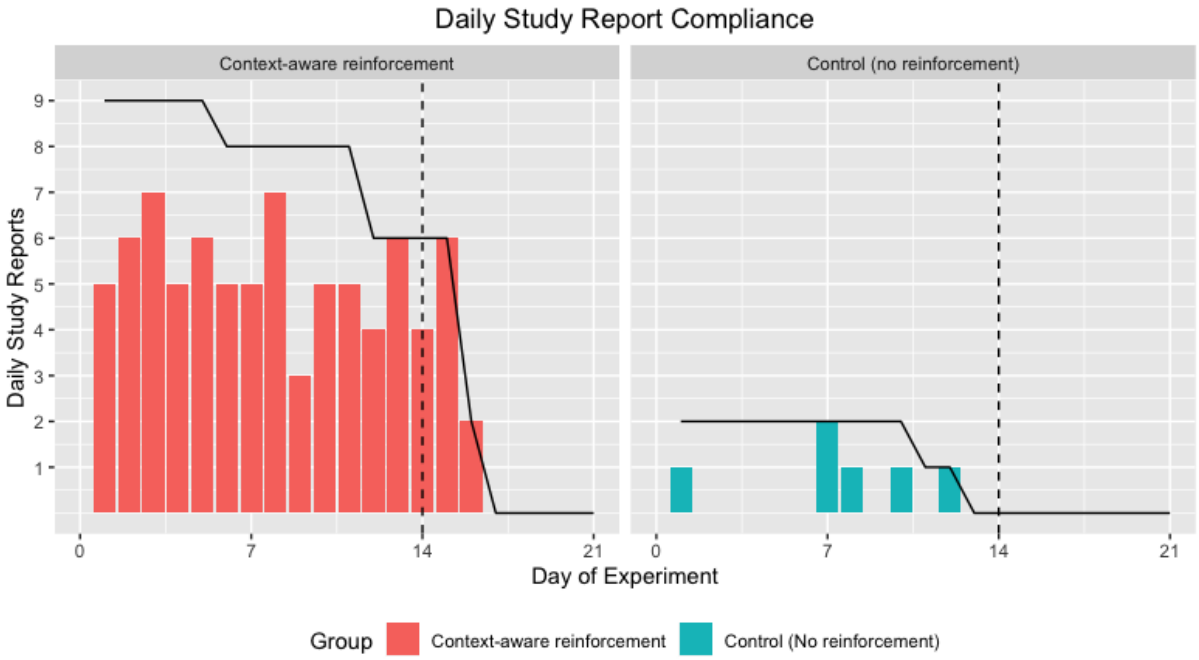


Figure 6.12: The changes of compliance between context-aware reinforcement and control group

We noticed an interesting pattern from participants in the control group where there was a period of no reports from the 2nd day until the 6th day, and suddenly, the reports were back again on the 7th day. We can assume, this is due to the SRBAI questionnaire that was triggered automatically after a week, which reminded participants to complete their task again. Nonetheless, overall compliance from participants in the control group remained low, with only 2 or fewer reports per day.

In addition to the number of actual reports, we were also interested to understand how many participants were active (who were still using the app) throughout the study. Participants were considered active if they still had the Task Journal app installed, and kept sending reports at least once in two consecutive weeks. Similar to the findings discussed in the previous chapter, our results indicated that the number of participants who were still active was higher than the reports since many would miss completing some reports (See the line in the Fig. 6.12). The number of active users from context-aware reinforcement decreased after one week.

We were also interested to see how participants' commitment compared against the actual reports of their daily study activity. At the beginning of the study, we measured their

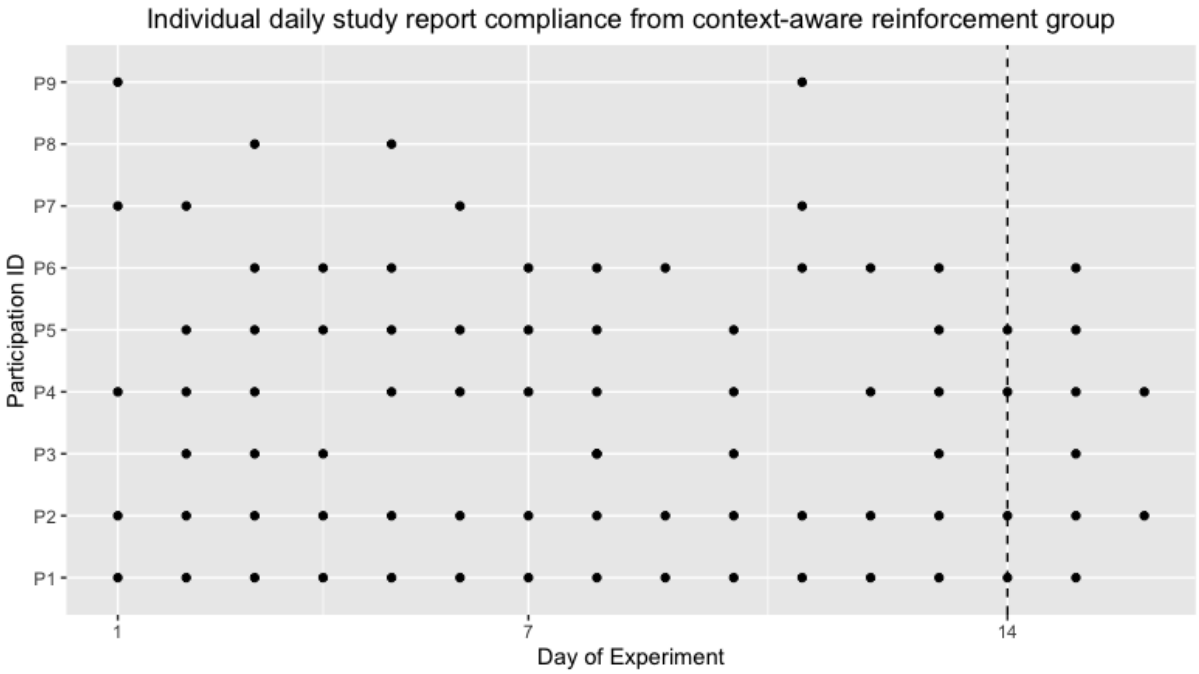


Figure 6.13: Individual compliance from context-aware reinforcement group

commitment using the HWK scale. Both groups had a slightly different score of their goal commitment with the mean score of 18 (72%) for the context-aware reinforcement group and 15.9 (64%) for the control group. The difference level of goal commitment score affects participants' compliance. Participants in the context-aware reinforcement group were averaging 5.21 report per day, compared to 0.646 from participants in the control group. However, with the goal commitment score of 72% from the context-aware group, their actual compliance is still lower (58%) than their commitment, even though we sent them mental imagery tasks daily. Meanwhile, the majority of participants in the control group failed to act upon their intention with only two of them who reported their daily study.

When we look at the data beyond 14 days of the study, we found 6 participants from the context-aware group were still active, and we still receive reports from them. In fact, all 6 were still sent their report on the 15^{th} day, and 2 more on the 16^{th} day, the last reports that we received. Participants in this study stopped sending report 2 days after the study ended, a significantly shorter time than our previous studies where participants were still sending their reports weeks after the study period has passed. Considering participants received monetary incentives after completing the study, it could be the main motivation, so they stopped sending

the reports after the study ended.

Time distribution of daily study reports

The time of report should indicate participants' the response towards reinforcements. We expected participants to comply with their implementation intention of reporting the daily study at night, even though they received reinforcement in the afternoon. And since the message in the reinforcement was clear that participants had to imagine the situation in which they should send their report, we did not want them to report their study immediately upon receiving the reinforcements. Participants received reinforcements containing the mental imagery task between 12:00-17:00 every day. Therefore, we were interested in comparing their actual report time against the time-frame when reinforcements were sent.

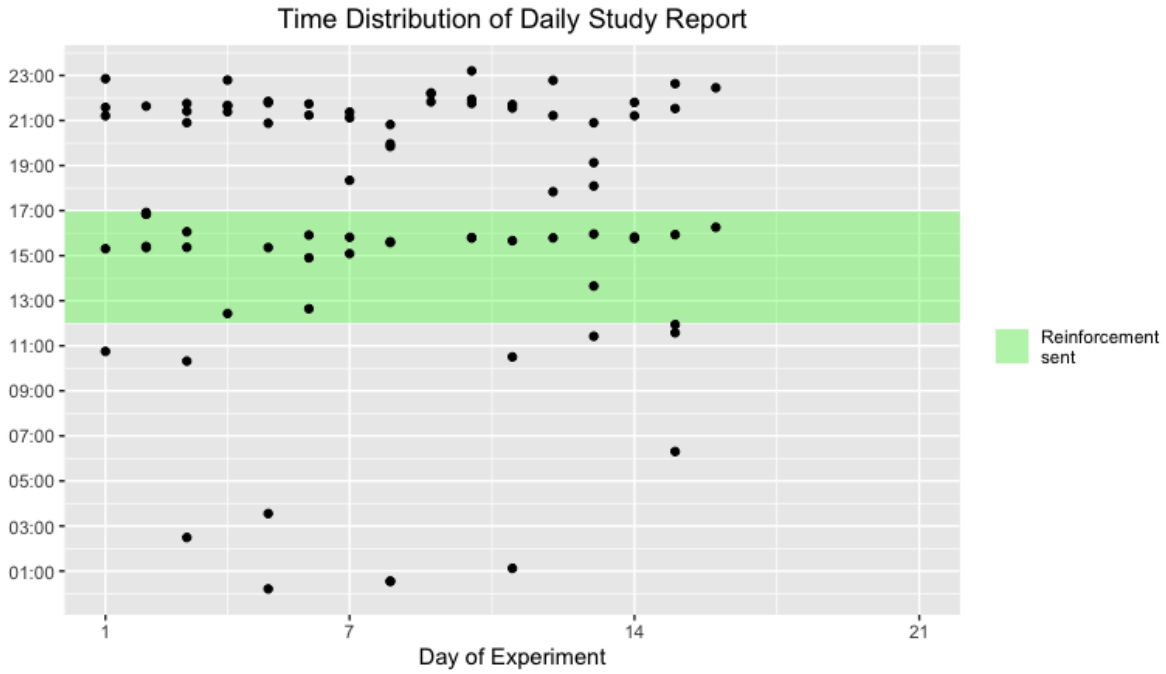


Figure 6.14: Time distribution of mood reports

We visualised the time distribution of the daily study reports that were sent daily. On the graph shown in Figure 6.14), only daily study reports received from the context-aware reinforcement group were included because only participants in this group received reinforcements.

We noticed that although the majority of reports were sent at night, consistent with the

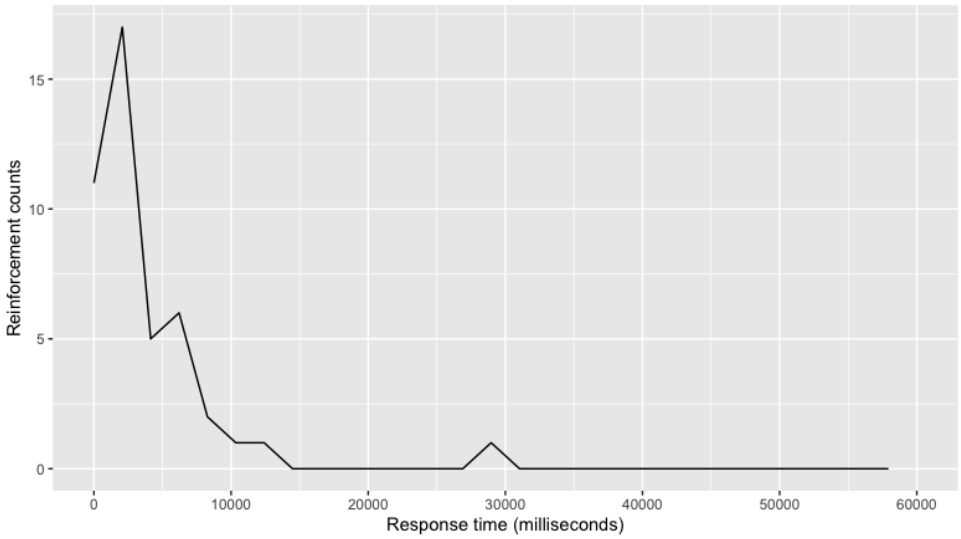
planned implementation intention, we found some reports that were sent around the same time of reinforcement. In addition, we also noticed some reports sent in the early morning.

From the 73 reports received from the active reinforcement group during the duration of the study, 38 (52.05%) were reported between 17:00-23:59 (evening until night), 6 (8.21%) were reported between 0:00-4:59 (midnight until early morning), 4 (5.48%) were reported between 5:00-11:59 (morning until midday), and 25 (34.25%) were reported between 12:00-16:59 (when the reinforcements were sent). These findings indicate that majority of participants performed their plan to report their study at night. However, we found the number of reports sent at around the time of reinforcements was still relatively high, accounted for more than one-third of total reports.

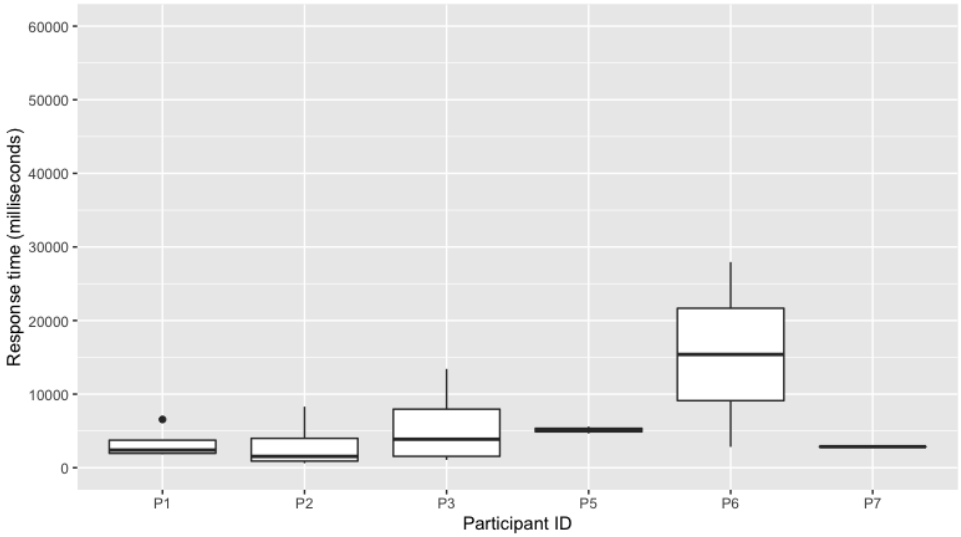
Response towards reinforcements

When participants received the reinforcements, they should read the instruction to perform the mental imagery task. We measured response time towards reinforcements to determine if participants acknowledged the mental imagery task or simply ignored the message when they received it. Based on the instruction's text length to perform the task, we set 10 seconds (10,000 milliseconds) time limit before participants dismissed the reinforcements by tapping the button. The data shows that majority of reinforcements were dismissed within 10 seconds with a mean response of 5,212 milliseconds (5.21 seconds) and median of 2,743 milliseconds (2.73 seconds). Considering that reinforcements were dismissed quickly, we wanted to know the individual response towards the reinforcements. Even though 9 participants were active from the context-aware group, only 6 responded to the reinforcements. The 3 others did not response to any reinforcements sent automatically to their mobile phone.

The individual response time graph shows that only 4 participants had a median response time less than 10 seconds. However, since the 2 others only responded three times, it is difficult to interpret the data from those two. We performed a Kruskal-Wallis test to find the difference in response. The test suggests there was no significance difference of response time between each participant ($X^2(5) = 9.852$, $p = 0.079$). Even though almost all of the



(a) 1 second scale within 1 minute timeframe (60,000 milliseconds)



(b) Individual response time from each participant (1 minute scale within 15 minutes)

Figure 6.15: Response time towards active reinforcements

reinforcements were dismissed within 10 seconds, the fact that the majority of actual reports were sent according to the initial implementation intentions is encouraging.

Change of automaticity

SRBAI was used to measure the strength of automaticity in reporting mood every day. We asked participants to complete the SRBAI questionnaire at the end of the first and second week of the study. We were interested in the changes of the automaticity score between the two groups.

Figure 6.16: SRBAI score from both groups

Over the duration of two weeks, only 5 participants responded to the SRBAI questionnaire that was sent automatically within the app, comprised of 4 from the context-aware reinforcement group, and 1 from the control group. The mean SRBAI score from the context-aware group decreased from 21.75 at the end of the first week to 20.31 at the end of the second week. Meanwhile, the SRBAI score from the control group remained the same on 17. However, considering the control group's score came from one person, it is difficult to conclude even though this person responded to the questionnaire on both occasions. Nevertheless, it is difficult to draw a conclusion in term of automaticity due to the small sample size.

6.3.4 Discussion

In this study, we modified the behaviour to become more meaningful: reporting the daily study activity. In addition, only students were recruited as participants, and we offer monetary incentives for taking part in this study.

The findings suggest that those changes contributed to the increase of compliance level, where 9 participants in the context-aware group reported 5.21 (57%) daily study activity on a daily basis. While the compliance level from participants int the context-aware group relatively stable throughout the study, changing the task into more meaningful behaviour and offering incentives did not necessarily increase compliance for participants in the control group, where their compliance remained low for the whole duration of the study, averaging only 0.646 reports (6.46%) per day from 10 participants. These findings indicate that making the behaviour more meaningful or offering incentives does not guarantee an increase in compliance. Consistent with our previous studies, consistency in reporting is the key. We found participants who reported their study in several consecutive days had better compliance than participants who sent their report irregularly.

In the individual level, we notice that 6 participants still sent their daily study after 14 days (total duration of the study), with the last reports were received 2 days after the study has ended. However compared to the previous study (see Chapter 4 & 5), the frequency of reports sent after the study ends is significantly lower. This might be due to the financial incentives that might be the key motivation, instead of the actual intention of keeping a diary of the study itself.

In terms of how the goal commitment score fared against compliance, we still notice similar patterns where the actual compliance level is lower than the goal commitment score, suggesting that most participants failed to act on their own goal. Again, this finding support existing argument from a previous study that suggests intention can change over time (Sutton, 1998). Instead of intention, the consistency of reporting the daily study is more important. We noticed that participants who repeatedly sending mood report on several consecutive days tend to last longer. It is in line with existing research which suggest that repetition is important during

early development of new habits (Lally & Gardner, 2013; Lally et al., 2010). While repetition is important, the task needs to be repeated consistently in a stable context, thus keeping the context the same is important. In our case, making sure that participants send their reports at night is key. When we look at the time of reports, we found that majority of them were sent at night, adhering to the specified implementation intention (52.05% daily study reports were sent at night). This is encouraging since even though participants received reinforcements in the afternoon, they still complied to their implementation intentions.

While the actual time of reports is important, we also analysed how participants responded to the reinforcements. We found that majority of reinforcements were dismissed within 10 seconds, more specifically, on average, the reinforcements were dismissed on 5.21 seconds. However, consistent with our previous study's finding, the quick dismissal of reinforcements does not imply that it does not work. In fact, the number of reports was much higher compared to the number of reinforcements itself. This is partly due to the rule of determining the opportune moments that could result in no reinforcements being sent for that particular day.

We cannot draw a firm conclusion for the automaticity due to the small size, with only 5 participants responded to the SRBAI questionnaire that was sent automatically within the Mood Journal app. Early indication suggests that the automaticity score from the context-aware group decreased after two weeks. However, because this data was only gathered from 4 participants, it is insufficient to be concluded.

6.3.5 Limitations

Similar to our previous studies, the main limitation of this study is the small sample size. Only 19 participants included in the final analysis, so there might be bias within the data. In addition, even though we have balanced the data based on age and goal commitment score, participants in the control group had a slightly lower goal commitment score.

We also offered financial incentives for participants who took part in this study. This incentive could give participants extra motivation to send their reports every day, which could

introduce bias. We received a few responses for the SRBAI questionnaire so that we could not run inferential statistics. What we could do better is to send a follow-up questionnaire that includes SRBAI.

In terms of experiment design, we used between-subject with two different groups in this study: context-aware and control groups, where the difference of results was expected. Adding more intervention groups should give more insightful findings, such as adding active reinforcement and passive reinforcement groups as interventions.

For the context-aware mechanism, similar to our previous study, the rules set for determining opportune moments were too strict, resulting in a fewer number of reinforcements being sent. Some participants contacted us about not receiving reinforcements on some particular days. The opportune moments could not be predicted, due to the strict role—making the rule adaptive based on participant response might enhance the results.

6.4 Summary

This chapter investigates the impact of making active reinforcements context-aware by predicting opportune moments for delivering the interventions. We conducted two separate studies using the same mechanism of context-aware reinforcements.

For the first study, we followed our existing method, used in previous studies (see Chapter 4 & 5), where we used mood report as the target behaviour, without offering financial incentives. We found that making the reinforcements context-aware has resulted in fewer reinforcements being sent but a higher impact in terms of compliance. Making reinforcement context-aware has also made participants dismiss the reinforcements faster, with the majority of reinforcements were dismissed within 10 seconds.

For the second study, we tested the framework on different target behaviour: daily study, and we gave participants financial incentives for taking part in this study. Those two additions improve the compliance level, but the effect lasted shorter. Whereas in the mood study,, some participants still reported their mood 9 weeks after the study ends. Participants in the daily

study report stopped sending reports 2 days after the study period has ended. This suggests that the incentives have become the motivation instead of original intention itself.

Overall, the findings from this chapter suggest that making reinforcements context-aware enhances its performance and has helped most participants comply with their implementation intentions. Although, we cannot conclude in term of automaticity due to small sample size.

CHAPTER 7

GENERAL DISCUSSION

This thesis aims to investigate the use reinforced implementation intentions to support habit formation. Implementation intentions are effective in helping to translate intentions into actions (Gollwitzer, 1999; Gollwitzer & Sheeran, 2006; Orbell et al., 1997). There is also an opportunity of using implementation intentions to support the development of new habits by strengthening the cue-response link (Holland et al., 2006). However, the potential benefits of implementation intentions remain underused, especially in mobile apps that support habit formation (Stawarz et al., 2015). The majority of habit formation apps does not support the critical element of habit: a strong association between the cue and the subsequent response that follows (Stawarz et al., 2015). Instead, the existing habit formation apps focus on self-tracking and reminders that could lead to dependency towards the reminder itself (Renfree et al., 2016).

Despite the potential use to support habit formation, implementation intentions are prone to forgetfulness, especially in the early process when a person just started to form a planned behaviour. This is because the accessibility of performing the planned behaviour will decrease over time (Tobias, 2009). Therefore, we proposed a reinforcement framework, targeting the underlying processes of implementation intentions. More specifically, we used reinforcement on implementation intentions of tracking mood on daily basis. We conducted several empirical studies investigating the impact of applying such a framework on mobile apps that help people to develop a habit of tracking their mood everyday. This chapter summarises the studies that

we have carried on, addresses the research questions, and discusses the findings. Practical and theoretical contributions are also discussed, followed by the limitations and recommendations for future research.

7.1 Summary of findings

We summarise the key findings of our studies by answering the research questions outlined at the beginning of this thesis:

Research Question 1: *How can implementation intentions be strengthened to support habit formation?*

To answer this question, we conducted literature review on habits and how implementation intentions can support formation of new habits. Based on the literature review, we identif

we proposed a framework of adding reinforcements on implementation intentions. We then tested the framework by running four empirical studies, investigating the impact of adding reinforcements on implementation intentions. In all studies that we have conducted, our findings indicate that reinforcements significantly improve the impact of implementation intentions in term of compliance but not necessarily in term of automaticity. Participants who received reinforcements were more consistent in reporting their mood every day than participants without any reinforcements.

Our study's findings support existing research that adding reminders of the plan (reinforcements) should enhance the effect of implementation intentions (Prestwich et al., 2009, 2010). We also found that participants with reinforcements were more committed to their plan by reporting their mood later in the evening/night, even though they received reinforcements in the afternoon. It is important that we did not create dependency towards the reinforcements, allowing participants to rely on the cue-response link instead of reinforcements.

In the study outlined in Chapter 4, we found that participants with reinforcements had better recollection of their implementation intention, compared to participants who did not

receive reinforcements. The majority of participants receiving reinforcements were able to recall the condition that triggers the mood report. On the other hand, none of the participants in the control group could recall the condition. This is due to the accessibility of performing a behaviour decreasing over time (Tobias, 2009). Since implementation intentions rely on the ability to remember the plan, the reinforcements were able to strengthen the *if* and *then* part of the plan, allowing participants to execute the planned task when the specified condition was encountered. As existing studies have suggested, implementation intentions help delegate the planned task's execution to the specified cue that would act as a trigger, and strengthening the cue-response link should help enhance the effect of implementation intentions (Prestwich et al., 2010).

We also found that intentions failed to predict the outcomes since the compliance from both groups were low, even though the reported intentions, measured using goal commitment score were more adequate. It is consistent with existing studies that suggest intentions may change over time, so intentions alone cannot be relied on for predicting behaviour activation (Sniehotta, Scholz, & Schwarzer, 2005). While the decrease of compliance of reporting mood was expected, adding reinforcements has slowed down the decay.

Research Question 2: *How does the impact of using passive reinforcement on implementation intention?*

To answer this question, we investigated passive reinforcements on implementation intentions of reporting mood every day. We measured the impact of reinforcements on two important elements related to forming new habits: compliance and automaticity. We use the term "passive reinforcements" since the reinforcements were sent quietly using Android push notification, containing the following message: *"Remember this condition: If I arrive at home, then I will report my mood"*.

Our findings suggests that participants with reinforcements had significantly higher compliance of reporting their mood every day than the control group, where they only formed implementation intentions without receiving any reinforcements. The passive reinforcements

also strengthen the cue-response link, as indicated by several participants' ability to recall the condition that would trigger them to report their mood. Whereas in the control group, none of the participants could remember their situation to report the mood. These findings are consistent with previous studies that argue, reminding the planned intentions should strengthen the underlying processes of implementation intentions, mainly, the mental link between the cue and its associated response (Prestwich & Kellar, 2014). Considering that the mood report used in both studies was an prospective memory task that was not part of the participants' existing routines, the results were promising. Also, we still received more reports from the passive reinforcement group participants within 3 weeks after the study has ended.

While we found a significant effect of passive reinforcements in terms of compliance, we could not conclude the automaticity due to the small number of responses that we received for the SRBAI questionnaire that we used to measure automaticity score.

Research Question 3: *How can we use active reinforcement to improve the impact of reinforcement on implementation intention?*

We conducted a follow-up study to answer this question. Existing works have suggested that using mental imagery should improve implementation intentions' effectiveness, even for mundane goal (Knäuper et al., 2011, 2009). Since our previous studies' goal was to report the mood every day, we could consider it as mundane, and we wanted to investigate the impact of using mental imagery as part of reinforcements. For participants in the intervention group, we sent reinforcements that would ask them to imagine the situation vividly and vividly imagined reporting their mood when such a situation is encountered. Since mental imagery requires participants to perform a particular task, we called it "active reinforcements".

We measured the impact of using active reinforcements by comparing the compliance and automaticity from two different groups: active reinforcement and control group. The findings support previous studies (Knäuper et al., 2011, 2009), suggesting that adding mental imagery on implementation intentions leads to higher goal achievement. Our findings have shown that adding mental imagery as part of the reinforcements has significantly improved mood report

compliance compared to only forming implementation intentions without any reinforcements. Even though the active reinforcement group's compliance was significantly higher than the control group, the overall level of compliance from both groups remained low throughout the study.

When we compare the overall compliance from the intervention group between active vs passive reinforcements, the findings suggest that making the reinforcements active by adding mental imagery does not necessarily improve the performance of reinforcement itself. We found that the passive reinforcements used in our previous studies lead to better compliance. However, we cannot conclude comparing the two reinforcements since both studies were conducted separately with different sample size. Even though, in term of methods, both studies were similar.

Concerning automaticity, we encountered similar problems with our previous studies where we did not get enough responses to the SRBAI questionnaire, even after we send the questionnaire automatically every week until the end of 4th week.. We only managed to get responses from 6 different participants (5 from the active reinforcement, and 1 from the control group). Of those, the only participant from the control group responded to the SRBAI questionnaire every week. With the small number of sample, we cannot conclude the results in term of automaticity. However, we noticed that the active reinforcement group's mean score decreased from the first week until the third week of the study and slightly increased again in the fourth week. One thing that is consistent from the previous studies; some participants were still sending their mood reports after the period of study ended. We still receive reports from 3 different participants, all coming from the active reinforcement group. Also, we noticed that participants who were consistent in reporting their mood on several consecutive days tend to last longer. This supports existing research that performing the intended behaviour should increase accessibility, making it easier to remember performing the same behaviour again in the future (Tobias, 2009).

Research Question 4: *How can we utilise context to deliver active reinforcement of im-*

plementation intention at opportune moments?

Delivering active reinforcements means that the receiver should perform the mental imagery task immediately upon receiving the reinforcements. Otherwise, the active reinforcements will obstruct the ongoing task and create adverse effects. Therefore, we applied a context-aware mechanism, allowing the active reinforcement to be sent at opportune moments. We called it as context-aware reinforcement.

We utilised smartphone's sensor data to determine the opportune moments, mainly using the following context: time, location, and activity. We set a specific rule that would only send the reinforcements if all the requirements of the rule were satisfied. Whenever the app senses opportune moments, it would trigger a question, asking whether participants are available or not. If participants responded "Yes", then the reinforcements, containing the mental imagery task, will be shown. Otherwise, the app would try again later.

We argue that making reinforcement context-aware should improve the effect, mainly, allowing participants to acknowledge the mental imagery task at opportune moments and as a result, leads to better performance of their implementation intentions.

We conducted two separate studies investigating the use of context-aware reinforcements on two different target behaviour: mood report and daily study report. Both studies' hypotheses were the same: participants with context-aware reinforcements would have better compliance and automaticity compared to participants without reinforcements. Our findings indicate that making reinforcements context-aware leads to significantly higher compliance than without any reinforcements. The average response time towards the reinforcements also decreased compared to our previous study discussed in Chapter 5. However, even though the response time has decreased, the number of mood reports that were sent at night increased, suggesting that participants had better acknowledgement towards the mental imagery task, sent as part of the reinforcements.

Meanwhile, in the study discussed in Section 6.3, we found that changing the behaviour from mood report to daily study and offering financial incentives have increased the task's overall compliance. However, those two changes did not affect the control group's perfor-

mance, where the compliance level remained low, even when we offered financial incentives. It suggests that intrinsic motivation still has stronger effect than the extrinsic ones.

However, similar to our previous studies, we did not manage to get sufficient response to the SRBAI questionnaire. As a result, we could not run any inferential statistics for the automaticity score. To our surprise, when we compare the results between active, passive, and context-aware reinforcements, we found that passive reinforcements has lead to the highest compliance level. Interestingly, in both active and context-aware reinforcements, combining mental imagery task and context-aware mechanism to deliver the reinforcements at opportune moments did not lead to the increase of implementation intentions performance. Our hypothesis was due to the nature of both active and context-aware reinforcements that require immediate attention, which could lead to interruptions and may increase the likelihood of participants to dismiss the reinforcements immediately.

7.2 Design guidelines for habit formation apps

Based on our findings summarised above, we outline several design recommendations that can be applied on the development of habit formation apps in the future.

Facilitate cue-response association

At the beginning, habit formation apps should help their users to associate the intended habit with their existing routines. A habit can develop when a behaviour is consistently repeated in the stable contexts (Lally et al., 2010). Existing routines work better as a cue compared to location or time-based reminder because they have been performed consistently in similar situations.

The association between the existing routines as a cue and the intended habit as a response should be made explicit when users start using the app. More specifically, implementation intentions should be used to create the association, following the structure: "If (cue) happens, then I will do (response)". By forming an implementation intention, users can start develop

a mental link between the cue and its response, making them easier to remember and to act when the cue is encountered (Gollwitzer, 1999). In addition, habit formation apps should help their users to rehearse their newly formed implementation intention, for example by asking them to slowly repeat their plan in their head. The rehearsal helps to represent the plan in their memory.

Reinforce the implementation intentions

Instead of using reminders prompting users to act on their intended habit immediately, habit formation apps should target the cue-response association through reinforcement. The reinforcement should specifically remind users of their implementation intention, for example: "Remember if (cue) happens, then do (response)". Reinforcements help users to recall their implementation intentions. Targeting the planned intentions will help users to have higher accessibility of the routines specified as the cue and its associated behavioural response. When the cue-response association is maintained over a period of time, automaticity will develop and eventually the response becomes habitual.

Reinforcements of implementation intentions should not only be delivered once at the beginning of use. Instead, the reinforcements should be sent everyday, allowing the planned intentions to be rehearsed consistently and heightening the chance of success. However, developers should be careful for not delivering the reinforcements close to when the planned intentions will be performed to minimise dependency.

Deliver reinforcements in advance

Since the reinforcements aim to target the implementation intentions, they should be delivered in advance to avoid dependency towards the reinforcements to perform the planned intentions. One of the most common mistakes of existing habit formation apps is delivering reminders prompting their users to perform the intended action immediately upon receiving the reminders. As a result, users develop a dependency towards the reminders and associate the reminders as a trigger to perform the intended habit (Renfree et al., 2016).

By delivering the reinforcements in advance, for example several hours before the intended action happens, habit formation apps could reduce the risk of dependency. In addition, when reinforcements are received, users can remember their planned implementation intentions instead, allowing them to rehearse the cue-response link that will turn into a habit. As Tobias (2009) has suggested, the accessibility of remembering certain task will decrease over time. But when implementation intention task is already represented in the memory, it becomes easier to access when the cue is encountered and the planned subsequent response will follow automatically (Gollwitzer, 1999).

Use mental imagery at opportune moments

Using mental imagery could enhance the performance of implementation intentions (Knäuper et al., 2011, 2009). However, when reinforcements consisting of mental imagery task are sent via notifications at inopportune moments, they tend to be ignored. Notifications can be disruptive when users receive them in the middle of finishing a task (Mehrotra, Pejovic, Vermeulen, Hendley, & Musolesi, 2016).

To minimise disruption, habit formation apps can sense users' availability using context-aware mechanism by gathering smartphone's sensors data. Based on our study, certain data such as location, time, movement, and app's usage can be useful to determine whether the reinforcements should be sent or not. If users' are not available, then the app can delay to deliver the reinforcements at later time. Our findings suggest that making reinforcements with mental imagery context-aware leads to better compliance and retention over a longer period of time, compared to only using mental imagery task.

7.3 Theoretical contributions

The first contribution is addressing the theoretical gaps in the area of habit formation. From our literature review, we found that implementation intentions have the potential to support performance memory task and make it into habit. On the other hand, the use of implemen-

tation intentions remains underused in the majority of habit formation apps. In addition, we identified that implementation intentions could become prone to forgetfulness since the accessibility to perform the planned intention decreases over time (Tobias, 2009). To address the gap, we proposed a reinforcement framework strengthening the two underlying processes of implementation intentions. Firstly, strengthening the mental link between the specified condition and its associated response. Furthermore, secondly, heightening the accessibility of the cue, allowing the planned intention to be performed immediately when the specified cue is encountered.

This thesis also gives contribution in term of addressing the weakness of implementation intentions. To our knowledge, existing works on focus on the positive impact of implementation intentions on different type behaviours (Chapman, Armitage, & Norman, 2009; Elliott & Armitage, 2006; Prestwich et al., 2009; Sheeran et al., 2005; Webb & Sheeran, 2007). Since implementation intentions rely on the ability to remember performing the planned intention on the future, there is a risk of forgetfulness due to the decrease of accessibility in performing the behaviour (Tobias, 2009). Our framework minimises this risk through a constant rehearsal of the planned intention.

In terms of application, to our knowledge, we are the first to investigate the use of mental imagery tasks daily to enhance the effect of implementation intentions. A study examined the effect of mental imagery on implementation intentions (Knäuper et al., 2009). However, the study only sent the reminder of performing mental imagery once a week, and the setting is limited in a very controlled environment. Also, majority of existing studies focus on health-related behaviour such as fruit intake (Armitage, 2007; Chapman et al., 2009; Knäuper et al., 2009), weight loss (Luszczynska, Sobczyk, & Abraham, 2007; Verplanken & Faes, 1999), healthy diet (Adriaanse, Vinkers, et al., 2011; Carrero, Vilà, & Redondo, 2019), brisk walking (Prestwich et al., 2009, 2010), exercising (Andersson & Moss, 2011), and physical activity (Hall et al., 2012). On the other hand, our work investigates an prospective memory task: mood report, allowing us to reduce bias where the task was not part of our participants existing routines.

7.4 Limitations and lesson learned

In this section, we outline several limitations from the studies that we have conducted.

Our study's main limitation is the design of the experiment, where we only use a control group and experiment group in all of our studies. This is mainly due to the small number of participants that we could get so that we could not have multiple experiment groups on each study. For instance, we could add active and context-aware reinforcement to compare with passive reinforcement. Instead, we compare the performance of experiment groups against the control group. The control group's condition remained the same in all our studies: only forming implementation intentions without any reinforcements. Another limitation in terms of the experiment's design is we did not take off reinforcements beyond the 4 weeks duration of the study, which would allow us to see whether the participants would depend on the reinforcements to report their mood. Instead, we only measure the change of compliance and elapsed time between receiving the reinforcements and sending the mood report.

The small number of the sample was also prominent in terms of responses towards the SRBAI questionnaire, making us unable to conclude or run inferential statistics on the automaticity score. Even though we have made the questionnaire automatically opened within the app every week, only a few participants responded to the questionnaire. We could have followed up this issue by conducting user interviews or re-delivery of the questionnaire if it was not opened on the first try. Also, there might be better options to measure automaticity and not solely relied on the SRBAI questionnaire.

Another limitation is the way we balance our groups. We only balanced the groups based on participants' age and goal commitment score for all our studies. Adding new criteria, such as age would give better balance towards the data. We assumed that using age and goal commitment score was sufficient to get balanced groups, where we tested the difference of variance using Levene's test. In our study, there were no significant differences between the intervention and the control group.

In term of the targeted behaviour, we used daily mood report as a prospective memory task that was not part of our participants' existing routines. The decision was made to compare the

impact of adding reinforcements on the same behaviour, and minimise bias if the behaviour is commonly practised routines such as exercising. However, we realised that not all participants had sufficient motivation to carry with the task, as indicated by the low compliance level, especially within the control group. Allowing participants to set their own target behaviour may improve the strength of intention, and as a result, improving the compliance.

We also measured participants' motivation by using the HWK questionnaire (Klein et al., 2001) that assessed the goal commitment score through self-report. Even though the questionnaire has been tested in terms of validity and reliability, we could have used additional measures to determine participants' motivation, such as interviewing at the beginning of the study. However, such a process would be time-consuming and not feasible within our research's time-frame, since we had 19-58 participants for each study. Also, conducting such an interview could yield different results than the reported motivation measured using the HWK questionnaire.

In term of our study related to active reinforcements, we sent the instruction to perform the mental imagery task directly to their phones, without checking their availability. Even though we have conducted a follow-up study that measures the impact of making such reinforcements context-aware, we could have made the active reinforcements more salient without being obtrusive, for instance, sending it via push notification. We noticed from the data that on average, it took 11 minutes to dismiss the active reinforcements.

Another limitation from our work is the study's short-term duration, where we conducted the study for 4 weeks and 2 weeks. A long-term study should be necessary to allow for the behaviour to develop into a habit. Although our duration of the study was short, we found that some participants were still committed to their planned intention to report their mood beyond the 4 weeks. We found that one participant still reported their mood 9 weeks after the study has ended in our context-aware reinforcements.

Furthermore, finally, we have not conducted an in-depth interview at the end of the study to understand some interesting findings. For example, we found that some mood reports were sent in the morning, even though they have set an implementation intention to report their

mood in the evening/night. We could have followed such findings with the interview. Our decision to not doing a follow-up interview was due to the feasibility issue. Since we have deleted participants' personal information such as an email from the data, we could not track back the interview results and match it with the mood report data. Nonetheless, a follow-up interview would be useful to understand participants perception towards their planned intention and how the reinforcements have helped them. More generally, we could have also understood participants' perception toward such an app that utilises implementation intention to support their goal. Moreover, we could have investigated how they would use the reinforcements of implementation intentions that would allow use to design better reinforcements.

7.5 Future research

Our works have investigated the impact of adding reinforcements on implementation intentions to support the formation of new habits. We have raised several interesting questions that create opportunities for future research in this area, particularly use of smartphone apps to support habit formation.

Targeting user-generated behaviour. Our studies are limited in term of the behaviour being targeted. Whereas for common habit formation apps, they would allow their users to choose the appropriate goal of the behaviour they want to make habitual. We believe that this should lead to better compliance since choosing the goal that they care will give them more intrinsic motivation to perform such a goal. Also, allowing for user-generated behaviour would allow the researchers to measure the impact of our framework in the real world settings

Long-term study. Since the goal of using reinforcements to support implementation intentions is to translate the behaviour from Type 2 (conscious, thoughtful, slow) into Type 1 (unconscious, automatic, fast) through consistent repetition, conducting a long-term study should allow measuring such impact. Existing research from Lally et al. (2010) has suggested

that it could take 66 days to reach an asymptote of automaticity as an indication that the behaviour has become automatic. Therefore, allowing for a longer duration of study should allow researchers to measure the impact of reinforcements in term of automaticity. In addition, a long-term study can facilitate the analysis of change in term of intentions. Since intentions may change over time, allowing for a longer duration of study can measure the impact of change on the targeted behaviour itself.

Large-scale study. We have identified the limitations in our study where the sample size is small, ranging from 19-58 participants in each study. This could introduce bias on the findings due to similar characteristics and behaviour from a select amount of participants. Another potential benefit of conducting a large-scale study is the ability to test the reinforcements on multiple experiment groups simultaneously. It would allow researches to perform more robust analysis, for instance, understanding the impact of using different reinforcements simultaneously. Also, conducting the study on large-scale can test the generalisability of the framework on a wide range of groups, and measure the impact *in-the-wild*, not limited to an experiment setting.

Making reinforcements adaptive and interactive. In our study, we kept sending the reinforcements every day, throughout the period of the study. Making the reinforcements adaptive, for instance, by reducing the frequency if someone has started to build consistency, should help us to understand whether the reinforcements create dependency or not. The reinforcements could also be made interactive, allowing participants to reflect on their performance and help them commit to their implementation intention. Giving the participants an opportunity to reflect their intended goal would motivate them to complete the goal.

Better context detection. We applied a set of simple rules to detect the context and determine the opportune moments to deliver the reinforcements. Further research might investigate more into context and using better algorithms and rules to detect opportune moments. With

the latest technologies from various sensors, gathering data and information from smartphones can help to increase the accuracy of context detection.

7.6 Summary

This thesis has identified the theoretical gaps in habit formation research, mainly that utilise smartphone apps. We have proposed a reinforcement group that aims to strengthen the underlying processes of implementation intentions by strengthening the link between cue and its associated response. The framework can be applied in a wide range of habit formation applications.

We have also tested the framework using different strategies of implementations: passive, active, and context-aware.In each study, we measured the impact of adding reinforcements on implementation intentions and comparing participants' performance on two essential elements of early habit formation process: compliance and automaticity. We found that participants with reinforcements had a significantly higher compliance rate than the control group where they did not receive any reinforcements. However, it is not necessarily the same in terms of automaticity, where we cannot draw a conclusion due to the sample's small size.

Our works open a new avenue of habit development research, mainly around using implementation intentions for habit formation apps. We also outline some recommendation for the direction of future research that can extend our studies.

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