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DOI:
10.1093/iwc/iwz012

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Document Version
Peer reviewed version

Citation for published version (Harvard):
Wicaksono, A, Hendley, R & Beale, R 2019, 'Investigating the impact of adding plan reminders on implementation intentions to support behaviour change', *Interacting with Computers*, vol. 31, no. 2, pp. 177-191. https://doi.org/10.1093/iwc/iwz012

Link to publication on Research at Birmingham portal

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https://academic.oup.com/iwc/article/31/2/177/5448908.
10.1093/iwc/iwz012.

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Investigating the Impact of Adding Plan Reminders on Implementation Intentions to Support Behaviour Change

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The use of reminders in habit-formation apps could lead to dependency towards the reminders and hinder the automaticity of the behaviour. Implementation intentions (if–then plan) have been found to be an effective technique that can be used to support forming new habits/breaking unwanted habits. However, implementation intentions could suffer due to forgetfulness and lack of strong intention. In this study, we investigated how adding plan reminders could impact implementation intentions by conducting a 4-week study on daily mood report task. Our findings suggest that adding plan reminders leads to better compliance and better recall of the plan but not necessarily increased automaticity. We also discuss how plan reminders of implementation intentions can be improved.

RESEARCH HIGHLIGHTS

- Implementation intentions are specific action planning that have been found to be powerful in supporting behaviour change by helping someone to break unwanted habits or form new habits.
- Implementation intentions could have a weak effect when there is no strong motivation to perform the intended behaviour.
- Existing habit formation/behaviour change apps focus on using reminders. This could lead to dependency towards the reminder. We propose an alternative approach by sending specific reminders of implementation intention (plan reminders) in advance before the actual action happens.
- Adding plan reminders on implementation intentions leads to better compliance, however, it is not necessarily the same in term of automaticity.

Keywords: behaviour change intervention; habit formation; human computer interaction; implementation intentions

1. INTRODUCTION

Forming new habits allows behaviour change interventions to persist for a prolonged time because when a behaviour has become habitual, the strength of habit will overpower the behavioural intention (Verplanken and Aarts, 1999). Additionally, a habitual behaviour will require less cognitive effort, and it will be performed automatically when a specific situation is encountered (Lally and Gardner, 2013; Lally *et al.*, 2010; Orbell and Verplanken, 2010; Wood and Neal, 2007). The rapid growth of mobile phones has opened a new avenue for developing mobile-based behaviour change intervention, and developers and researchers have worked together to design mobile apps that could support changes in behaviour.

Despite the growing popularity of behaviour change apps, only a few of them are built based on the theories of habit and behaviour change. According to Stawarz *et al.* (2015), the majority of apps that aim to help people form new behaviours 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 a new habit 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 availability of the reminders 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 most important 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 behaviour change apps.

Whereas the majority of behaviour change apps focus on self-tracking and reminders as the key features in helping people change their behaviour, some important features and techniques that support behaviour change remain overlooked (Stawarz *et al.*, 2015). Habits are consistent actions that follow a cue in the presence of a constant environment (Verplanken and Aarts, 1999). One of the techniques that can be used in to strengthen this effect and supporting behaviour change via habit formation is implementation intentions (Holland *et al.*, 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 to increase the automaticity of behaviour by heightening the accessibility of the cue and strengthening the mental link between the cue and its associated response (Adriaanse *et al.*, 2011; Holland *et al.*, 2006; Lally and Gardner, 2013). Implementation intentions are also effective in helping people to achieve their goal (Webb and Sheeran, 2007). Currently, implementation intentions remain underused in digital behaviour change (Pinder *et al.*, 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 *et al.*, 2003; Sheeran *et al.*, 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 improve the impact of implementation intentions is plan reminders (Prestwich and Kellar, 2014). In the previous studies, the content and the delivery time of the reminders were unclear as participants were allowed to decide both of the content and delivery (time, day and frequency) of the reminders (Prestwich *et al.*, 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 toward 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 special type of reminders that we refer to as *plan reminders*. plan reminders are different from reminders in term of their respective goal. Whilst reminders aim to prompt the intended behaviour, plan reminders for implementation intentions aim to strengthen the mental link between the cue and its associated behavioural response. With plan reminders, people will be made more aware that they have an intention to change behaviours, and the plan reminder aims to increase the saliency of the cue that triggers the intended behaviour. It, therefore, tries to reinforce the habit-forming approach itself.

In this paper, we present our research which suggest that adding reinforcement could strengthen implementation intentions. Participants in our study who received reinforcement had a higher compliance rate compared to the ones who did not receive reinforcement. Additionally, adding reinforcement could help people to recall their implementation intentions by remembering their IF condition as the cue for their intended action. However, the results are not necessarily the same in term of automaticity because we cannot measure the automaticity score due to the small sample size.

2. THE ROLE OF HABIT IN BEHAVIOUR CHANGE

Habits are repeated behaviours that will be automatically executed as a response towards a particular situation, in which the behaviours are performed consistently (Verplanken and Aarts, 1999). Repeating a behaviour in stable contexts could lead to the formation of a new habit (Lally *et al.*, 2010). However, repetition alone is not enough. To become habitual, behaviour needs to have the four elements of automaticity: lack of awareness, unintentionality, uncontrollability and efficiency (Bargh, 1994).

Promoting habit formation to support behaviour change is more effective than relying on the intentions. A study from Aarts *et al.* (1997) argues that changing unhealthy habits using the attitude-intentions-behaviour route seems inefficient because intentions no longer guide the behaviour in the long-term. In another study, Cheung and Limayem (2005) investigated the relationship between intentions and habits in using information systems. Their findings also suggest that intentions cannot predict the intended behaviour. They found that prior usage of information systems has a more significant role in predicting their use. This finding suggests that intention alone could not be relied upon for successful behaviour

change. In reality, it is difficult to maintain the same intentions for prolonged periods because intentions may change over time (Sutton, 1998).

The idea of using habit formation to support behaviour change intervention arises as an alternative solution (Tobias, 2009). Instead of relying on the intention, habit formation uses unconscious aspects of the mind and could be enhanced by increasing the accessibility of the situational cues. Whereas goal-directed behaviour powered by motivation requires deliberate effort, habits are performed automatically and often unconsciously.

Targeting interventions that help people to perform a behavioural action repeatedly and consistently should lead to habit formation and help maintain the change in behaviour in the long-term. Lally and Gardner (2013) argue that forming new habits should follow four stages. First, 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 have a strong effect on the action initiation (Fishbein and Ajzen, 1975; Gollwitzer, 1993). Second, the intentions have to be translated into action. In their study, Webb and 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 lapse during action initiation. It will also provide a clear pathway from the motivational phase (intention) to volitional phase (post-intention). Third, 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 and 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. Based on the finding from Lally *et al.* (2010), Lally and Gardner (2013), repeating a particular behaviour in a stable context leads to a higher level of automaticity. It means, 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. Therefore, the long-term change in behaviour should be greater.

2.1. Implementation intentions to support habit formation

Combining behavioural control and current intentions can be effective to enhance habit formation. Oettingen *et al.* (2001) argue that intentions in the form of expectations can improve goal commitment. Ajzen (1991) has also suggested, with the theory of planned behaviour, that intention can be a powerful tool that acts as a motivational factor to perform an action. However, the intention to perform such action can only be achieved if the behaviour being intended is under volitional control (Ajzen, 1991). This volitional control can be a specific condition 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 (1999) further investigated the relationship between intention and goal attainment. His findings suggest that successful goal attainment requires a strong commitment from a person to get started and perform the intended action until the goal is achieved. He also identifies two reasons for how goal pursuit can be effectively achieved. First, it is important for a person to frame his intention in achieving a certain goal by setting a specific goal rather than merely a vague goal. Second, it is also worth considering that self-regulatory skills in initiating goal-directed behaviour affect the goal attainment.

Compared to the theory of planned behaviour, the theory of goal intentions explains further how intentions can affect goal attainment (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 rather than just having the desire to pursue that goal. Therefore, it explains how goal intentions work. It not only sets a specific target for the goal but also commits people to perform such action to realize the goal. In line with the theory of planned behaviour, goal intentions urge people to have a strong intention toward their goal to commit changes in their behaviour.

However, it has also been suggested that having goal intentions is not 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 and 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 (1993) came up with a theory called implementation intentions. This theory bridges the gap between intentions and the 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. Implementation intentions follow a pattern: '*If situation X happens, then I will do action Y*'. 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 perform 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 more specific situational context, including when, where and how the intentions will be performed. When the contextual cues are encountered, they will activate the consciousness of the individual and trigger their mental state to perform such action.

Implementation intentions have been found to have a medium-to-large ($d = 0.65$) positive impact on goal attainment (Gollwitzer and Sheeran, 2006). Additionally, implementation intentions are also shown to increase the rate of goal attainment with evidence on some studies, such as cervical cancer screening (Sheeran and Orbell, 2000), promoting exercise (Prestwich *et al.*, 2003), drivers' compliance with speed limits (Elliott and Armitage, 2006) and fruit intake (Luszczynska *et al.*, 2007).

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). Therefore, implementation intentions need reinforcement to strengthen their effectiveness. One type of reinforcement is to remind someone of the cue and its associated response, which results in strengthening the link between the cue and the response, and making the cue more salient when encountered.

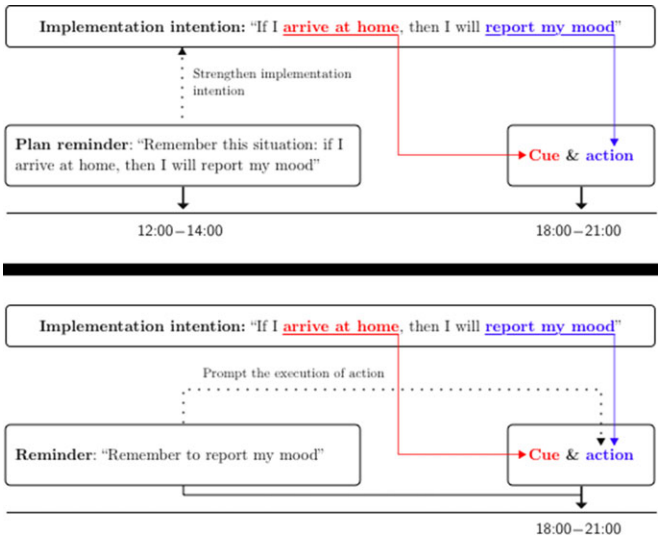

FIGURE 1. Different mechanism between reminder and plan reminder.

2.2. Reminder vs. plan reminders

Forgetfulness is common when there is an absence of memory in a certain situation (Nørby, 2015). Reminders act as an external aid for minimizing forgetfulness by helping the memory to recall the task (Brewer *et al.*, 2017). In this study, we define reminders as an external aid to prompt an intended task, and delivered at the time when the task is supposed to happen, i.e. 'Remember to report your mood'. Reminders are widely used by existing habit-formation apps to keep their users engaged and sticking to their habit. However, reminders could cause 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 a bad idea 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, see Gardner *et al.*, 2012). Therefore, even though reminders are beneficial in keeping someone engaged and sticking to the task, it could hinder the development of automaticity as one of the important elements in habit (Fig. 1).

Reminders have been used in previous studies to improve the impact of implementation intentions (Prestwich *et al.*, 2009, 2010). However, it remains unclear on when the reminders were delivered in those two studies since participants were given a choice to decide on the delivery time of the reminders. If the plan reminders were sent at the time when the plan was supposed to be executed, then they had a potential of causing dependency.

Therefore, we introduce a special type of reminder which we refer to as *plan reminders*. In our study, plan reminders have different characteristic from reminders, including

- Reminders aim to prompt the intended behaviour immediately, whereas plan reminders utilize prospective memory to strengthen the impact of implementation intention by making the cue and its associated response more salient.
- Whilst reminders are usually sent when an action/task is supposed to happen, we send the plan reminders in our study 5–6 h in advance to minimize the dependency. By sending the plan reminders in advance, we wanted our participants to execute their implementation intentions based on the condition specified, not when they received the plan reminder.
- The construct between reminders and plan reminder is different. 'Remember to do X' is a reminder, whereas 'Remember, if X happens, then do Y' is a plan reminder.
- Reminders are an extrinsic process as the execution of the task depends on the availability of the reminders, whereas plan reminders stimulate intrinsic process by improving the accessibility of the cue and its response, and as a result, minimize the dependency towards the plan reminder as an external aid.

Plan reminders aim to improve the impact of implementation intention by targeting the two underlying processes of implementation intentions. First, plan reminders make the cue more salient (Prestwich and Kellar, 2014). Implementation intentions demand the attention from a person to take action when the specified cue is detected. By adding plan reminders, that person

will have better accessibility towards the cue and increase his awareness whenever the cue is encountered. Second, plan reminders strengthen the mental-link between the cue and its behavioural response (Prestwich and Kellar, 2014). When the mental link between cue and its associated response is maintained in a stable context, it will become stronger and there is a higher chance that implementation intentions could make the targeted behaviour become automatic.

According to previous literature, there are two different 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 12 pm. 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. With implementation intentions, forming a specific if–then plan takes time to become habitual. In the beginning, forming implementation intentions requires deliberate effort and sufficient intention to perform the intended behaviour, otherwise people will forget about their plan.

Translating intention into behaviour is not always easy. In implementation intentions, a person should have sufficient accessibility to identify the situation in the *if* condition and its associated response in the *then*. Accessibility is the ease of recalling the intended behaviour (Tobias, 2009). When the accessibility of the implementation intention is high, there is a greater chance that a person will act upon their plan when the cue is encountered. Unfortunately, it is not always the case since the cognitive resources to identify the cue can change. Implementation intentions are still prone to forgetfulness, especially during the beginning of the process when there is a need for high cognitive resources to identify the cues. This is where plan reminders of the implementation intention could be the key.

There have been previous studies that investigated how adding plan reminders of implementation intentions could enhance their effect. The study from Prestwich *et al.* (2009) suggests that using text-messages (SMS) as plan reminders of implementation intentions could have a positive impact on physical exercising. Further, Prestwich *et al.* (2010) also found that adding plan reminders of implementation intentions improved the results of promoting brisk walking. In both studies, the group who received plan reminders scored the best results at the end of the study, compared to the other groups (implementation intentions without plan reminders, and a non-interventional control group). Despite promising results, it remains unclear whether the plan reminders of implementation intentions in both studies were treated as reminders (sent at the time when the task was supposed to be done, asking for immediate action) or as plan reminders (sent before the task happened, containing the implementation intention). This is due to the fact that they gave participants freedom to choose the content and the delivery time of the intervention. If the messages were sent at the due time of the action, then it could hinder the effectiveness of implementation intentions being the reason for the action, as well as hindering the automaticity which is important for the development of new habits. In a study conducted by Stawarz *et al.* (2015), participants were given the task to report their lunch every day for 4 weeks, and the participants in the plan reminder group received a message to perform the task at lunchtime, every day. Even though the participants in the plan reminder group scored best on the adherence of lunch reporting task, they had the lowest score in term of automaticity when performing the behaviour, showing that they depended on the reminder to execute the task. Furthermore, the results of the study have also demonstrated that instead of relying on the situational cues (time for lunch), those groups relied on the message to execute their plan (to report their lunch).

In mobile apps, it is common to receive all sorts of reminders via phone notification. Whilst notifications containing the intervention could be useful to help people remember a certain task, when delivered at inopportune moments, they can cause interruptions and adverse effects (Mehrotra, 2017). More importantly, if the interventions are constantly delivered at inopportune moments, they can weaken the intention to perform the intended plan because the messages become annoying. In our study, to ensure that we are increasing the accessibility of the implementation intention and not activating the task, instead of sending messages about one's plan when the actual action is supposed to happen, we send plan reminders about their implementation intention, containing the *'if'* condition and its associated *'then'* response in advance (5–6 h) before the actual desired action.

3. METHOD

Previous research investigating how implementation intentions could be enhanced is limited to adding reminders via SMS and they did not specify the delivery time of the reminders (Prestwich *et al.*, 2009, 2010). In those studies, participants were also allowed to choose the content of the reminders by themselves. Hence, we applied a different approach in this study by sending plan reminders of

implementation intentions plan 5–6 h before the actual plan happens. We also used the same content of the messages on all of our participants (see Fig. 5). Thus, the aim of plan reminders in this study was to improve the impact of implementation intentions, not to encourage an immediate action of executing the plan.

Participants were asked to form an implementation intention of reporting their mood every day for 28 days. Mood report was selected as a task because it is an artificial task, easy to do and it is not a part of any existing routine, and participants are likely to have no significant bias towards or against doing this. Studies often use exercise or weight loss as topics, but these are likely to engender much stronger individual reactions and hence make the strength of the implementation intention much more variable, and so we chose a relatively neutral activity that is likely to have less individual variation.

Implementation intentions should be executed automatically and immediately when the cues are encountered, repeated in a stable context, in order to create the habit. By adding plan reminders, implementation intentions should be strengthened. So, our hypotheses of this study are

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

3.1. Participants

We recruited participants using email, social messaging apps, and meeting them face-to-face, without offering a financial incentive. We conducted pre-screening to only recruit participants who used an Android phone. 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), and one gender unspecified.

3.2. Design

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

- Control group: Participants in this group were asked to form an implementation intention of reporting their mood every day. They had to select part of their existing routine as the cue (IF condition). No intervention was given to this group.
- Plan reminder 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 plan reminders that reminded them of their implementation intentions. The plan reminders were sent at lunchtime, way in advance of the actual action to report their mood in the evening.

Two dependent variables were used in this study to measure the differences between the reinforcement and control groups: compliance and automaticity. Compliance was measured by the consistency in reporting the daily mood. Automaticity was measured using the Self-Report Behavioural Automaticity Index (SRBAI) questionnaire.

3.3. 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 plan reminder group, they received plan reminders about their implementation intentions at lunchtime. The plan reminder consisted of the specified routine event that they have selected as a cue (if condition) alongside its associated response (to report their mood). For the control group, they did not receive any reminders. The app recorded their daily mood data, and when they recorded it, and transferred the data securely to our server.

We use the 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 to 28 points, where the higher points mean a higher level of automaticity. The SRBAI questionnaire was available online, and the link to access the questionnaire was sent to participants in the second week and fourth week (last day of the study).

To balance the group, we used a goal commitment score, measured using 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.

3.4. Procedure

At the start of the study participants were asked to complete a consent form and pre-test questionnaire. The pre-test

questionnaire contains the goal commitment questionnaire, used to measure participants' intention in reporting their mood every day. Upon completion, participants were allocated into two different groups: a control group and a plan reminder group, balanced by their goal commitment score and gender. 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 were asked to choose one existing routine from pre-defined routines that they usually do in the evening, for example arriving at home. The routine event was used as a cue for reporting mood. So, upon completion of setting implementation intentions, each participant was presented with an if–then plan inside the Mood Journal app. The format of the plan was 'Every evening, If I <routine event here>, then I will report my mood'.

In the intervention group, a daily plan reminder will be sent at lunchtime, consisting of the implementation intention (routine event as the cue and reporting mood as the response). Participants in the promote group were also given an example of the plan reminder at the beginning, right after finished setting up their implementation intention.

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. 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 plan reminder group, with 20 participants in the control group, and 21 participants in the plan reminder group. The groups were balanced by participants' goal commitment, measured using HWK Scale (Klein *et al.*, 2001). However, from 41 participants who downloaded the app, only 24 of them reported their mood at least once using the app: 14 came from the plan reminder group and 10 came from the control group respectively. We only included participants who reported their mood in the analysis.

Over the duration of 4 weeks, 241 mood reports were received. We found a noticeable difference between the two groups with 212 mood reports received from participants in the plan reminder group, compared to only 29 mood reports from within the control group.

4.1. Level of compliance

We used compliance to measure the consistency of participants in reporting their mood every day. Our findings showed that participants in the plan reminder group had a better compliance rate compared to participants in the control group. However, the overall compliance level was much lower than expected. Participants in the plan reminder group had a 54% compliance rate compared to 10% of those in the control

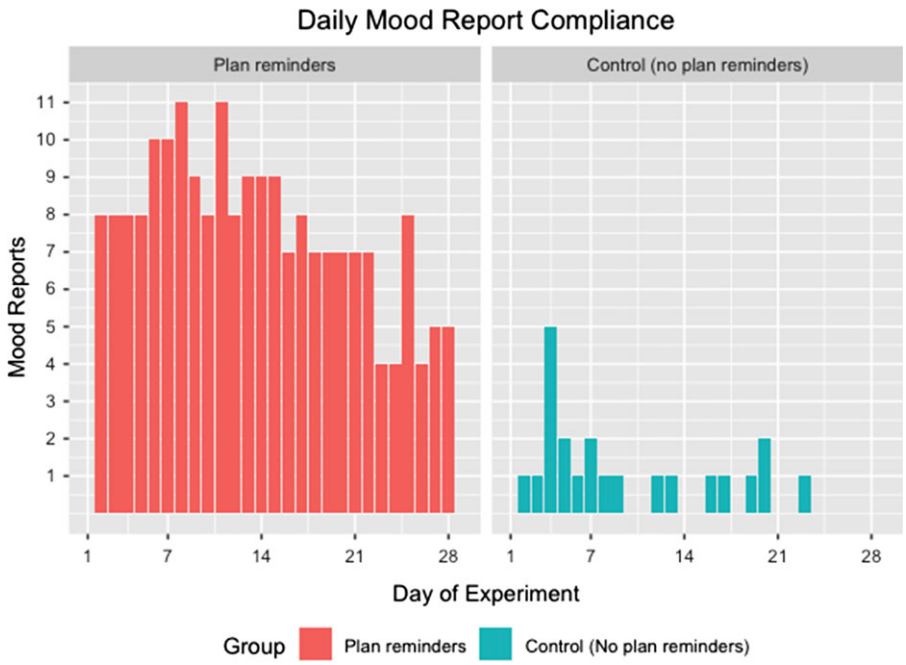

FIGURE 2. The changes of compliance between two groups, measured using mood report counts.

group. We then looked into the changes of compliance and found that an interesting pattern emerged from the mood report data. Participants in the control group dropped off significantly after the first day and remained low in compliance throughout the rest of the study. Meanwhile, participants who received plan reminders had their compliance level at a relatively stable rate, although it started to decrease in the fourth week. Figure 2 shows that even though both groups had a high drop-off rate, participants in the plan reminder group lasted longer than the control group.

Whilst the overall mood reports were low, we were interested to understand how many participants were active (still using the app) throughout the study. Our results indicated that the number of participants who were still active was higher than the reports since many would miss completing some reports (Fig. 3). Participants were considered as active if they still had the Mood Journal app installed, and kept sending mood report within a specific time-frame. For example, if a person sent a mood report on the first day and went missing, and then reported again on the seventh 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 went down to 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 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, whilst in the plan reminder group, the decrease in compliance was slower. Interestingly, 2 weeks after the study ended, eight participants from the plan reminder group were still reported their mood. Conversely, all participants in the control group stopped reporting their mood after the 27th day of the study.

4.2. Time distribution of mood reports

We sent plan reminders 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. All of these cues for reporting the mood were supposed to happen in the evening, whereas the plan reminders were sent at a random time during lunchtime (12:00–14:00). We are interested to understand how the gap between the plan reminders affected the actual mood report.

Therefore, we visualized the time distribution in which mood reports were received (Fig. 4) to see whether participants followed their implementation intentions (to report their mood in the evening) or not. The result was interesting because even though the majority of participants reported their mood in the evening, according to their plan, some of them chose to report their mood at the time when they received the plan reminder. More interestingly, many of them reported their mood early in the morning. At the moment, we cannot draw a conclusion as to why some participants chose to report their mood in the morning as we did not have any supporting data to answer this question, though it seems that some chose to treat the plan reminder as the cue and then

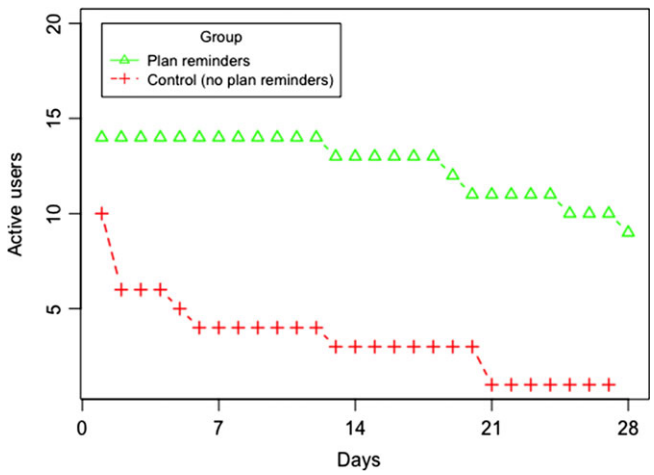

FIGURE 3. Active users from the beginning until the end of the study.

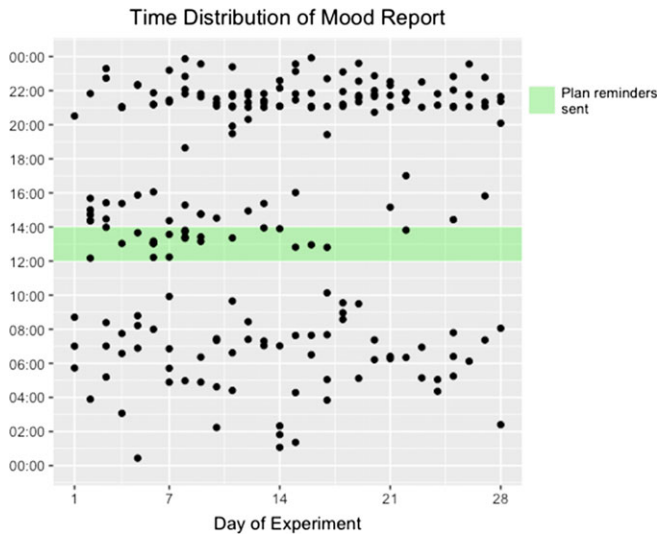

FIGURE 4. Time distribution of mood reports.

undertake the action, which is not what we wanted to achieve as it does not support habit formation.

4.3. 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 detailed analysis.

On the second week of our study, there were only six participants who responded to the SRBAI questionnaire (five from the plan reminders group, one 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 plan reminders 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.

4.4. 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. There were eight participants who answered the questionnaire either on the second or the fourth week. We then compared the routine events which are recalled by each participant in Table 1.

Overall, 60% of participants in the plan reminder 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 plan reminder group also mentioned that initially, he/she chose going to bed/sleep at night for the routine events but because the app sent the plan reminder at lunchtime, he/she reported his/her mood immediately after receiving the intervention.

5. DISCUSSION

Previous studies have suggested that adding reminders of implementation intentions could enhance their effect (Prestwich and Kellar, 2014). Indeed, in our study, we found that the participants who received reminders of their plan in the form of plan reminders had better compliance in reporting their mood, compared to participants without interventions. The compliance, as measured using the daily mood reports, has been shown to decay from the beginning towards the end of the study. However, adding plan reminders has been shown to slow down the decay of compliance. Even after the study ended, there were still eight participants in the plan reminders group who reported their mood. Considering that the mood report is an artificial task that has not been part of our participants' existing routine, this finding suggests that adding a plan reminder to reinforce the implementation intention can indeed be used to support action initiation and habit formation.

It has been argued that intentions alone cannot be relied upon when committing to perform a behaviour (Scholz *et al.*, 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 HWK scale at the beginning of the study). It is indeed common that people fail to act upon their good intentions. However, in our case, intention might not be the only

TABLE 1 Recall of routine events as the cue in the implementation intentions to report daily mood.

			Recall of the cue	
Participant ID	Group	Original 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

factor that determines behavioural action. In our study, we suspect the drop-off might also be affected by the type of the behaviour itself. As we mentioned earlier, mood report is an artificial task that does not belong to our participants' existing routine. Most people probably do not have any intention to report their mood every day unless they are forced to do it. Therefore, the artificial intention we asked them to form to record their mood every day may not be strong enough to make the task consistently performed on a daily basis. As the theory of planned behaviour suggests, attitudes towards the intended behaviour still acts as an important predictor for the intention to perform such behaviour (Fishbein and Ajzen, 1975). However, even though intention is still needed to perform behaviour, it is not sustainable for long-term behaviour change: the intention to perform the behaviour will decay over time, as our findings have shown with the decrease of mood reports throughout the study.

The aim of adding plan reminders 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 a behaviour needs to be repeated consistently in the same context to make it habitual (Lally and Gardner, 2013; Lally *et al.*, 2010; Ouellette and 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 plan reminders 5–6 h in advance should also have an effect in promoting behaviour as suggested by our findings on the compliance of mood report. 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 creation of new behaviours, it makes their users dependent on the reminder for remembering to perform the behaviour. Instead, we utilize prospective memory by sending a plan reminders of one's plan way in advance, so they can recall their original plan and help them to strengthen their cue-response link.

Accessibility also has an important role in determining behaviour change. According to Tobias (2009), accessibility to perform a behaviour decays over time. He argues that remembering to perform a behaviour becomes more difficult as the time passes. In our findings, the data show a similar trend where the compliance of mood report decreases over time. However, adding the plan reminder slows the decay, making people remember their intention to carry out the 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 have been enough of a concern for some participants that their worries before foremost in their mind and thus it reduces the accessibility of the behavioural cues, and then they decided to stop using the app.

According to the previous research, repeating a particular behaviour consistently in a stable context should lead to a higher level of automaticity, and our results are consistent with this and show that the automaticity score from the plan reminders group increased from the beginning until the end of the study (and whilst the automaticity score from the control group decreased significantly after the second week, these data are meaningless owing to the insignificant sample size).

In terms of recalling the trigger event as a part of the implementation intention, our results suggest that the participants had difficulty remembering their triggers as the cue for reporting their mood. We supposed that by sending the plan reminder in advance from the actual action, we can minimize the dependency towards the plan reminder for reporting a mood. Yet, it seems that the participants expected to receive the intervention based on the routine event that they chose. For example, when they chose 'going to bed' as the cue, they expected to receive a plan reminder about their implementation intentions at night when they are going to sleep. This may well be due to their expectations of the wide range of existing notifications they get on their phones which tend to demand more immediate attention and sometimes action.

Future work should investigate how different strategies and timing of the plan reminder could affect the implementation intention. In order to minimize the dependency towards the plan reminder, we might be able to phase it out if the participants started constantly enacting their intended plan. The plan reminder could also be made context-aware, for example adapting to the situation of an individual, in order to reduce adverse reactions when occurring at inopportune moments. In the following parts, we discuss recommendations for future work in the area of plan reminders to support behaviour change intervention.

5.1. Using context-aware reinforcement

In our study, the plan reminders were sent at lunchtime for performing the task of mood report in the evening. In spite of better results for participants in the plan reminder group, we feel we need a better approach for the plan reminders. Sending them at around the same time every day without considering the context of the recipients could cause adverse effects making the recipient ignore the reinforcements. To

avoid this potential issue, we should make the plan reminders context-aware by sensing the situation around the recipients, and adjusting the delivery time to be in opportune moments. The growth of smartphone ownership has opened a new avenue of research in context-aware computing by sensing human behaviour (Lathia *et al.*, 2013a). Information such as time, location, activity and connectivity can be easily gathered from a smartphone to understand the context of its user (Lathia *et al.*, 2013b), and by utilizing this contextual information, we can tailor the notifications to be unobtrusively sent at an opportune moment, when the recipient is available (Pejovic and Musolesi, 2014b).

Developing context-aware systems to support behaviour change intervention is a challenging task, especially in term of technical implementation (Pinder *et al.*, 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 poor accuracy (Burns *et al.*, 2011; LiKamWa *et al.*, 2013). There is no such sensor in our smartphone that has the capability of sensing the current psychological state at the moment. To gather information about psychological state such as mood and emotion, researchers and developers have to build their own solutions, usually in the form of a machine learning model. These models aim to predict the psychological state by processing information gathered from multiple data sources (Pejovic and 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 an affective state such as mood where the result was poor (Burns *et al.*, 2011). The poor accuracy of mood detection using smartphone data might be solved by giving enough time for the model to train the data—for example, LiKamWa *et al.* (2013) developed a model to infer daily mood data and has 93 percent accuracy after a 2-month training period. However, waiting for 2 months to infer the user's psychological state is not an ideal situation for digital behaviour change interventions.

Due to the difficulties of inferring psychological states from multiple sensor data, researchers opt to use alternative methods, 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 and Csikszentmihalyi, 1983). ESM aims to get a sample of data in multiple occasions, hoping to get the most accurate representation of participants at the moment they send the self-reports (Csikszentmihalyi and Larson, 2014). ESM is very useful to obtain data that cannot be collected using sensor data. These data are often related to psychological states, such as emotional and cognitive states, as well as other personal data such as thoughts and opinions (Csikszentmihalyi and Larson, 2014).

Another challenge in designing context-aware reinforcements is to determine which contextual data should be selected (Pinder *et al.*, 2018). With multiple contexts to choose from, it is impossible to combine all of them into one model. Not only will it be difficult to implement, it will also require a huge 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. For example, if we are designing plan reminders to support healthy behaviour via exercising, using existing physical activity level and participant's routines as the contexts would be sensible. It will allow the plan reminder to be sent when the participant is free and the existing physical activity level is low. Again, 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 plan reminders remains an open question.

5.2. Selecting the appropriate modality of the plan reminder

In our study, we sent the plan reminders in the form of Android notifications, containing the instruction to remember the if–then plan that participants have created. When the notification is clicked, it opens a page that has an instruction to repeat the plan in the participants' head, as well as highlighting 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 plan reminder of the implementation intention is passive, in that requires participants to simply remember their plan to be executed later, as seen in Fig. 5.

Tobias (2009) argues that accessibility to perform an intended behaviour decays over time, and as a result, it will become more difficult to remember to perform a behaviour. Although the decay of accessibility in performing behaviour is slow, it could increase when the cues related to the behaviour are encountered. Nevertheless, it is not a good idea in the long-term to deliver plan reminders with passive instruction: not only is it prone to be forgotten, it also requires more cognitive effort to remember the content within the plan reminder. Therefore, instead of using a passive instruction like 'Remember, if you arrive at home, then track your mood', we should make the instruction active, i.e. 'Now, close your eyes and imagine vividly that you are arriving at home, then say this sentence loudly *if I arrive at home, I will*

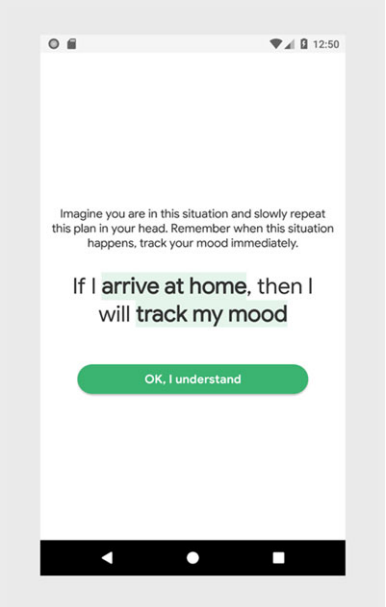

FIGURE 5. Plan reminder of implementation intention in Mood Journal app.

track my mood'. Active intervention is better than passive because it increases the accessibility of the behaviour itself, making it easier to remember (Tobias, 2009). When we ask someone to imagine the situation and to say the instruction, s/he will have increased accessibility towards the behaviour that s/he imagines, making the intervention more effective.

The other aspect that needs to be investigated further is the form of the plan reminder. The existing plan reminder in our study is simple text, asking the participants to read through the instructions. Whilst using textual instructions works in helping participants to remember their plan, the effect can be improved by adding pictures or illustrations to the instructions. Illustrations act as visual cues that help participant recall their plan. Moreover, as previous studies suggest, pictures are easier to remember compared to words (Carney and Levin, 2002). Several studies have been investigating how pictures/illustrations could improve the performance of understanding reading materials (Balluerka, 1995; Bétrancourt and Bisseret, 1998; Gyselinck and Tardieu, 1999). In a review of research from Levie and Lentz (1982), which investigates the effects of text illustration, they found that adding illustration to the text increased learners' understanding in 98 percent of the experiments in their review. Therefore, adding illustrations to the plan reminders, especially illustrations related to the *if* condition should improve the effectiveness of the reinforcement—the illustrations will help participants to recall their plan quickly without the need to read all of the textual instructions, reducing the cognitive load when the critical cues are encountered.

5.3. Targeting large-scale studies

Our study has a limitation in term of the number of participants. Overall, from 58 participants who signed up, only 24 of them were included in the final analysis. The small number of participants means we are unable to run inferential statistics. For example, we cannot compare the automaticity score (as measured with SRBAI questionnaire) because there were only six participants who responded to our post-test questionnaire.

In our study, we used traditional methods to recruit participants, including mailing lists, social messaging and meeting them face-to-face. The existing approach requires a lot of time. Moreover, we did not offer monetary incentives to avoid motivation bias. To overcome this issue, we can use a crowdsourcing platform, i.e. Amazon Mechanical Turk (AMT) to get a huge number of participants in a relatively short amount of time. AMT has been widely used in experimental studies, allowing researchers to collect data from participants with various demographic backgrounds (Paolacci *et al.*, 2010). AMT is an online crowdsourcing platform that allows employers (called requesters) to recruit people (called workers) for completing tasks (called Human Intelligence Tasks or HIT) with a monetary incentive (called reward).

There have been some concerns regarding the data collected using AMT (Bates and Lanza, 2013; Behrend *et al.*, 2011; Peer *et al.*, 2014). However, previous studies suggest that the data collected from AMT has a good reliability and validity, and can be used for further analysis (Behrend *et al.*, 2011; Peer *et al.*, 2014). Despite the good reliability score of the data from AMT, it does not mean that AMT has no limitations. AMT does not have the mechanism to assign the workers into different groups, making between-subject experiment designs difficult to conduct (Kittur *et al.*, 2008). AMT is also prone to bias if we are not careful when selecting the workers. As Behrend *et al.* (2011) found that 70% workers that participated in their study choose financial incentive as the primary motivation. Alternatively, Peer *et al.* (2014) suggest that we can select high reputation workers (above 95% approval ratings) to ensure that the data has the highest quality and to minimize bias.

Overall, our existing study has a limitation where the sample size is too small. Using alternative strategy such as a crowdsourcing platform with AMT can be used as a feasible option to conduct a large-scale study, allowing us to recruit a huge number of participants with minimal resources, and at the same time, it can produce highly reliable data.

6. CONCLUSION

This paper investigates how implementation intentions can be enhanced by adding reinforcement. Unlike prior studies that

tried to enhance implementation intentions by sending reminders at around the actual times of the intended action, we investigated a different approach by sending the reminder of one's plan (a plan reminder) way in advance before the actual action should happen. We tested whether the plan reminder had a positive impact on the implementation intentions or not. We measured the changes of compliance and automaticity of a daily mood report task.

Our initial findings suggest that giving plan reminders improves compliance, but it is difficult to draw reliable conclusions due to the small sample size. The type of behaviour the users are asked to perform and the nature of the plan reminder might be factors in users completing the activity over the four week period. Mood report as the task in this study is an artificial task that does not belong to our participants' existing routines, and therefore, the task might not be interesting for some of them. More rigorous work is needed to investigate how using a different type of behaviour might affect the compliance.

With regard to intention to perform behaviour, even though intention is not suitable for predicting long-term behaviour change, it still has an important role to play. In our findings, participants failed to act upon their good intentions, including the intervention group. The role of intention cannot be underestimated when we intend to change behaviours. With the addition of plan reminders, we can observe that the intention is strengthened, and more importantly, the behaviour that is aimed for can be executed consistently until it becomes habitual.

Implementation intentions require a strong commitment from an individual who wants to use them. Additionally, when people start forming an implementation intention, they still need to be reminded because they tend to forget about their plan, as our findings have demonstrated. As the plan reminders were sent way in advance from the actual action, we hoped that the participants could remember their implementation intentions and did not rely on the plan reminder to report their mood. Participants who received plan reminders had indeed a better recall performance compared to the others without. Unfortunately, we could not measure the dependency towards the plan reminder because of the small sample in our study.

We also discussed potential work that could be carried out in the area of behaviour change, more specifically, to investigate how habit formation via implementation intention could be supported. These potential areas of works include using context-aware systems to give better predictions when delivering the plan reminders, making the plan reminders instruction active not passive, adding illustrations related to the cues and conducting larger studies by utilizing crowdsourcing platform such as AMT. These separate bodies of work could give us better understanding of how to improve existing approaches to digital behaviour change interventions (DBCI). In conclusion, this paper analyses a novel approach on how DBCI can be improved by using a simple yet effective strategy by adding promoting of implementation intentions.

ACKNOWLEDGEMENT

A.W. would like to thank the Indonesia Endowment Fund for Education (LPDP) for providing scholarship during his study.

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