Beyond Self-Tracking and Reminders: Designing Smartphone Apps That Support Habit Formation

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ABSTRACT
Habit formation is an important part of behavior change interventions: to ensure an intervention has long-term effects, the new behavior has to turn into a habit and become automatic. Smartphone apps could help with this process by supporting habit formation. To better understand how, we conducted a 4-week study exploring the influence of different types of cues and positive reinforcement on habit formation and reviewed the functionality of 115 habit formation apps. We discovered that relying on reminders supported repetition but hindered habit development, while the use of event-based cues led to increased automaticity; positive reinforcement was ineffective. The functionality review revealed that existing apps focus on self-tracking and reminders, and do not support event-based cues. We argue that apps, and technology-based interventions in general, have the potential to provide real habit support, and present design guidelines for interventions that could support habit formation through contextual cues and implementation intentions.

Author Keywords
Smartphone apps; habit formation; behavior change

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. H.5.2 User Interfaces: User-centered design

INTRODUCTION

Designing apps that support behavior change has become an important theme within the HCI research [14], spanning across domains from encouraging physical activity [4] to supporting medication-taking habits [29]. This focus on smartphone apps is not surprising as, due to their ubiquity, personal nature and capabilities, smartphones have the potential to support individuals in the process of adapting and sustaining a new healthy behavior [6, 9]. To ensure that behavior change apps have maximum impact, designers of these technologies need to understand the mechanisms of behavior change and tailor interventions accordingly [14]. They also need to recognize the role of habit formation, as habits help to ensure that the change in behavior will have long lasting effects [16]. A habit is defined as a consistent repetition of a behavior in the presence of stable contextual cues that increases the automaticity of that behavior [16]. Understanding how habits develop would help the HCI community design apps and other technology-based interventions that not only help users change their behavior, but also make that change permanent.

At present, behavior change apps often do not support habit formation and instead focus on tracking, self-monitoring and social support [14]. The lack of habit support might be related to the overall lack of theoretical grounding of such apps. For example, studies reviewing theoretical underpinnings of health and fitness apps [5, 34] discovered that they were not based on behavior change literature. Among apps that did use behavior change techniques, the focus was on supporting motivation and developing relevant skills. Features that could support habit formation, such as support for trigger events and implementation intentions, were lacking.

Even though habit formation is a part of the behavior change process, people can also form habits independently by simply repeating a task in a stable context. As a result, dedicated habit formation apps are available and are designed to help people start a new habit they want to repeat regularly, from daily meditation to reading before sleep. However, such apps have not been evaluated by academic researchers and it is not clear how effective they are. Understanding what functionality they offer and how they support habit formation could help us design better behavior change interventions.

In this paper we report the results of two studies: a 4-week study exploring the impact of different types of cues and positive reinforcement on the development of automaticity of behavior; and a functionality review of 115 habit formation apps. Our work makes three contributions. Firstly, we show how reminders and trigger events influence habit formation. While reminders support repetition and help users remember to complete the task, they hinder habit development. In contrast, reliance on trigger events to cue

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task completion increases the automaticity of the new behavior, although it does not support memory as well as reminders. Secondly, we highlight the fact that currently available habit formation apps are not grounded in the habit literature and do not actually support habit formation by helping users associate their new behavior with a trigger event. Instead, they support self-monitoring and tracking – actions that can support behavior change, but not through the formation of new habits. Finally, we present design guidelines for habit formation apps.

HABITS IN BEHAVIOUR CHANGE

Habits play an important role in supporting behavior change and ensuring it has long-term effects [16]. Once a person makes a decision to change their behavior and takes action, that action needs to be regularly repeated. To ensure the change becomes permanent, the repetition needs to be maintained until the task becomes automatic; the new behavior needs to turn into a habit.

Elements of Habit Formation

Habits are defined as automatic responses to contextual cues (e.g. location, existing routine events, objects or preceding actions). They form as the behavior is repeated in a stable context and the repetition helps to create associations between the task and its cues [17, 35]. Behavior can be considered automatic when it reaches the 'automaticity plateau' i.e. the asymptote of a curve representing the relationship between repetition and habit strength [17]. The number of repetitions required to reach the asymptote depends on the complexity of the task and it can vary from 18 days for easy tasks (e.g. drinking more water) to an estimated 254 days for more complex tasks (e.g. going to the gym) [17]. However, repetition alone is not enough to form a habit.

Cues and trigger events support the habit formation process, as they start to drive the behavior [21, 31, 36]. Existing routines can be used as prompts to action [23, 31], as tasks linked to routine events (event-based tasks), e.g. taking medication after breakfast, are generally easier to remember than tasks that need to be completed at a specified time (time-based tasks), e.g. meditating at 10pm every evening. Although associations between the task and contextual cues form automatically through repetition, it is possible to steer this process by forming implementation intentions [12].

Implementation intentions are action plans in the following format: "When situation X arises, I will perform response Y" [12], e.g. "when I finish eating dinner, I will drink a glass of water". They help to connect the new behavior with an existing routine and turn it into an event-based task. When the relationship between the task and its cues is explicitly stated, each repetition reinforces that association, which leads to a more efficient action initiation in the future and increases the automaticity of the behavior [12]. The trigger routine needs to be relevant and meaningful to make it easier to associate it with the new task, and needs to be reliable, i.e. occur as frequently as is desired of the new target behavior.

External memory aids (e.g. reminders, notes) can also serve as cues and play an important role in supporting habit development. They are especially useful when they refer to the target behavior and the situation in which it needs to be executed [13], although the effectiveness and salience of reminders decreases with time [30]. While automatically responding to a reminder could be seen as a habit, it is not related to the target behavior and does not help to make that behavior automatic. People who expect to be reminded score worse in prospective memory tests [27], as they put less mental effort into trying to remember and therefore are more likely to forget. However, in some cases reminders could support the start of a new habit, as the automaticity of the new behavior might develop faster than the decay of effectiveness of the reminder [30].

Another factor that can influence habit formation is positive reinforcement. Even small successes increase the feeling of satisfaction and can strengthen the habit [1, 16]. Satisfaction can also trigger the feeling of being in control, which reinforces the need to repeat the action in the future [1]. These feelings help with maintaining long-term behavior change, as they increase the belief that starting the new behavior was a good choice [26]. Therefore, to successfully form a habit, people need to start identifying the execution of the task with its rewarding nature [33, 36].

Rewards can be extrinsic, such as financial incentives, or intrinsic, such as pleasure or satisfaction [7]. However, there is a danger that if they are extrinsic and expected, they will hinder habit formation by reducing intrinsic motivation [7]. While extrinsic rewards can still help to develop automaticity of the behavior [8], they may not be feasible or practical and it might be difficult to distinguish between whether the action is truly habitual and whether people are engaged just to get the reward [16]. Thus, extrinsic rewards are likely to facilitate habit formation only when the reward is not a goal in itself and the behavior offers other, ideally intrinsic, benefits to the person [8, 16]. However, people develop habits even when they do not receive any explicit positive reinforcement [17], which suggests that while it can support habit formation, reinforcement plays a lesser role in the process than other factors.

The increasing popularity of smartphones (58% of US adults owned one in 2014 [24]) makes them an ideal platform for delivering targeted, low cost interventions [9]. Thousands of behavior change apps are available in various app stores and are being used as tools for behavior change. However, as we discuss in the next section, they hardly ever incorporate features that support habit formation.

CHANGING BEHAVIOR WITH APPS

Behavior change apps tend to focus on personal health and wellness, physical activity and healthy eating [34], although they could help with other types of behaviors, such as good

work habits, e.g. making to-do lists every morning or house chores, e.g. washing up after meals. As any type of behavior targeted by these apps requires regular repetition and can be associated with relevant contextual cues, it could benefit from habit support. However, behavior change apps often do not support habit formation, which is partly related to the fact that they tend not to be grounded in research.

Studies exploring the theoretical grounding of behavior change apps show that their features are seldom informed by the literature. For example, Cowan et al. [5] conducted a content analysis of 127 Health & Fitness apps to determine the extent to which these apps are based on health behavior theory and discovered that they lacked any theoretical content. Similarly, West et al. [34] conducted a content analysis of descriptions of 3,336 paid health and fitness apps to identify approaches to supporting the change in behavior. Again, theory grounding was lacking. In both studies, apps that were based on theory focused primarily on supporting initial stages of the behavior change process and provided options that helped to teach skills, track progress or record actual behavior. Habit formation was not supported.

The lack of theoretical grounding is an issue not only for commercial apps. Free et al. [9] conducted a systematic review of 26 mobile health behavior change interventions developed by researchers. They focused specifically on studies that used mobile technologies, including mobile phones, smartphones and other hand-held devices as the primary platform for the intervention. Only seven studies reported using behavior change techniques such as feedback on performance, goal setting or self-monitoring to underpin the intervention. Among them, only three interventions supported habit formation by teaching participants to use prompts and contextual cues.

Apps developed by HCI researchers are no different. They tend to focus on tracking, self-monitoring and social support [14]. By encouraging people to use them on a regular basis, they teach them to rely on technology. Regardless of whether these apps are designed as a behavior change aid that can be removed when the new behavior is achieved or whether they are supposed to be used continuously, this approach is dangerous. Users not only tend to abandon apps [19, 28], but self-monitoring in general is only effective if the monitoring continues. Once it stops, the target behavior tends to return to its initial levels [14, 15, 22].

Another approach is needed: Stawarz et al. [29] presented three requirements for designing apps that support habit formation. They argued that apps should offer routine creation (in the form of implementation intention, to help fit the behavior into a daily routine), back-up notifications (in case the routine changes) and post-completion checks (to check whether the task has already been completed). This approach could be applied to all types of habits and illustrates that smartphones already have capabilities to do so. However, Stawarz et al. focused on medication-taking habits and improving medication reminders; whether existing habit formation apps provide that kind of support is not known.

Dedicated habit formation apps exist and their aim is to help people repeat a new behavior, which may or may not be part of a wider behavior change goal, such as getting up early, writing for an hour every morning or watering plants regularly. Unlike behavior change apps that tend to focus on initial stages of the behavior change process, habit formation apps are supposed to support the repetition and maintenance of the new behavior. Understanding how they work could inform the design of features that effectively facilitate the development of new habits. However, habit formation apps have never been evaluated before.

Below we present two studies that investigate how apps could effectively support habit formation. First, we explore how different types of cues and positive reinforcement delivered via mobile technology facilitate the development of automaticity. Then, we review the functionality of existing habit formation apps: whether they are grounded in research and how they support the development of new habits.

STUDY I: HABIT FORMATION IN THE WILD

Previous studies investigating habit formation focused on understanding how long it takes for the new behavior to become automatic [17] and what strategies people develop to support that process [18]. We build on that research to explore which types of cues are most effective at supporting the development of automaticity of behavior in a real-life setting. We conducted a 4-week study that aimed to test the following hypotheses:

- Presence of cues would be beneficial in supporting habit formation, although relying on trigger events (event-based tasks) would be more effective, i.e. would lead to higher levels of automaticity, than relying on reminders (time-based tasks) [17, 21, 23, 31, 35, 36].
- Regardless of the type of the cue (trigger event, reminder, no cue), the presence of positive reinforcement would lead to higher automaticity [1, 17].

Method

Participants were asked to report via SMS what they had for lunch every day for four weeks. Lunch was selected as a trigger event as it is a familiar task and takes place every day. To ensure the trigger event was meaningful, participants were led to believe that the study explored their eating habits. The real goal was to study whether the act of sending text messages becomes automatic. As simple tasks become automatic faster than complex tasks, some even in 18 days [17], it was assumed that sending an SMS was simple enough to allow us to observe an increase in automaticity in only four weeks. Participants were informed of the real focus of the study in the debrief email they received after submitting the final survey.

Positive reinforcement	Cue		
	None	SMS reminder	Lunch
None	Control group	Reminder group	Trigger group
SMS confirmation	N&PR group	R&PR group	T&PR group

Table 1. Independent variables and study conditions

Participants

Overall, there were 133 participants, 22 in each condition (23 in the control group). They were recruited on social networks and among university staff and students. They were 18-55 years old (mean age: 25 years old, SD=5.8), 81% were women, 82% were students. Participants were offered a £5 voucher in recognition of their SMS costs, a summary of their lunch patterns and a chance to win one of five £25 vouchers.

Design

The study used a 3 × 2 between-subject design: cue (none, SMS reminder, lunch) × positive reinforcement (none, SMS), which resulted in six conditions. SMS reminder represented a time-based cue, while lunch was selected to serve as an event-based cue. Dependent variables were automaticity of behavior, representing habit strength [11, 17, 32], measured at the end of the study using Self-Report Behavioral Automaticity Index (SRBAI) [11]; and adherence, defined as consistency in sending SMS reports, measured to track the repetition of the behavior and engagement with the study.

Participants were randomly assigned to conditions that varied in terms of type of cue and presence of positive reinforcement (see Table 1):

- *No cues (Control) group*. Participants were told to report every day what they had for lunch. No cues were specified and there was no positive reinforcement.
- *Reminder group.* Participants received an SMS reminder in the afternoon and had to respond with a description of their lunch. No positive reinforcement was provided.
- *Trigger group.* Participants were explicitly instructed to send text messages as soon as they finish their lunch (implementation intention), which served as a trigger event. No positive reinforcement was provided.
- *No cues and positive reinforcement (N&PR) group*. Cues to action where not specified (as in the Control group), but after sending a lunch report participants received a confirmation message (e.g. "Great, thank you!", "You're great!", "Awesome!") that served as positive reinforce -ment. Messages were inspired by [10]. They were sent with a delay to disguise the fact that they were automatic.
- *Reminder and positive reinforcement (R&PR) group*. Participants received SMS reminders in the afternoon and confirmation messages in response to their reports that served as positive reinforcement.
- *Trigger and positive reinforcement (T&PR)*. Participants were instructed to send text messages after lunch and received confirmation messages (positive reinforcement).

Participants from all conditions received summary emails at the end of each week that served as implicit reminders.

Materials

Twilio (https://www.twilio.com/) was used to record and store participants' text messages, and to manage reminders and confirmation messages. IronWorker (http://www.iron.io/worker) was used to schedule reminders.

The 4-item SRBAI questionnaire [11] was used to measure automaticity levels. Questions were presented on a 7-point Likert scale with answers ranging from "Strongly Agree" to "Strongly Disagree". Scores ranged from 0 to 28 points, with higher scores indicating higher self-reported levels of automaticity. Average adherence rates for each condition were calculated based on the number of messages received throughout the study and the number of expected messages.

Procedure

Participants were asked to report via SMS at what time they had lunch and what they ate each day. Example meal descriptions were provided, e.g. "12:30 – fish & chips", "1pm – vegetarian curry with rice". The content of each lunch report and the time of its arrival were recorded. The study lasted 28 days. Participants in the reminder conditions received reminders at 14:30 on weekdays and at 15:30 on weekends.

At the end of each week participants received a summary of the previous week's lunches. After four weeks they received a link to the final survey that explored how they remembered to send text messages and included SRBAI questions. After submitting their responses, each participant received a debrief email that explained the main objective of the study and included vouchers.

Findings

Ninety-six participants (72%) completed the study and were included in the final analysis. Overall, the fewest participants dropped out from R&PR and Reminder groups (two and four respectively), while the Trigger and Control group lost nine participants each. Overall, participants sent 2,228 text messages. As the study lasted four weeks, participants were expected to send 28 messages each. Participants from Reminder and R&PR group sent the most (on average 26 and 27 messages per person respectively), while participants from T&PR group sent the fewest (on average 19.5 messages per person).

Automaticity

Automaticity was used to assess the strength of the texting habit. SRBAI scores for each condition are presented in Figure 1; higher values indicate higher automaticity. The Trigger group had the highest score (mean=22, SD=3.2, N=13) with Control close behind (mean=21, SD=4.3, N=14). The mean automaticity score for T&PR was 19 (SD=4.6, N=16) and for N&PR was 17 (SD=4.7, N=15). Participants from both reminder conditions reported the lowest automaticity levels: Reminder group score was 16 (SD=5.2, N=18) and for R&PR was 15 (SD=5.3, N=20).

A two-way between-subject ANOVA compared all cue types to each other and explored the impact of cue type and positive reinforcement on automaticity. There were significant main effects of cue type ($F(2,90)=10.65$, $p<.001$, part. $\eta^2=.19$) and positive reinforcement ($F(1,90)=6.39$, $p=.013$, part. $\eta^2=.07$), indicating that automaticity was higher for conditions without positive reinforcement (mean=19.5, SD=.7, N=45 vs. mean=17, SD=.66, N=51). The interaction between these two factors was not statistically significant ($F(2,90)=1.32$, $p=.27$, part. $\eta^2=.03$). Bonferroni post-hoc test showed a statistically significant difference for reminders (mean=15, SD=5, N=38) vs. trigger (mean=20, SD=4, N=29), and reminders vs. no cues (mean=19, SD=5, N=29), with $p<.001$ and $p=.004$ respectively. There was no significant difference for trigger vs. no cues.

Adherence

Adherence rates were calculated to understand how consistently users repeated their behavior. They are summarized in Figure 2. Adherence of 71% was an equivalent of reporting lunches every day on weekdays only. Participants from the Reminder and R&PR groups were the most adherent with the adherence of 93% and 95% respectively, while the T&PR had the lowest average score.

The influence of the type of cue and the presence of positive reinforcement on adherence rates was evaluated using a two-way between-subject ANOVA. There was a statistically significant main effect for cue type: $F(2,90)=15.46$, $p<.001$, part. $\eta^2=.26$, but not for positive reinforcement: $F(1,90)=1.94$, $p=.17$, part. $\eta^2=.02$. There was no significant interaction ($F(2,90)=1.87$, $p=.16$, part. $\eta^2=.04$). Bonferroni post-hoc test showed significant difference for reminders (mean= 94%, SD=7%, N=38) vs. trigger ($p<.001$) and reminders vs. no cues ($p<.001$). There was no significant difference for trigger (mean=76%, SD=18%, N=29) vs. no cues (mean= 75%, SD=22%, N=29).

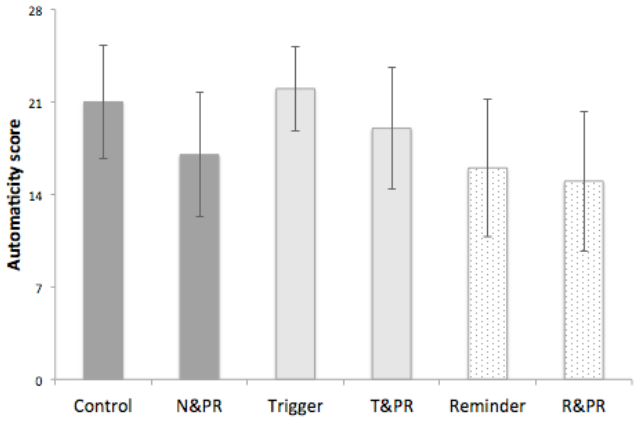

Figure 1. Automaticity scores for study conditions grouped by cue type: no cues (dark gray), event-based cues (light gray) and time-based cues (white dotted)

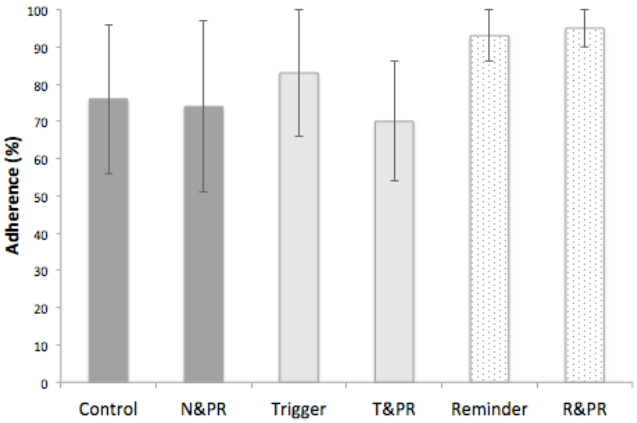

Figure 2. Adherence scores for study conditions grouped by cue type: no cues (dark gray), event-based cues (light gray) and time-based cues (white dotted)

Remembering Strategies

The final survey included open-ended questions exploring remembering strategies developed by participants and 90 of them provided answers. The majority of participants who received SMS reminders named them as their main cue to action (16 participants in the Reminder condition and 13 in the R&PR). Seven participants in the N&PR group and five in the Control group reported using their own reminders, which shows that if no explicit cues are provided, people tend to choose their own. Across all conditions, participants generally reported using phone alerts, notes and calendars; one person set the wallpaper on their phone with the words "send lunch report" so that they would see it every time they used their phone. Previous lunch reports also served as reminders, as participants saw them when composing and receiving other messages. Some participants reported relying on a trigger event: the lunch itself, going to bed or eating breakfast (to report a previous day's lunch). Eleven participants (from all conditions but Control) reported that sending text messages had "become a habit" or "a part of my routine".

Missing Positive Reinforcement Messages

Due to technical issues, for the first two weeks of the study positive reinforcement messages were not always sent, although throughout the study the majority of participants (88%) received at least 75% of confirmations they were supposed to receive. The issue affected all conditions, although usually a missed confirmation was preceded or followed by a day when the message was sent. Five participants (four from R&PR group and one from N&PR) did not

receive confirmations for three days in a row and one participant (N&PR) did not receive them for four days.

Discussion

Based on the literature, we hypothesized that relying on cues, especially on trigger events, would effectively support the development of automaticity. While this was supported by the data, participants using trigger events as cues tended to forget more often – adherence was better with reminders. This is not surprising, as habits take time to develop [17]. Nevertheless, the four weeks of the study were long enough to observe that automaticity developed faster for participants using trigger events than those relying on a reminder. Participants from reminder groups reported the lowest automaticity scores, which suggests that while reminders helped them remember the task and stay engaged with the study, the task did not become a habit, as habit strength is associated with high automaticity of behavior [11, 17, 32]. Since the automaticity was lower than in the control group, it could be argued that, in this case, reminders might have hindered habit development. As participants learned to rely on reminders and respond only when prompted, they had no reason to try to remember on their own.

We also hypothesized that positive reinforcement would support the development of automaticity regardless of the type of cues, but the opposite turned out to be true: groups without positive reinforcement had better results. As the messages were inspired by [10], some participants might have found their enthusiastic nature too annoying, which might have influenced the results. Moreover, since they were automatic (although delivered with a delay), they might have been perceived as not genuine. The technical issues reported above might also have had an impact on the results but these seem unlikely to explain why positive reinforcement messages had the small but opposite effect to the one we predicted. Indeed, as the role of positive reinforcement in habit formation is to support repetition, the aim was to acknowledge that a lunch report was received and to evoke positive feelings; occasional missed messages did not interfere with this aim, as being rewarded (i.e. receiving positive reinforcement) was not the participants' goal. As participants were interested in understanding their eating habits, intrinsic motivation was already present, which could explain the lack of effect of confirmation messages.

The choice of a trigger task also might have influenced the outcomes of the study. It could be argued that the task was artificial, however, while texting after lunch is not something people would want to turn into a habit, in this case it was linked with specific benefits. Participants were motivated to report their lunches to uncover their eating patterns; the more information they provided, the more useful their weekly lunch summaries were. Moreover, the fact that the task was not a "real" habit further emphasizes the benefits of event-based cues and suggests that they may be even more effective when the task is meaningful and people are trying to develop a new, desirable habit.

Conclusion

Results show that while event-based cues supported the development of automaticity, it might develop too slowly to make this approach effective on its own. On the other hand, time-based cues (reminders) kept people engaged and helped them repeat the behavior. However, they could hinder the development of automaticity as people learn to rely on reminders instead of trying to remember by themselves. In addition, positive reinforcement messages appear to be ineffective. The process of habit formation is complex and the results suggest that people could benefit from more support. Smartphone apps, with their ubiquity, personal nature and capabilities, have the potential to help.

STUDY II: REVIEW OF HABIT FORMATION APPS

Hundreds of habit formation apps are currently available and can be downloaded with a single click. Results of our previous study and existing design recommendations for designing apps that support users' daily routines [29] suggest that effective apps should allow users to select trigger events that would serve as cues and help maintain repetition until a habit is formed. However, habit formation apps have not been evaluated by academic researchers and their effectiveness or theoretical grounding are not known. Therefore, we conducted a study to investigate what functionality they offer. As habit formation is part of a broader behavior change process, the study explored whether the apps were grounded in both habit formation and behavior change research.

Method

The keyword "habit" was used to search for habit formation apps in the UK version of Apple iTunes Store (http://www.apple.com/itunes/) and Google Play (https://play.google.com/store/apps). The search was conducted in April 2014 and returned 859 apps (553 for iPhones and 306 for Android phones). Results were scanned to identify apps designed specifically to support the development of new habits. The following types of apps were excluded as they did not support habit formation: habit cessation apps, general behavior change apps, food and activity trackers, exercise routines, books about habits, and research apps that require registration codes. Apps for tablets and apps not available in English were also excluded. In the end, 115 apps were selected as relevant: 54 Android apps and 67 iPhone apps. Six apps were available for both platforms, but since they had identical descriptions, they were counted only once.

A list of feature categories was created based on descriptions of 20 identified apps (10 from each app store). App features were listed in detail and grouped into 14 broader feature categories. These categories were later used in the main data collection phase and for each of the 115 identified apps their presence was noted. Supporting features, such as backups, data export or password protection, were also noted, but were excluded from the analysis as they were not directly related to habit formation.

To assess whether the apps support habit formation, we coded for whether the features of the apps supported the use of contextual cues, helped to form implementation intentions or provided positive reinforcement. The assessment was done by the first author and discussed with colleagues. Next, since habit formation is a part of the wider behavior change process, features were also matched with corresponding behavior change techniques from Behavior Change Techniques Taxonomy [3, 20]. Based on the Taxonomy, a list of techniques that could be delivered by smartphone apps was created. Items from the list were then matched with functionality by the first author. To validate the results, matching techniques were presented as a list to two other researchers who were asked to independently match them with functionality by selecting up to three techniques that could be supported by each feature.

Findings

Functionality

Figure 3 summarizes feature categories of the 115 identified habit formation apps. The most popular feature was task tracking, i.e. recording daily whether a task has been completed; it was available in 77% of the apps. Forty apps (35%) allowed users to set overall goals that could be achieved through development of specific habits (e.g. if writing a book was a goal, new habits included waking up early, writing for an hour every day, etc.) and 26 apps (23%) provided options for tracking the progress towards the overall goal, such as progress bars. Graphs and stats (36%) and calendars (31%) were also available to help users monitor their behavior.

Apps also offered features that encourage repetition: reminders (44%), game elements such as points and rewards (17%), peer support and feedback (6%) or visual cues on the smartphone's home screen (3%). To keep users engaged, they allowed them to add notes (16%) and pictures reminding of the task (9%), and enter statements about the goal or read motivational quotes (9%). Some apps (15%) also provided a library of habits, where users could select a predefined habit or find an inspiration of what type of habits they could develop and how best to define them.

Only three apps (3%) focused on helping people define contextual cues and fit the new habit into their daily routine. Two apps provided a step-by-step guidance to help users develop a morning routine (e.g. 1. wake up, 2. meditate, 3. eat breakfast, 4. write for an hour). The third app closely followed recommendations from the literature: for each habit, users had to specify a cue (e.g. waking up), a new routine they wanted to develop that was linked to a trigger event (e.g. reading a book after eating breakfast) and a way they would reward themselves for completing the task (e.g. by eating a piece of chocolate). However, the app still provided tracking options and users were expected to record and track their behavior.

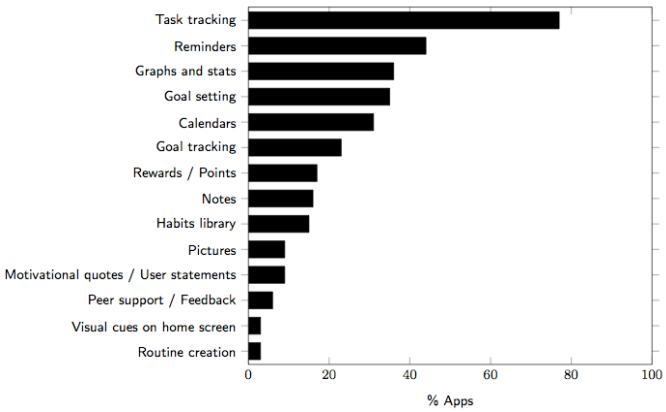

Figure 3. Functionality of habit formation apps (N=115)

Habit Formation Support

When assessed against the habit formation literature, only a few features of habit formation apps provided relevant support (see Table 2 overleaf). Literature and Study I suggest that contextual cues, trigger events and, to a lesser extent, positive reinforcement support habit formation; features that could support these factors were generally lacking.

Among features that did support habit formation, those providing positive reinforcement were the most common, even though it is the least important factor in the development of automaticity and made no difference in Study I. Some apps provided features that could serve as cues to action, although they were mostly smartphone-based (e.g. memorable pictures, icons). They made the new behavior depend on the presence of the smartphone instead of helping users build associations between the task and contextual cues. Explicit routine support and features that help to select meaningful cues to action and form implementation intentions were seldom available, even though this is the most important factor in supporting habit formation.

Behavior Change Techniques

Table 2 also presents apps functionality with corresponding behavior change techniques (and examples of apps that provide these features). The majority of apps focused on supporting self-monitoring: tracking own behavior and receiving feedback. Users were able to record each time they completed the task, view how many times they did it in the past without any breaks or track their progress towards goals. While self-tracking plays an important role in the behavior change process [2], it does not support habit formation and it does not help to embed the new behavior into a daily routine. Moreover, it is only effective if the monitoring behavior is maintained and once the tracking and monitoring stops (e.g. when the app stops working or users get bored) the behavior can revert to pre-intervention levels [14, 15, 22].

Apps also provided features that help to maintain motivation, such as positive reinforcement, goal setting, rewards and incentives, and positive self-talk. High motivation is

Functionality	Habit formation elements	Behavior change techniques	Examples apps
Task tracking	-	Self-monitoring, Feedback on behavior	Daily Habit[a]
Reminders	-	Prompts / cues	Healthy Habits[i]
Graphs & stats	-	Feedback on behavior and its outcomes, Self-monitoring	Way of Life[i]
Goal setting	-	Goal-setting	HabitFlow[a]
Calendars	-	Feedback on behavior, Self-monitoring, Goal-setting	Habit Calendar[a]
Goal progress tracking	-	Feedback on outcomes of behavior, Self-monitoring	Strides[i]
Rewards / points	Positive reinforcement	Rewards & incentives	Habit RPG[ia]
Notes	-	Prompts / cues	Any Habit[i]
Habits library	-	Goal-setting, Action planning	The Fabulous[a]
Pictures	Cues	Positive self-talk, Rewards & incentives, Prompts / cues	The Habit Factor[ia]
Motivational quotes / own statements	Positive reinforcement	Positive self-talk, Rewards & incentives	Good Habit Maker[i]
Peer support / feedback	-	Social support, Feedback on behavior	Lift[ia]
Visual cues on home screen	Cues	Prompts / cues, Feedback on behavior	3 Week Habit[a]
Routine creation	Implementation intentions	Action planning, Goal-setting	Habitual Free[i]

Table 2. Apps functionality with corresponding elements of habit formation, behavior change techniques, and examples of apps that provide such functionality. Apps marked with *i* are available for iOS and with *a* for Android phones.

needed to start the new behavior and continue repeating it; however, the role of motivation decreases as the behavior becomes automatic [21, 35]. The presence of these features suggests that apps were designed to support motivation, and as a result, habit support was seldom available.

Discussion

The functionality review showed that apps primarily focused on providing features that support self-tracking; they did not seem to be designed to explicitly support habit formation. Self-monitoring is important in the early stages of the behavior change process and is often used in interventions [9] as it helps people understand their behavior, set realistic goals, monitor progress and maintain motivation [2, 25]. However, it does not help them form associations between the task and the environment, nor does it support the development of automaticity. Using the app to track their own behavior may help users see trends, but there is a danger that it might also teach them to depend on technology. Presence of reminders also teaches users to rely on them, as does positive reinforcement. Because of this dependence, apps that require constant engagement might hinder the development of automaticity of behavior.

Only five out of 14 identified feature categories could be matched with factors supporting habit formation and only one of them – routine creation – could help users to find the right trigger event. At the same time, all features could be matched with behavior change techniques, which is encouraging, but also suggests a lack of understanding of habit formation and its role in supporting behavior change.

GENERAL DISCUSSION

We have reported the results of a 4-week study exploring how different types of cues and positive reinforcement influence the development of automaticity, together with a functionality review of 115 habit formation apps. Results of Study I show that while the use of event-based cues supported the development of automaticity, relying on time-based cues helped participants stay engaged and supported repetition. However, reminders did not provide any incentive for participants to try to remember to complete the task. The positive reinforcement we provided appeared to be ineffective. Our second study revealed that habit formation apps are not grounded in the habit literature; instead, they tend to provide functionality to enable tacking of task completion and reminders. In their current form, habit formation apps do not support habit formation. However, apps do have the potential to do so if they are designed to support identification of and reliance on trigger events rather than reliance on reminders and tracking.

Due to the choice of the trigger event (eating lunch), Study I could be seen as a simulation of a food tracking app. The Control and N&PR groups resemble 'standard' tracking apps where users need to report completion of their task, while Reminder and R&PR groups imitate a tracking app with reminders. Trigger and T&PR groups could be seen as habit formation apps based on implementation intentions (our review highlighted that only three apps offered that type of functionality). As habit formation support and technology solutions in both studies were similar, combined results provide insights into how to design better apps.

Design Guidelines for Habit Formation Apps

In this section, we provide explicit guidance for the design of future habit formation apps:

Support trigger events. Allow users to form implementation intentions and explicitly ask them to select trigger events, e.g. "I will do X after eating breakfast" (see [29] for more information on how this could be done). Monitor their behavior by asking later if the task was completed. If users keep forgetting, suggest selecting a different trigger event.

Use reminders to reinforce implementation intentions. Remind users of their implementation intentions in advance by sending notifications *before* their selected trigger actions, e.g. "Please remember to do Y after brushing your teeth" or "Don't forget to do Z before going to sleep". This could help users form associations between the task and its trigger, and would encourage them to remember on their own. To ensure users do not become reliant on notifications, they should phase out with time.

Avoid features that teach users to rely on technology. Reminders and self-tracking teach users to rely on the technological solution and can interfere with the process of developing associations between contextual cues and the task. They should not be used in habit formation apps as they hinder the process of habit formation.

Limitations and Future Work

On average, it takes 66 days to form a habit [17]. However, simple tasks become automatic quicker than complex actions. We assumed that sending an SMS was simple enough to observe an increase in automaticity in only four weeks. While our assumption turned out to be correct, future work in this area should validate the results over longer periods.

The positive reinforcement we provided was not effective, possibly due to the way it was delivered or its content. Technical issues experienced during the first two weeks of the study might also have had an impact by reducing the efficacy of our interventions. We decided to analyze the full study data because most participants received most of the messages. Removing participants who had not received all text messages from the data set would have made it difficult to compare positive reinforcement conditions with others. It would also require limiting data from the whole study to just two weeks, which is too short a period to measure the impact on habit formation. Moreover, data would have been confounded by the fact that the study had already been running for two weeks. While habits can form without explicit positive reinforcement [17], understanding its links with intrinsic rewards and the development of automaticity requires further studies.

CONCLUSIONS

This paper makes three contributions that are of interest to the CHI community. First, we show how reminders and trigger events influence habit formation. Secondly, we highlight the fact that currently available habit formation apps are not grounded in the habit literature and do not help users associate their new behavior with trigger events. Finally, we present design guidelines for technology-based behavior change interventions that support habit formation.

Developing automaticity of a new behavior can help to ensure that the change will have long-lasting results. As habits are an important part of behavior change, we need to better understand how the mechanisms of habit formation can be facilitated by mobile technologies. We have presented the results of two studies exploring how technology could support habit formation and outlined design guidelines that can help us move away from self-tracking and reminders. By supporting contextual cues and implementation intentions, apps and other behavior change technologies could help users develop new long-lasting habits.

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