Towards better medication adherence apps: Preventing forgetfulness by facilitating the formation of routine-based remembering strategies

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Declaration

I, Katarzyna Stawarz, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Forgetfulness is one of the main causes of unintentional non-adherence. While different types of adherence technologies exist that aim to address this issue, people still forget to take their medications. This thesis shows that adherence apps could effectively support long-term regimens by facilitating the formation of medication routines based on multiple contextual cues.

The first part of the thesis explores common remembering strategies and examines existing smartphone apps. It shows that people who are successful in remembering their medications tend to rely on daily routines and other contextual cues to help them remember. However, currently available medication reminder apps do not support people in adopting these strategies. Similarly, apps intended for supporting habit formation—that could help people to stay adherent to long-term regimens—ignore the importance of contextual cues, even though their presence is essential in order to develop a habit.

Starting a new regimen relies on prospective remembering, while ongoing adherence depends on the presence of habitual behaviour—both of which can be supported by contextual cues. Therefore, to extract requirements for adherence apps grounded in users' everyday behaviour, the second part of the thesis investigates the important characteristics of successful contextual cues. The findings show that not all cues that facilitate habit formation can also support prospective memory. As a result, to help develop medication habits, remembering strategies should be made of multiple interconnected cues, with a daily routine event as the main component.

Through a series of empirical studies, this thesis shows that the selection of the right cue is key in ensuring long-term adherence, and highlights the need to account for prospective remembering in future habit formation theories. It ends with a set of design requirements, illustrated with examples, for apps that facilitate the formation of routine-based strategies that support the development of medication habits.

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Contributing publications

My research has been disseminated through the publications presented here. At the beginning of each chapter (from Chapter 3 onwards), using the short reference numbers listed below, I list specific publications to which the studies reported there contributed.

Journal papers

[J.1] **Stawarz, K.M.**, Rodríguez, M.D, Cox, A.L. & Blandford, A. (2016). Understanding the role of contextual cues: Design implications for medication adherence technologies that support remembering. *Digital Health*, 2:1-18.

[J.2] Vincent, C.J., Niezgen, G., O'Kane, A.A. & **Stawarz, K.M.** (2015). Can standards and regulations keep up with health technology? *JMIR mHealth and uHealth*, 3(2):e64.

[J.3] Rodríguez, M.D., Zárate, E., **Stawarz, K.M.**, García-Vázquez, J.P., Ibarra, E.J.E. (2015) Ambient Computing to Support the Association of Contextual Cues with Medication Taking. *Revista Mexicana de Ingeniería Biomédica*, 36(3):193-209.

Conference papers, peer-reviewed

[C.1] **Stawarz, K.M.**, Cox, A.L. & Blandford, A. (2015). Beyond self-tracking and reminders: Designing smartphone apps that support habit formation. In *Proc. CHI 2015*. ACM Press.

[C.2] **Stawarz, K.M.**, Cox, A.L. & Blandford, A. (2014). Don't forget your pill! Designing effective medication reminder apps that support users' daily routines. In *Proc. CHI 2014*. ACM Press.

Workshop papers, peer-reviewed

[W.1] Stawarz, K.M., Cox, A.L. & Blandford, A. (2014). Personalized routine support for tackling medication non-adherence. *Workshop on Personalizing Behavior Change Technologies, CHI 2014.*

[W.2] Stawarz, K.M. & Cox, A.L. (2013). How technology supporting daily habits could help women remember oral contraception. *1st Workshop on Habits in Human-Computer Interaction. British HCI 2013.*

Extended abstracts, peer-reviewed

[E.1] Stawarz, K.M., Cox, A.L. & Blandford, A. (2016). Understanding the role of contextual cues in supporting the formation of medication-taking habits. *Front. Public Health. Conference Abstract: 2nd Behaviour Change Conference: Digital Health and Wellbeing.*

Contents

List of Tables

List of Figures

Chapter 1

Introduction

This chapter:

- ❖ Motivates the research question and outlines the methodology used to answer it.
- ❖ Defines key terms used throughout the thesis.
- ❖ Outlines the structure of the thesis and introduces my contribution to knowledge.

1.1 Motivation and the research question

Medication non-adherence reduces the effectiveness of a treatment and increases healthcare costs (Hughes, Bagust, Haycox, & Walley, 2001; WHO, 2003), yet people continue to not take their medications as prescribed. Adherence rates across regimens oscillate around 50% (Haynes, McDonald, & Garg, 2002; Kardas, Devine, Golembesky, & Roberts, 2005; Osterberg & Blaschke, 2005), even though, depending on the condition, they should be no lower than 70-90% for the medication to stay effective (Peterson, Takiya, & Finley, 2003).

Non-adherence can be caused by different factors. Many patients make a deliberate decision to modify or discontinue their treatment (intentional non-adherence; Clifford, Barber, & Horne, 2008; Horne, Weinman, & Hankins, 1999), while others can become non-adherent because of factors beyond their control (unintentional non-adherence; Horne et al., 2005; Johnson, 2002; Lehane & McCarthy, 2007), even when they want to take their medications as prescribed. For

example, even if women want to avoid pregnancy and are aware of the consequences of not taking the contraceptive pill regularly, they can still forget (Black, Gupta, Rassi, & Kubba, 2010; Jones, Darroch, & Henshaw, 2002; Smith & Oakley, 2005). As a result, approximately one million unwanted pregnancies reported each year are caused by irregular use or discontinuation of oral contraception regimens (Black et al., 2010; Rosenberg & Waugh, 1999; Smith & Oakley, 2005).

Forgetfulness is one of the main causes of unintentional non-adherence (Unni & Farris, 2011). However, the majority of adherence interventions focus on intentional non-adherence to treatment for life-threatening chronic conditions such as diabetes, cancer or HIV/AIDS (Haynes, Ackloo, Sahota, McDonald, & Yao, 2008; WHO, 2003), especially among older adults (Wu & Ozok, 2009). As a result, unintentional non-adherence and preventative therapies are largely unattended, even though preventative therapies are more difficult to remember: there are no symptoms that could serve as additional reminders (Park & Kidder, 1996). Interventions that explicitly address forgetfulness are few and far between, and tend to focus on reminders alerting patients (mainly older adults and the chronically ill) to take their medications at a specified time (Haynes et al., 2008; Vervloet et al., 2012). Similarly, researchers working on novel approaches to supporting patients' memory also use reminders as their primary tools (e.g. Dalgaard, Gronvall, & Verdezoto, 2013a; de Oliveira, Cherubini, & Oliver, 2010; Lee & Dey, 2014; McGee-Lennon, Wolters, & Brewster, 2011; Rodríguez, García-Vázquez, & Andrade, 2011; Siek et al., 2011). However, while reminders are effective for short-term regimens (Vervloet et al., 2012), their effectiveness and salience decrease with time (Tobias, 2009), which makes them less reliable as a memory aid for long-term medications.

Remembering long-term regimens is a two-stage process. At the beginning it relies on prospective memory, i.e. a set of cognitive processes that regulate the formation, retention, and retrieval of intended actions at a particular point in the future (Ellis, 1996). With time, however, a regular medication regimen can become part of a daily routine (Johnson, 2002; Park & Kidder, 1996). Prospective memory research shows that tasks associated with existing routine events are easier to remember (Guynn, McDaniel, & Einstein, 1998), which helps to maintain higher adherence (Johnson, 2002; Park & Kidder, 1996). Such tasks can also provide additional support to those on preventative therapies or with asymptomatic conditions, who cannot rely on the symptoms as additional cues (Park & Kidder, 1996). In addition, memory cues such as preceding actions or surrounding objects facilitate the process of habit formation: with time the elements of the environment start to drive the behaviour, making it automatic (Lally & Gardner, 2011; Neal,

Wood, Labrecque, & Lally, 2012). This is especially beneficial for long-term regimens where a daily pill needs to be taken for years. However, while relying on routine events is effective and can facilitate habit formation, the automaticity of habits can introduce new vulnerabilities.

As habits depend on a stable environment and contextual cues, disruptions to the routine increase the likelihood of omission and repetition errors (Einstein, McDaniel, Smith, & Shaw, 1998), especially when the behaviour is automatic and enacted mindlessly (Bargh, 1994). This highlights the opportunity for adherence technologies: instead of providing simple timed alerts, they could facilitate the formation of medication routines and guard against the limitations of automaticity. Smartphones in particular are well suited to this task, as their ubiquity combined with their functionality (apps, automated sensing, Internet access, etc.) and personal nature make them an effective platform for delivering health interventions (Fjeldsoe, Marshall, & Miller, 2009; Klasnja & Pratt, 2012; Ventä, Isomursu, Ahtinen, & Ramiah, 2008; Vervloet et al., 2012). Therefore, the aim of this thesis is to answer the following research question:

> **How can smartphone apps support the creation of reliable routine-based remembering strategies that lead to the formation of medication habits?**

Addressing this research question requires a good understanding of people's existing behaviours, their needs, and tools that are already available to them, as well as a deeper knowledge of relevant concepts: habits, routines, cues. Therefore, I have taken a mixed-methods approach to investigate various aspects of my research question from different perspectives. I discuss my approach in the next section.

1.2 Methodology and scope

A mixed-methods approach is widely used in Human-Computer Interaction (HCI) research (van Turnhout et al., 2014, 2013). It allows researchers to combine the strengths of qualitative and quantitative methods, which gives a more complete view of the problem space and leads to stronger understanding of the research question (Creswell, 2014; Robson, 2011). As the approach helps to address complex issues (Robson, 2011), it has value in tackling real world problems such as understanding the role of contextual cues in preventing forgetfulness and gathering requirements for routine-based adherence apps. Therefore, to answer the research question, this thesis combines the following quantitative and qualitative methods:

Online surveys provide quantitative data describing how people remember medications and in what circumstances they forget, how important daily routines are for them, and what technology they use to help them remember. They also identify the characteristics of good cues and effective remembering strategies.

Reviews of existing smartphone apps and their customer reviews provide insights into what features are currently available and how apps support memory and daily tasks, whether they meet users' needs, and what could be improved to ensure that routine-based remembering strategies are supported.

Longitudinal experimental studies investigate the process of habit formation and the role of contextual cues, and compare them with standard reminders commonly used in adherence and habit formation apps.

Situated study with semi-structured interviews conducted with people who have started a new medication regimen show how people choose cues and develop effective remembering strategies, and what influences this selection process.

The rationale for each method is discussed in more detail in their corresponding chapters.

I am primarily interested in supporting preventative long-term therapies. The goal of such therapies is to maintain the current state of health and, as a result, often there are no visible physiological symptoms that could provide additional internal cues. Therefore, adherence to regimens such as oral contraception depends on people's own memory and external cues. Understanding the role of such cues is one of the goals of this thesis. I also focus on younger populations as they are more likely to use apps (90% of 16-24 year olds and 87% of 25-34 year olds in the UK own a smartphone; Ofcom, 2015) and thus are the potential audience for the type of technology I propose in the final chapters.

1.3 Definitions

Throughout the thesis I make a distinction between *routines*, *habits*, and *habitual tasks*. While among lay audiences *routines* and *habits* are often used interchangeably, I use the latter term to refer to a specific type of learned automaticity (Gardner, 2014; habits and their characteristics are described in detail in Chapter 2.3). In contrast, I use *routine* to describe regular behaviours or sequences of tasks. While habits are automatic and often mindless, routines are not: getting

ready for work each morning is a routine, but automatically going to the bathroom to brush one's teeth is a habit. In addition, prospective memory research defines *habitual tasks* as regular actions that can be guided by contextual cues (Meacham & Singer, 1977; prospective memory is described in Chapter 2.2). In other words, they are regular—often routine—tasks that could be turned into habits and become automatic, e.g. taking daily medications.

The adherence literature distinguishes between *adherence*, *compliance* and *concordance*. Each has a slightly different meaning: *adherence* is defined as the extent to which person's health-related behaviour corresponds with agreed recommendations from a health provider (WHO, 2003); *compliance* accentuates the role of the physician as a person who devises the treatment to which patients need to comply (Myers & Midence, 1998); and *concordance* focuses on a wider context, from prescribing to general patient support in medication-taking (Horne et al., 2005). However, people can forget their medications regardless of their relationship with the healthcare system, whether they or someone else devised the regimen. Therefore, for consistency and clarity, I use *adherence* as an umbrella term throughout the thesis.

1.4 Thesis structure

This thesis consists of eight chapters. **Chapter 2** discusses related research. It starts by introducing medication non-adherence and its causes, factors that support remembering, and strategies people develop to remember their medications. Adherence technologies, including apps, are also described. As long-term medications rely on conscious remembering at the beginning of a regimen and later can become part of a routine, the role of prospective memory and habits in supporting medication regimens is described next. Behaviour change and habit apps are also described, as they could inform the design of apps that facilitate the formation of medication habits. The chapter concludes by highlighting the need for adherence apps grounded in people's everyday behaviours, which lays the foundations for my work.

Chapters 3-6 describe studies conducted to answer the research question. **Chapter 3: Exploring remembering strategies**, describes online surveys I conducted to investigate how people remember their medications and in what circumstances they forget. The first survey focuses on remembering oral contraception, as the Pill represents a simple, long-term, habitual regimen adhered to by a population likely to use smartphone apps. Next, I describe two other surveys: one I conducted with parents administering antibiotics to their children, and another one con-

ducted with older adults with chronic conditions. The surveys allow me to compare strategies developed to remember a single-dose habitual regimen with strategies used to remember more complex regimens that involve multiple doses and multiple medications. The chapter highlights the use of the same contextual cues across regimens and the low uptake of adherence apps.

Chapter 4: Evaluation of existing smartphone apps presents functionality reviews of medication reminder apps and habit formation apps to understand how they currently support memory and repetition, and whether they provide features that take advantage of contextual cues people commonly use. I also analyse customer reviews of the most popular medication reminder apps to identify users' pain points and unmet needs. The chapter shows that both adherence apps and habit formation apps rely on reminders or self-tracking; neither provides features that encourage the use of routine events as cues to action.

To help understand which factors supporting habit formation should be exploited in adherence apps, **Chapter 5: Developing habits in the real world** describes two longitudinal experimental studies that investigate the impact of contextual cues and positive reinforcement on adherence and automaticity of behaviour, and compares them with reminders. Even though contextual cues should effectively support both prospective remembering and habit formation, the studies show that this is not always the case: routine events support habit formation better than reminders, but the opposite is true for adherence. This highlights the limitations of habit research: it is not clear what constitutes good cues and what influences their selection.

Chapter 6: Developing reliable remembering strategies investigates cues in more detail to understand the characteristics of good strategies that can support everyday remembering from the start and habit formation in the long term. It describes two studies: a retrospective analysis of strategies reported by the most adherent participants from Chapters 3 and 5, and a 3-week situated study with participants who have started a new vitamin regimen. The combined results show that precise multi-cue strategies are the most effective at supporting adherence and making vitamins part of a daily routine, but their formation requires trial and error as people often do not understand which cues will work best.

Chapter 7: General discussion summarises the key findings by highlighting my contribution to medication adherence, habit, and HCI research. It also discusses how the findings can be applied when designing routine-based adherence apps that help people form medication habits, and demonstrates the implementation of proposed design recommendations through two working examples. The thesis ends with **Chapter 8: Conclusions**.

1.5 Contribution

The primary contribution of my thesis is a better understanding of the critical role of contextual cues and reminders in supporting long-term habitual behaviours such as medication-taking. In contrast with prospective memory and habit research that highlights the importance of routine events and other contextual cues (Lally & Gardner, 2011; Park & Kidder, 1996), I demonstrate that not all cues support both remembering and habit formation equally well. While contextual cues can facilitate the development of new habits, the automaticity of behaviour develops too slowly to guide it from the start and prevent forgetting until it becomes part of a daily routine. I also show that while commonly used timed reminders support prospective memory well, they can hinder habit development. This means that if the goal is short-term repetition without the need for a long-term habit, reminders can be useful. However, if the goal is to adhere to a long-term medication regimen, contextual cues need to support both adherence and habit development from the start. Therefore, contrary to the notion that anything can be a habit cue, as long as it is regularly encountered (Gardner, Abraham, Lally, & de Bruijn, 2012; Wood & Neal, 2007), my work shows that only specific event-based cues that are a part of a well-defined remembering strategy can guarantee that a behaviour will be regularly repeated from the beginning and become part of a daily routine. This has implications for future habit formation theories.

Based on my findings, I argue that the consistency of prospective remembering influences the process of habit formation: prospective memory cues can help to associate the behaviour with its trigger and thus enhance the process of habit development. At present, repetition, contextual cues and positive reinforcement are seen as the key factors supporting habit development, and habit researchers also acknowledge the influence of intentions and motivation (Lally & Gardner, 2011). But just as motivated patients can forget to take their medications, people motivated to develop a new habit can also forget to enact the behaviour. Therefore, future theories of habit formation should take into account the role of prospective memory.

My findings have implications for researchers working in the areas of medication adherence, habit formation (including wider behaviour change research) and HCI, whose goal is to help people repeat a new behaviour and turn it into a habit. Therefore, the applied contribution of my work is a set of design recommendations and working implementation examples that will help researchers and developers produce apps that facilitate the creation of reliable routine-based remembering strategies that support habit formation.

Chapter 2

Background and related work

This chapter:

- ❖ Summarises relevant adherence research and describes existing phone-based adherence technologies and interventions.
- ❖ Discusses prospective memory research related to remembering medications.
- ❖ Summarises relevant habit research, including technologies designed to help people start and maintain a new behaviour.

The aim of this thesis is to investigate how smartphone apps could facilitate the formation of reliable routine-based remembering strategies in order to help people take their medications on time and develop medication habits. This chapter summarises relevant research that lays the foundation for my work. It starts with an overview of different types of non-adherence, factors influencing forgetfulness, and people's strategies for avoiding it. It also describes existing phone-based adherence technologies and interventions. As the focus is on long-term medication regimens, it is important to understand the characteristics of such regimens: at the beginning they heavily depend on memory and conscious remembering, but as the person becomes used to the medication schedule, medication-taking can become ingrained in the daily routine. Therefore, the chapter discusses next the role of prospective memory and habit formation in supporting long-term regimens. It concludes by highlighting the limitations of existing technologies and the need for adherence support that is grounded in theory and people's everyday practices.

2.1 Medication non-adherence

Medication non-adherence is a problem. It reduces the effectiveness of a treatment and imposes a financial burden on health care systems (Hughes et al., 2001; WHO, 2003). In the UK alone, the National Health Service (NHS) spends over £500 million every year because of patients' non-adherence (PharmaTimes Online, 2013), and the estimated cost of non-adherence in the US reaches $100 billion each year, including the cost of 10% of hospital and 23% of nursing home admissions (Vermeire, Hearnshaw, Van Royen, & Denekens, 2001). Yet, typical adherence rates are low (Haynes, McDonald, & Garg, 2002), including adherence to treatment for life-threatening and chronic conditions, e.g. 43% for asthma (Reid, Abramson, Raven, & Walters, 2000), 25-51% for hypertension (WHO, 2003), and 37-83% for AIDS/HIV, depending on the drug or the studied population (WHO, 2003). The situation is similar with clinical trials, where adherence rates vary between 43-78%, despite the selection and close monitoring of participants (Osterberg & Blaschke, 2005). Medication adherence rates for acute treatment are usually higher compared to chronic conditions (Osterberg & Blaschke, 2005), although they are still low, e.g. mean adherence to antibiotics is around 62% (Kardas et al., 2005). Non-adherence is also a problem for other types of medical treatment, including preventative therapies. For example, approximately 20% of unwanted pregnancies in the US are caused by non-adherence to contraception (Jones et al., 2002; Rosenberg & Waugh, 1999).

For the treatment to be effective, adherence rates need to be higher than typical rates highlighted above. The cut-off point usually falls between 70-90%, depending on the study and the condition (Peterson et al., 2003). Some clinical trials specify acceptable adherence rates as above 80%, although for serious infections like HIV, acceptable rates need to be higher than 95% (Osterberg & Blaschke, 2005). However, even though high rates are important, obtaining reliable measures is difficult (Myers & Midence, 1998).

Adherence can be measured in different ways, although each method has its limitations (see Table 2.1). One of the most popular and easiest to use method is self-reporting, often in a form of interviews, questionnaires, or diaries. However, patients tend to under-report their non-adherence (Wagner & Rabkin, 2000). Reasons for that vary from conscious deception to forgetting how often they forget their medications (Myers & Midence, 1998), although when reporting instances of non-adherence, patients are often accurate (Cramer, 1991). Objective measures, such as blood and urine tests or the assessment of patient's clinical response can be

Table 2.1: Methods of measuring adherence

Method	Advantages	Disadvantages
Patient questionnaires, self-reports and diaries	Simple, inexpensive, easy	Unreliable, prone to distortions, especially with increases in time between visits
Observations	Most accurate	Patients can hide pills in their mouth instead of swallowing; impractical for routine use or with outpatients
Blood and urine tests	Objective	Expensive, invasive; impractical for outpatients; not reliable for short-lived medication
Pill counts	Objective, quantifiable, easy	Unreliable, easily altered by patients, no guarantee that pills were digested
Prescription refills data	Objective, easy	Unreliable, no guarantee that medication was digested
Assessment of the patient's clinical response	Easy to conduct	Confounding factors: non-adherence is not the only thing that may affect the clinical response
Electronic medication monitors	Precise, quantifiable, additional information about medicine taking patterns	Expensive, data may be altered by patients (possible to remove multiple doses at one time), no guarantee that medication was digested

used to detect traces of medicine or metabolite in the patient's body, are more accurate, but also invasive, expensive, and impractical for short-lived medications (Osterberg & Blaschke, 2005). Pill counts and electronic medication monitors can provide quantifiable measures, although there is no guarantee that patients actually digest their medication and the data can be easily altered. Reliability of measures therefore depends on the type of non-adherence.

2.1.1 Intentional and unintentional non-adherence

There are different types of medication non-adherence. It can start even before the person visits a pharmacy: primary non-adherence, a situation where patients fail to redeem their prescription in the first place, affects an estimated 15% of patients (Beardon, McGilchrist, McDevitt, & MacDonald, 1993). However, redeeming the prescription is just the first obstacle. Once patients obtain their medications, they may still fail to adhere to their regimen (Johnson, 2002; Lehane & McCarthy, 2007; Lowry, Dudley, Oddone, & Bosworth, 2005): they may consciously decide to modify or discontinue their treatment (intentional non-adherence), or they can become non-adherent because of factors beyond their control (unintentional non-adherence).

Intentional non-adherence is often caused by the avoidance of side effects, people's beliefs, and medication-related concerns (Clifford et al., 2008; Horne & Weinman, 1999; Horne et al., 2005, 1999; Rosenstock, 1974). These beliefs and concerns can arise from the lack of understanding of the illness or the treatment (Horne et al., 2005), and can be influenced by a cost-benefit analysis of the treatment and its side effects (Horne et al., 2005; Rosenstock, 1974). According to the

Necessity-Concerns Framework (Clifford et al., 2008; Horne et al., 1999), beliefs about the necessity of taking medications and concerns people have about them can predict non-adherence: when people do not trust the treatment or do not think they need it, they will not adhere to it. From a patient's perspective, such behaviour is reasonable. Leventhal's Common Sense Model (Leventhal, Brissette, & Leventhal, 2003) shows that people are "common sense scientists" who draw conclusions and plans for managing the illness based on their understanding of several factors: symptoms, internal and external causes of the illness (e.g. infections and genes), expected duration of the illness, severity of pain and its impact on their daily life, and whether the illness was perceived as preventable, curable or controllable. Therefore, when patients believe that side effects outweigh the benefits of the treatment or that treatment is taking too long because the illness should have been cured by now, they may modify the regimen or stop taking their medications altogether and turn to alternative treatments that are perceived as more appropriate (Leventhal et al., 2003). Other factors that can influence patients' behaviour and lead to intentional changes in regimen include: low levels of support from family, friends, and healthcare providers (DiMatteo, 2004; Horne et al., 2005); the quality of communication with the physician (Zolnierek & DiMatteo, 2009); or patient's self-identity in relation to the illness and the treatment (Horne et al., 2005). However, even if none of these factors negatively influences people's attitudes, they may still fail to stay adherent for reasons beyond their control.

Unintentional non-adherence can be caused by the inability to access medications (e.g. they are unavailable at the local pharmacy), unclear communication with the health practitioner, misunderstanding the regimen (Johnson, 2002; Lehane & McCarthy, 2007), or deficiencies in memory or dexterity (Horne et al., 2005). Such practical barriers can also lead to intentional non-adherence in the long term, as taking medications as prescribed requires more effort and relies on motivation to overcome the obstacles (Chaptman et al., 2015). According to the Perceptions and Practicalities Approach (Horne, 2001), perceptual factors, such as preferences or motivation, and practical factors, such as person's capabilities and available resources, influence adherence (Chapman et al., 2015). As a result, people can be non-adherent intentionally and unintentionally to the same medication regimen at different times (Chapman et al., 2015; Clifford et al., 2008; Horne, 2001). But just as unintentional non-adherence can lead to the intentional one, the opposite is also true, albeit to a lesser extent. One's beliefs can lead to unintentional non-adherence, as people with unresolved concerns are more likely to report forgetting (Unni & Farris, 2011) and their lower motivation to take medications means that they are less likely to put effort into developing a reliable remembering strategy (Horne, 2001).

2.1.2 Forgetting to take medications

Forgetting is often caused by the lack of attention or a memory failure (Barber, 2002; Reason, 1990). It accounts for the majority of cases of unintentional non-adherence and can affect anyone, including people who would like to stay adherent. For example, Unni & Farris (2011) conducted a cross-sectional study of adult US population with 420 participants taking cholesterol-lowering medications and 399 taking asthma medications. Their results showed that forgetting due to a busy schedule was the main reason of unintentional non-adherence (other barriers included running out of prescription, medications not being available at a local pharmacy, inability to open the container or to swallow the pill): it was reported by 33% of their cholesterol group and 52% of the asthma group. The second biggest reason was running out of prescription (reported by 24% and 42% of participants, respectively), which might also have been related to forgetfulness, although the authors did not investigate the reasons for not renewing the prescription.

There are several aspects of a medication regimen that people can forget (Asai et al., 2011): they can forget to take medications on time; to anticipate taking medications, e.g. forgetting to pack them when going away on holidays or whenever there is a change in a daily routine; to prepare medications for future use, e.g. forgetting to order prescription refills; or they can forget their regimen, e.g. the number of doses per day, a number of pills per dose, whether medications can be mixed with others or taken with food. In addition, people may forget whether they have already taken their dose by confusing the intention to take it with a memory of taking it earlier (Bargh, 1994; Einstein et al., 1998; Johnson & Raye, 1981).

The first type of forgetting—to take medications on time—is the most prevalent, as it can occur even if a person remembers the regimen and has medications at hand. This type of forgetting takes place when people fail to correctly carry out an intended action (Ellis, 1996), usually an automatic routine task (Barber, 2002), or when their cue appears at a time or in a context where they are not able to act immediately and must delay the action (Einstein, McDaniel, Manzi, Cochran, & Baker, 2000). In general, people forget to take medications as planned because they are busy, absorbed with other tasks, distracted, ill or anxious, or because their routine changes and their memory aid fails to remind them (Maylor, 1990).

The type of condition can influence the likelihood of forgetting. As symptoms can serve as internal reminders, e.g. inflamed skin or pain may remind the patient that it is time to take medications, adherence is higher among patients with visible symptoms. For example, those

taking thyroid medications (physiological visible symptoms) forget less often compared to people taking hypertension medications, who have no symptoms (Park & Kidder, 1996). This also explains why preventative therapies such as oral contraception are difficult to remember: there are no reliable internal cues.

The characteristics of a regimen can also make forgetting easier. Adherence declines as the number of daily doses increase (Claxton, Cramer, & Pierce, 2001; Greenberg, 1984; Kardas, 2002) and therefore complex, multi-dose regimens are difficult to remember. Irregularities of the regimen can also increase chances of forgetting. For example, some types of oral contraception ("the Pill") need to be taken every day at the same time for 21 days followed by seven pill-free days before a new pack can be started (a "21/7" regimen). Women can take the Pill up to 12 hours late each day without compromising its effectiveness, although this advantage is counterbalanced by disruptions to the routine caused by pill-free weeks, which significantly increases chances of forgetting during the first week after the break (Aubeny et al., 2002, 2004). In contrast, a different, single hormone Pill does not require any breaks: it has to be taken every day, ideally within a 3-hour window if it is to remain effective. Even though this regimen is stricter than the 21/7 regimen, the lack of breaks makes it easier to remember (Aubeny et al., 2004).

Forgetting to take medications on time is often caused by the disruptions to the daily routine (Barber, Safdar, & Franklin, 2005; Reach, 2005), e.g. unexpected events like a hospital admission, or simply being away from home, being in a rush, or leaving earlier than usual. Sometimes the difference between weekdays and weekends is enough to cause forgetting, as routines can vary (Barber et al., 2005). As the task is repeated and becomes habitual, it is increasingly more difficult to remember whether the task has already been completed, which also increases the likelihood of repetition errors (Einstein et al., 1998). At the same time, reliance on routine events and contextual cues can make remembering easier, and the lack of an established medication-taking routines is often associated with poor adherence (Rosenberg, Waugh, & Meehan, 1995). For example, women for whom taking oral contraception is not a part of a daily routine are 3-4 times more likely to miss a Pill than those with existing routines (Rosenberg, Waugh, & Burnhill, 1998; Rosenberg et al., 1995; Smith & Oakley, 2005). Thus, embedding medication-taking within daily activities can be effective and is one of the most common strategies people develop to help them take their medications on a regular basis.

2.1.3 Remembering to take medications on a regular basis

Consistent long-term adherence is a habitual behaviour (Vrijens, Urquhart, & White, 2014). Medications can become part of a daily routine, as people often have to take them regularly and within a particular period of time. By doing so they learn to associate their medications with specific times (morning, evening, etc.), events (eating breakfast, brushing teeth, etc.), or locations (e.g. kitchen, bathroom). These patterns of behaviour form over time and are guided by the physical environment and temporal rhythms of the day (Palen & Aaløkke, 2006). They are unique and reflect people's lifestyle and daily activities, and the associated cues make it easier to remember to take medications regularly (Johnson, 2002).

Similar to knowledge being distributed across teams and their tools (Hollan, Hutchins, & Kirsh, 2000; Hutchins, 1995), people tend to "distribute" their memory and offload it into the environment (Gilbert, 2015a,b; Henry, Rendell, Phillips, Dunlop, & Kliegel, 2012). For example, using calendars, post-it notes, schedules or checklists can be an effective way of managing one's regimen (Wilson & Park, 2008); even more so, when medication timetables include routine events such as wake up time or meals (Morrow et al., 2012), as their presence strengthens the associations between the pills and everyday behaviour. Older adults also tend to use pill organisers, as they help to remember which pills they need to take and when, and to check whether a medication has already been taken (Cramer, 1991; Gabriel, Gagnon, & Bryan, 1977; Park & Kidder, 1996; Wilson & Park, 2008). Moreover, leaving medication boxes or medications themselves in routinely visited places as part of a tailored remembering strategy has a positive effect on adherence (Insel & Cole, 2005). Their presence can serve as a visual cue reminding that they need to be taken (Palen & Aaløkke, 2006) or an indicator that it has already been done, e.g. turning over pill bottles right after taking the tablet (O'Quin, Semalulu, & Orom, 2014). Their placement may also provide additional information regarding the order in which multiple medications need to be taken (García-Vázquez, Rodríguez, Andrade, & Bravo, 2011). Packaging and design features such as days of the week printed on oral contraception blister packs can provide further cues and help with remembering whether a Pill has already been taken (Cramer, 1991).

However, this overview of effective remembering strategies is based on research conducted primarily with older adults; it is not clear whether these behaviours are universal. Relevant research with younger populations is scarce and their preferences tend to be considered in the context of their future needs (McGee-Lennon et al., 2011). When the focus is specifically on young populations and their current needs, research is seldom concerned with their existing behaviour.

For example, while several studies have investigated how women remember oral contraceptive pills and why they are non-adherent (Aubeny et al., 2002, 2004; Rosenberg & Waugh, 1999; Rosenberg et al., 1995) or how specific action plans (e.g. "When I put my mascara on, I will take my Pill from my make-up bag") could support adherence (Martin, Slade, Sheeran, Wright, & Dibble, 2011), none of them investigated existing remembering strategies developed outside the intervention or without prompts from the clinicians. Neither did they look at technologies that support remembering. For example, while studies evaluated the impact of a specific technology during an intervention aiming to increase adherence to the Pill regimen (e.g. Hou, Murwitz, Kavanagh, Fortin, & Goldberg, 2010), at the time of writing there were no studies that evaluated the technologies selected by women themselves.

The lack of information about users' everyday practices can have a negative effect on the technologies designed for this group (Rogers, Sharp, Preece, & Tepper, 2011). However, understanding their behaviour does not always guarantee that it will be reflected in the design or features provided by technology. Despite a rich body of research on how people remember medications summarised above, adherence technologies—including those designed specifically for older adults—do not support the common remembering strategies described earlier.

2.1.4 Adherence interventions and technologies

Several interventions have been devised over the past years to address the problem of non-adherence. However, their effectiveness is questionable. Systematic reviews of existing interventions consistently show that many are largely ineffective (Haynes et al., 2008; Haynes, McDonald, Garg, & Montague, 2002; Horne et al., 2005; Peterson et al., 2003; Roter et al., 1998). They tend to have a narrow focus, take a "one size fits all" approach, and lack theoretical grounding (Horne et al., 2005). Interventions explicitly addressing forgetfulness are not only few and far between, but also tend to focus on reminders alerting people to take their medications at a specified time (Haynes et al., 2008; Vervloet et al., 2012), which is in opposition to common remembering strategies described in the previous section.

Many interventions use text messages (SMS or short message service) as the main tool for supporting adherence. For example, SMS have been used to support paediatric asthma patients by increasing their awareness of the condition and its symptoms (Yun & Arriaga, 2013; Yun et al., 2012), to support weight loss and healthy behaviour (Gerber, Stolley, Thompson, Sharp, &

Fitzgibbon, 2009), to facilitate smoking cessation (Obermayer, Riley, Asif, & Jean-Mary, 2004), to remind repeated non-attenders about their medical appointments (Fairhurst & Sheikh, 2008), to remind adolescents about their contraceptive Pill and send educational messages encouraging regular use (Castaño & Martínez, 2007), and to send adult women daily reminders about their oral contraception (Hou et al., 2010). However, while text messages can successfully support interventions aimed at intentional non-adherence and raise patients' awareness (e.g. mentioned above Gerber et al., 2009; Yun & Arriaga, 2013; Yun et al., 2012), they are not flexible enough to support remembering in the context of busy everyday life. It is also difficult to establish whether they provide any benefits. For example, Hou et al. (2010) provided daily SMS reminders for 3 months to help 82 women remember the Pill. Despite the reminders, their adherence was no better than the control group's. Moreover, more than a third of participants reported that they also used additional reminders, usually an alarm clock on their phone, which suggests that simple SMS notifications were not sufficient. While there is evidence that reminder-based approaches can be effective in the short term (Vervloet et al., 2012), there is no guarantee that they can also support long-term regimens, as patients who are initially adherent can become non-adherent over time (Vrijens, Vincze, Kristanto, Urquhart, & Burnier, 2008).

HCI researchers have been investigating how technology could better support patients and fit into their lives, although the focus was mainly on older adults with chronic conditions. For example, DwellSense (Lee & Dey, 2014) shows usage statistics and missed doses on an ambient display; the goal is to maintain people's motivation. Colorado Tablet (Siek et al., 2011) allows older users and their carers to track doses, check medication information and prepare for doctor visits. None of the systems described above explicitly supports people's everyday behaviours or usual remembering strategies. The closest to supporting daily routines are Ambient Information Systems (García-Vázquez et al., 2011; Rodríguez et al., 2011) that display the number of doses already taken directly on medication containers and thus can fit into users' existing activities. However, while the early evaluation suggests that it might be effective, the system is a prototype and, apart from a small feasibility study (Rodríguez, Zárate, Stawarz, García-Vázquez, & Ibarra, 2015), it has not been tested with users.

Context-aware reminders have also been investigated as a tool for supporting medication adherence. Rather than providing alerts at a predefined time, such systems notify users only in specific circumstances, e.g. they warn users when they leave the building without taking their medications or when they are past their normal medication-taking time (Asai et al., 2011; Singh

& Varshney, 2014; Varshney, 2013). There is evidence that context-aware reminders can improve adherence in the short term (Singh & Varshney, 2014), although it is not clear whether they can effectively support long-term regimens as they do not help users form routines. Moreover, while they are more flexible than standard timed alerts and can intervene when users' routine changes (Asai et al., 2011), they cannot always recognise the whole context (Zhou, Chu, Yu, & Kim, 2012), which can reduce their utility.

Commercial adherence technologies also do not support common remembering strategies. Even though they come in many shapes and sizes—from complex medication management systems that can hold over a month's supply of medications and dispense them when necessary (Philips, n.d.; PivoTell, n.d.) to smart augmented containers that remind about missed doses and track adherence (PillDrill, Inc., n.d.; Vitality, n.d.)—their primary feature are timed reminders. While these devices are often designed with chronically ill patients and older adults in mind, they are not grounded in adherence research and do not take into account the strategies developed by their target populations.

Overall, regardless of whether they address intentional behaviour or factors beyond one's control, interventions and technologies devised by researchers often do not help people form medication habits. Novel adherence technologies are regularly designed and evaluated (e.g. Dalgaard, Gronvall, & Verdezoto, 2013b; Lee & Dey, 2014; Rodríguez et al., 2011; Siek et al., 2011), but the evaluations are short and the proposed solutions are hardly ever informed by the real-world use of the technologies people select for themselves. The situation is not much different for medication adherence apps.

2.1.5 Smartphone apps and remembering to take medications

According to the latest statistics, 93% of the UK adults own a mobile phone and 66% own a smartphone (Ofcom, 2015). This high uptake of mobile devices, combined with easy access to thousands of health-related apps (iMedicalApps, 2015), smartphones' personal nature (Ventä et al., 2008) and their capabilities make them an effective platform for delivering health interventions (Fjeldsoe et al., 2009; Klasnja & Pratt, 2012; Vervloet et al., 2012). However, the majority of adherence apps lack theoretical grounding and were designed without input from experts (Subhi, Bube, Rolskov Bojsen, Skou Thomsen, & Konge, 2015). Despite their potential benefits, they should be used with caution.

Over the past few years, several reviews of general health apps or broader adherence apps have been conducted (see for example: Dayer, Heldenbrand, Anderson, Gubbins, & Martin, 2013; Hussain et al., 2015; Kamel Boulos, Brewer, Karimkhani, Buller, & Dellavalle, 2014; Morrissey, Corbett, Walsh, & Molloy, 2016; Obiodu & Obiodu, 2012). However, until recently, medication reminders, i.e. apps designed specifically to help people remember to regularly take their medications, have not been assessed in detail. A review of the top 500 medical apps available in Italian app stores (Obiodu & Obiodu, 2012) identified 58 "health diaries" that included "medication scheduling apps", but no further information about these apps was provided. Another review (Dayer et al., 2013) described over 160 medication adherence apps available for different types of smartphones, and although medication reminders were included, the focus was on addressing intentional non-adherence and evaluating the apps from a pharmacist's perspective. Despite the lack of any formal evaluation of apps' effectiveness or an assessment of relevance to users' needs, authors concluded that these apps had potential to help with medication regimens.

This lack of understanding of what functionality medication reminder apps offer and how they support the habitual nature of medication-taking motivated the app review described in Chapter 4.1 (which I published in 2014; see [C.2] on the list of my publications on page 9). More recently, several relevant studies have become available: Gal, Zite, & Wallace (2015) reviewed the functionality of 39 dedicated oral contraception reminder apps; Heldenbrand et al. (2016) reviewed 367 medication reminder apps and tested the usability of 77 of them; Choi, Lovett, Kang, Lee, & Choi (2015) reviewed the literature on adherence apps to analyse pros and cons of available applications; and van Kerkhof, van der Laar, de Jong, Weda, & Hegger (2016) reviewed apps and other e-tools that support adherence to medications for chronic conditions. In addition, Morrissey et al. (2016) reviewed behaviour change techniques used in 166 medication adherence apps, concluding that some were based on valid behaviour change techniques such as action planning. However, even these techniques were implemented through the use of reminders. Overall, these newer studies showed that commercial apps primarily provide timed alerts, are simple, and offer little more than a smartphone's alarm clock; support for routine events and contextual cues is not available. As the results reported by Gal et al. (2015) and Heldenbrand et al. (2016) are consistent with findings described in Chapter 4.1, I discuss them there in more detail.

Rather than evaluating existing apps, some HCI researchers have proposed their own solutions. For example, Silva, Mouttham, & El Saddik (2009) designed a medication reminder app that allowed users to enter multiple medications, showed due times and taking instructions, and high-

lighted overdue doses. It did not differ much from commercial apps (Gal et al., 2015; Heldenbrand et al., 2016) and like them did not provide routine support. De Oliveira et al. (2010) took a different approach. Their app, MoviPill, used game elements to help participants develop medication routines: participants had to compete with their peers by taking medications on time and their adherence scores were displayed on a shared leader board. However, as the focus was on winning the game and taking medications at a specific time—rather than simply taking them every day—routines were not sufficiently well defined and users needed their own reminders to "win" the game. Even though their evaluation study showed an improvement in adherence and accuracy of the medication intake time, the app was tested with only 18 users for six weeks; whether it helped to develop routines is not known. Nevertheless, MoviPill showed that reminders do not have to be the main feature in adherence technologies—even though they almost always are.

Adherence interventions and apps designed to prevent forgetting tend to rely on reminders (Gal et al., 2015; Heldenbrand et al., 2016; Vervloet et al., 2012), even though timed alerts have several limitations. In the long-term, the need to respond to precise alerts and daily schedules might have a negative impact on people's attitudes towards technology, inducing the feeling of being under surveillance and having little control over one's health (Lupton, 2014). People find them disrupting, even when they acknowledge that they are useful (Mehrotra, Pejovic, Vermeulen, Hendley, & Musolesi, 2016)—and disruptive notifications are likely to be immediately dismissed, especially when they arrive while users are engaged with other tasks (Mehrotra et al., 2016).

While reminders can effectively remind about one-off or irregular tasks, they are not the best solution for long-term regimens; using them as the default approach highlights the lack of understanding of the processes governing medication-taking. Long-term regimens rely on prospective remembering at the beginning and on the development of a habit once the behaviour becomes part of a routine—both can be effectively supported without reminders. To understand the reasons and implications of that, the next two sections describe the role of prospective memory and habit formation in medication-taking.

2.2 Medication-taking as a prospective memory task

Remembering to take medications on time relies on prospective memory (Zogg, Woods, Sauceda, Wiebe, & Simoni, 2012), i.e. a set of cognitive processes regulating the formation, retention, and

retrieval of intended actions at a particular point in the future (Ellis, 1996; Kliegel, McDaniel, & Einstein, 2008). Prospective memory includes both retrospective and prospective components (for remembering what needs to be done and when; Arnold, Bayen, & Smith, 2012); I focus only on the prospective part, as it is responsible for remembering to take medications as scheduled.

Prospective memory develops in early years and then declines with age (Maylor, Darby, Logie, Della Sala, & Smith, 2002; Maylor, 1990). Prospective memory failures are therefore often influenced by age (Craik, 1986); however, age differences in performance are mainly recorded in lab experiments (Tobias, 2009) and disappear when the task is completed as part of a daily routine. Naturalistic studies show that sometimes older adults' performance is better compared to younger populations (Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997; Rendell & Craik, 2000), possibly because they tend to have more structured daily life (Freeman & Ellis, 2003).

Several other factors influence prospective remembering: the length of the delay between the intention and action, presence of incentives, task importance (Hering, Phillips, & Kliegel, 2013; Kliegel, Martin, McDaniel, & Einstein, 2001), the strength of the intention ("I must" vs. "I may"), emotional salience (Altgassen, Phillips, Henry, Rendell, & Kliegel, 2010; May, Manning, Einstein, Becker, & Owens, 2014; Phillips, Henry, & Martin, 2008; Rendell et al., 2011), workload, frequency of the behaviour (Andrzejewski, Moore, Corvette, & Herrmann, 1991), and perceived benefits of a successful outcome or potential consequences (Altgassen et al., 2010; Ellis, 1996; Kliegel et al., 2001, 2008; Rendell et al., 2011). The perceived importance has the greatest influence on tasks that have to be completed at a specific time (Kliegel et al., 2001). This suggests that tasks completed as part of a routine or done in response to events are easier to remember regardless of the strength of the intention, which has implications for remembering long-term medication regimens.

2.2.1 Remembering prospective memory tasks

Prospective memory research distinguishes between episodic and habitual tasks (Meacham & Singer, 1977). Episodic tasks are infrequent or irregular and depend on remembering to carry out the planned action, e.g. posting a letter on a way to work. Habitual tasks, on the other hand, are regular actions that can be guided by spatial and temporal cues in the environment, e.g. brushing one's teeth or taking long-term medications. The type of task to a degree determines the most effective types of cues.

Prospective memory relies on the identification and recognition of cues (Graf, Uttl, & Dixon, 2002). Based on the type of primary cue, tasks can be further divided into time-based tasks and event-based tasks. Time-based tasks are tasks that need to be completed at a specified time (e.g. "turn the oven on at 5 p.m.", "take the pill at 9 a.m.") or after a set time has elapsed (e.g. "turn the oven off in 2 hours time", "take antibiotics every 8 hours"). They mostly rely on internal cues and self-initiated monitoring (Einstein & McDaniel, 1996) and as a result require more cognitive processing, which increases the likelihood of forgetting (Park & Kidder, 1996).

Event-based tasks need to be completed when a specific trigger event occurs, e.g. going shopping while passing by a grocery store or passing on a message when a colleague returns from a meeting. To improve the performance and better support remembering, time-based tasks can often be turned into event-based tasks ("take the pill with breakfast" instead of "take the pill at 9 a.m."), as event-based tasks require less self-initiated retrieval (Einstein & McDaniel, 1996). The reliance on a routine action has a positive impact (Meacham & Leiman, 1982; Meacham & Singer, 1977), as regular events guide the behaviour by providing cues and preventing forgetfulness (Park & Kidder, 1996). Some researchers also distinguish activity-based tasks as a subtype of event-based tasks (Kvavilashvili & Ellis, 1996; McDaniel & Einstein, 2007), i.e. tasks that have to be completed before or after a certain activity takes place, although all event-based tasks happen in response to an event that serves as a cue.

2.2.2 Prospective memory cues

There are several ways of categorising prospective memory cues that can help to identify effective strategies for remembering habitual tasks. Based on their source, cues can be grouped into internal, e.g. one's own thoughts, symptoms; external, e.g. diaries, notes, alerts, meaningful objects; or paired with an event that serves as a trigger to action, e.g taking medications with meals (Henry et al., 2012). External and event-based cues are more effective than internal cues (Maylor, 1990), as they help people offload their memory into the environment (Gilbert, 2015a,b; Henry et al., 2012) and remove the need for constant remembering (McDaniel & Einstein, 2000). As a result, linking tasks to daily routines and using contextual cues can effectively support prospective remembering, especially when the task is habitual.

People use external cues to free cognitive resources (Hollan et al., 2000; Hutchins, 1995). They do so when they believe that their memory is poor or that they need extra support, regardless of

their actual ability to remember (Gilbert, 2015b). This is especially beneficial when one has to remember something while the ongoing task is distracting (Gilbert, 2015a; Maylor, 1990) or when an established routine needs to be overridden, e.g. remembering to buy bread on the way home (Intons-Peterson & Fournier, 1986). People also tend to use external cues such as reminders when there is a long interval between intention and action, e.g. remembering a doctor's appointment in a week's time; when the task has to be done at precisely the right time, e.g. removing cake from the oven after 40 minutes or taking a medication at exactly the same time every day; or when there is no time to properly encode the intention, e.g. leaving a printed report on the desk so it reminds about the need for action (Intons-Peterson & Fournier, 1986). However, a series of controlled experiments exploring everyday remembering, conducted with a total of 369 students, showed that despite benefits of external cues and their perceived dependability, reliance on them could make remembering strategies vulnerable, as it increased the odds of forgetting if the cue was not encountered (Intons-Peterson & Fournier, 1986).

Prospective memory cues can also be grouped based on their pervasiveness or distinctiveness. Cues that become visible at the right time (as opposed to the ones that are constantly visible) are more effective as they attract attention at the right moment (Vortac, Edwards, & Manning, 1995; Zogg et al., 2012). Similarly, distinctive cues that stand out (as opposed to nondistinctive cues that blend with the environment) are also easier to notice and thus are more effective at prompting memory (McDaniel & Einstein, 1993). Reminders are a good example of cues that become salient when needed (if set for the right time) and that stand out from the environment. They are especially beneficial for episodic time-based tasks and are equally useful for people of all ages (Henry et al., 2012), although pervasive and distinct cues in general work well for all age groups (McDaniel & Einstein, 2000; Rendell et al., 2011).

However, reminders are not always the best solution. While some studies demonstrate their effectiveness in supporting prospective memory (e.g. Einstein & McDaniel, 1990), other research shows no benefits (e.g. Guynn et al., 1998; Morita, 2006; Vortac et al., 1995), although prospective memory studies are often lab experiments and thus may not always be applicable to naturalistic settings. Nevertheless, there is evidence that people who expect to be reminded score worse in prospective memory tests (Schæfer & Laing, 2000), as they put less mental effort into trying to remember and therefore are more likely to forget. In addition, the effectiveness and salience of reminders decreases with time (Tobias, 2009). It makes them less reliable for long-term regular tasks as they can become too familiar and people can learn to ignore them (Tobias, 2009).

Based on their content, prospective memory cues can also be divided into those that refer to both the cue and the task (e.g. "I need to take my pill after I eat my breakfast"), refer only to the cue (e.g. "breakfast") or refer only to the intention (e.g. "take the pill"). Even though cues that simply remind that something needs to be done can be useful (Fish et al., 2007), the first group is the most effective in supporting prospective remembering (Guynn et al., 1998; Morita, 2006) as it makes clear what needs to be done and when (Kliegel et al., 2008). Such action plans, also known as implementation intentions, strengthen the connection between the task and its cue (Gollwitzer, 1999). Their format—"When situation X arises, I will perform response Y"—helps to link the behaviour with the right cues and increases the likelihood of the action being completed (Gollwitzer, 1999), especially when the trigger is an existing routine.

Implementation intentions are especially useful when remembering habitual tasks, such as taking daily medications. Every repetition reinforces the relationship between the intention and the environment, which leads to a more efficient action initiation in the future and an increase in automaticity of the behaviour (Gollwitzer, 1999). As a result, implementation intentions have been successfully used to support many health-related behaviours, including regular intake of vitamin supplements (Sheeran & Orbell, 1999) and oral contraception (Martin et al., 2011). There is evidence that using reminders to reinforce implementation intentions ("plan reminders"; Prestwich & Kellar, 2014; Prestwich, Perugini, & Hurling, 2009, 2010) can improve task recall and strengthen the associations between the task and its cues. For example, Prestwich and colleagues compared SMS-based plan reminders with other types of cues (regular SMS reminders, motivational messages, etc.) to encourage regular exercise (Prestwich et al., 2009) and brisk walking (Prestwich et al., 2010). Their research showed that combinations of SMS reminders and implementation intentions were more effective than either technique alone.

However, despite clear benefits of implementation intentions, when initiating the task is easy from the start, their presence does not provide any additional benefits (Gollwitzer & Brandstätter, 1997). This suggests that in the context of medication-taking, implementation intentions and plan reminders might be the most effective at the beginning of a new regimen, before the behaviour turns into a habit.

2.3 Medication-taking as a habitual task

To form a new habit or, more broadly, to change one's behaviour, an individual needs to make a decision and turn the intention to act into an action, which then must be repeated until the new behaviour becomes the norm. Several theories and cognitive models explain this process in detail, but—like adherence research focusing on the impact of intentions—they overemphasise the role of motivation. For example, the transtheoretical model of behaviour change (Prochaska & Velicer, 1997) describes stages through which people have to progresses to intentionally change their behaviour; the self-efficacy theory (Bandura & Adams, 1977) states that people's beliefs about their ability to change influence their motivation and determine whether they will take action and change their behaviour; the self-determination theory (Ryan & Deci, 2000) focuses on motivation and highlights competence, relatedness, and autonomy as main factors influencing self-motivation; and the theory of planned behaviour (Ajzen, 1991) draws connections between people's behaviour and their beliefs, arguing that their attitudes and perceived control influence intentions and determine whether they may change their behaviour. But many people with good intentions fail to act on them.

Orbell & Sheeran (1998) explored the uptake of cervical screening test among women who had never had one and discovered that only 57% of those who had planned to get tested within a year actually did so. It is no surprise then that only about 25-35% of variance in behaviour can be predicted by intentions (Armitage & Conner, 2001; Godin & Kok, 1996); previous behaviour is a better predictor (Gollwitzer, 1999). Focusing on motivations, beliefs, and readiness to change disregards the importance of subconscious processes, automatic behaviour, and mindless repetition of behaviours deeply ingrained in everyday lives (Pinder, 2013). People are creatures of habit: it is estimated that we undertake 45% of our behaviours in the same place every day (Quinn & Wood, 2005 in Neal, Wood, & Quinn, 2006) and 95% of our behaviour is governed by "cognitive unconscious" processes (Lakoff & Johnson, 1999) that are quick, holistic, stimulus bound, and based on heuristics (Evans, 2008). In other words, we let habits drive our behaviour.

2.3.1 Habits

Habits play an important role in supporting long-term changes in behaviour, from increasing physical activity (Lally & Gardner, 2011) to starting and maintaining a new medication regimen (Vrijens et al., 2014). There are two distinct, complementary views of habits: psychology defines

them as learned automatic cue-response actions (Gardner, Sheals, Wardle, & McGowan, 2014), while from the sociology perspective they are routine practices (Darnton, Verplanken, White, & Whitmarsh, 2011).

When viewed as automatic actions, habits can be understood as an effect of gradual learning of patterns of behaviour. They are triggered by strong associations between the task or its features and the environment (e.g. physical location, preceding actions), especially when tasks are regularly performed in a sequence (Gardner, 2012; Wood & Neal, 2007). Habits are represented mentally as goal-action pairs controlled by the contextual cues, and the strength of the association depends on the frequency of the behaviour (Aarts & Dijksterhuis, 2000). However, the frequency is not enough to establish whether the behaviour is habitual or a result of a deliberate action (Ajzen, 2002; Tobias, 2009; Verplanken, 2005, 2006); and conversely, learned automatic behaviour does not need to be frequent to be considered a habit (Gardner, 2012). The automaticity is what distinguishes habits from other types of regular behaviour.

The automaticity of a habit is characterised by its efficiency, but also by its unintentionality, uncontrollability, and the lack of awareness (Bargh, 1994). Habitual actions require less deliberation and make cognitive resources available for other tasks. As a result, when engaging in routine actions, around 50-60% of the time people think about other things (Wood, Quinn, & Kashy, 2002), e.g. they think about work while eating dinner or about plans for the day while driving a car. At the same time, this automaticity can have negative consequences. Even though habits are to some extent controllable, they can sometimes "override" planned actions, which leads to action slips (Heckhausen & Beckmann, 1989; Reason, 1990), especially omission and repetition errors (Einstein et al., 1998). For example, a person who drinks tea with milk every morning might automatically add milk to a glass of orange juice; or a person who takes a pill every morning may do it automatically, forget the pill was taken, and overdose accidentally.

In contrast, when defined as routine practices, habits can be seen as independent entities that can be reproduced by individuals (Darnton et al., 2011; Røpke, 2009). Rather than being an outcome of behaviour and contextual cues, they emerge from already existing elements such as infrastructure or lifestyle, and different combinations of elements can support different practices (Darnton et al., 2011). While the right combination of cues can trigger the right automatic behaviour, according to the practice perspective the right combination of elements can enable a specific behaviour, but may not necessarily lead to it being carried out (Darnton et al., 2011). However, once the practice takes root, people can become "locked in", i.e. their choice not

to undertake a specific behaviour becomes limited due to their circumstances (Darnton et al., 2011; Sanne, 2002). For example, the more people drive to work, the less cyclist-friendly the roads become and as a result the less likely drivers are to start cycling—they become locked in commuting by car (Darnton et al., 2011) and using this mode of transport becomes their habit. This view of habits emphasises the importance of existing behaviour on the formation of new habits. However, in the context of long-term medication regimens, the first perspective—habits as a result of automatic behaviour in a stable context—is more relevant.

2.3.2 Elements of habit formation

As habits are an integral part of the behaviour change process, the steps needed to deliberately form a new habit are the same. First, an intention to take a specific action must be formed (Ajzen, 1991; Webb & Sheeran, 2006), e.g. a person decides to start a new regimen. Next, the intention needs to turn into action (Schwarzer & Luszczynska, 2008; Webb & Sheeran, 2006) and that action needs to be repeated—the person starts to take daily medications and then continues to do so consistently for several weeks. The importance of intentions decreases as the behaviour is repeated, and with time the task can be automatically completed without reconsidering its purpose (Neal et al., 2012; Orbell & Verplanken, 2010; Triandis, 1977; Wood & Neal, 2007). Finally, the behaviour must be maintained to turn into a habit and bring long-lasting change (Lally & Gardner, 2011; Lally, van Jaarsveld, Potts, & Wardle, 2010). Regular repetition in the presence of consistent contextual cues and positive reinforcement supports this process.

Repetition

To turn into a habit, a new behaviour has to be repeated. Consistent repetition strengthens the associations between available contextual cues and the task, and leads to the development of automaticity. To date only Lally et al. (2010) investigated in detail the process of habit formation. Even though their data is limited—the study lasted 12 weeks and involved 96 participants—there is evidence that it takes between 18 to estimated 254 days (median=66 days) for the behaviour to become automatic. The length of the process depends on the complexity of the task: short, simple tasks, e.g. drinking a glass of water every day, can become automatic quicker than complex tasks that require more effort and involve multiple steps to complete, e.g. regular visits to a gym. This suggests that a few weeks of medication-taking might be enough to turn it into a habit.

However, the repetition does not have to be perfect. Missing a couple of days per week does not always have a negative impact (Lally, Chipperfield, & Wardle, 2008; Lally et al., 2010), especially when the behaviour is usually repeated daily. For example, a qualitative study conducted with 10 participants showed that when people stopped repeating their activity for the weekend or when on holidays, they often resumed it after the break (Lally, Wardle, & Gardner, 2011). Even though the sample size was small and the study did not explore the continuation of habits in detail, the results suggest that the behaviour may still reactivate when the old cues are encountered again, which is supported by other habit research (see Gardner, 2012). Moreover, Walker, Thomas, & Verplanken (2014) investigated workers' commute habits 19 months before and then 1 and 4 weeks after the office move. They discovered that among people who changed their travel mode, the strength of the old habit decayed slowly. The fact that the automaticity of behaviour did not immediately disappear can explain why habits can reactivate. Nevertheless, when developing a new habit, the repetition of behaviour should be consistent, especially when the task itself is infrequent (e.g. going to the gym once a week) or the behaviour is still new (Armitage, 2005).

Contextual cues

The repetition alone is not enough to form a habit: the task needs to be repeated in a stable context. Only then the environment—including the location, objects, other people, internal states, etc.—becomes associated with past performances and starts to drive the behaviour (Ji & Wood, 2007; Lally et al., 2011; Neal et al., 2012; Verplanken, 2005; Verplanken, Walker, Davis, & Jurasek, 2008; Wood & Neal, 2009; Wood, Witt, & Tam, 2005). However, the stronger the task is associated with its cues, the more vulnerable to change it can become, and any changes to the environment (e.g. moving house) can significantly disrupt existing habits (Verplanken et al., 2008; Wood et al., 2005).

Using preceding tasks and daily routines as cues can reduce the dependence on environment, as some routine behaviours are context-independent, e.g. people may continue to brush their teeth while on holidays, even though the environment is different. Moreover, when using sequences of routine actions as a cue, each step triggers the next (Botvinick, Niv, & Barto, 2009; Graybiel, 1998), e.g. brushing one's teeth can serve as a cue to floss them (Verplanken, 2005). Therefore, the boundaries between tasks in an existing sequence are the best place to insert a new routine: the end of an action provides a strong cue and there is less competition from an established habit (Judah, Gardner, & Aunger, 2013; Lally & Gardner, 2011).

Just as implementation intentions can support remembering event-based tasks, they can also be used to strengthen the relationships between cues and the new behaviour through supporting repetition and the development of automaticity. They do not require conscious thought and enable a partial transfer of control over the behaviour from the person (motivation, willpower) to the environment (contextual cues, routines) that starts to drive that behaviour (Sheeran, Webb, & Gollwitzer, 2005; Verplanken, 2005). In this context, implementation intentions can be seen as a subtype of automaticity (Sheeran et al., 2005): researchers describe them as "strategic automaticity" (Gollwitzer & Schall, 1998) and "instant habits" (Gollwitzer, 1999), as they can be formed on the spot and immediately acted upon. As a result, unlike habits, their automaticity does not stem from mindless repetition, but rather from anticipated opportunities for completing the planned task (Oettingen, Hönig, & Gollwitzer, 2000). As they may gradually develop into a habit (Verplanken, 2005), forming implementation intentions can be an effective first step towards integrating a new behaviour into one's daily routine. Since they also support prospective memory, implementation intentions could be used to support the formation of medication habits while helping people to remember about their regimen before the automaticity develops.

Mentioned earlier plan reminders (i.e. alerts that remind about the planned action and its trigger; see page 42) can be used to reinforce implementation intentions and support habit development (Prestwich & Kellar, 2014; Prestwich et al., 2009). They have been effectively used to increase physical activity (Prestwich et al., 2010), although they have not been tested in the context of medication habits yet. Regular reminders could also support habit formation, as the automaticity of the new behaviour might develop faster than the decay of effectiveness of the reminder (Tobias, 2009). However, when a reminder—or any other type of technology or external memory aid—is used as the main cue, there is a risk that people may become dependent on it, and once this cue is gone, their behaviour might also stop. For example, a series of interviews conducted with 16 current or prior users of behaviour change apps showed that while the apps helped to repeat the behaviour and served as cues to action, when people stopped using the apps their target behaviour often stopped as well; they did not develop a habit (Renfree, Harrison, Marshall, Stawarz, & Cox, 2016).

Positive reinforcement

Another factor that can influence habit formation is positive reinforcement. Current research shows that even small successes increase the feeling of satisfaction and can strengthen the habit

(Aarts, Paulussen, & Schaalma, 1997; Lally & Gardner, 2011). The satisfactory experience can also trigger the feeling of being in control and reinforce the desire to repeat the action in the future (Aarts et al., 1997), which helps to maintain long-term change, as it reinforces the belief that starting the new behaviour was a good choice (Rothman, 2000). Therefore, identifying the execution of the task with its rewarding nature can reinforce the behaviour and support habit formation (Verplanken & Wood, 2006; Wood & Neal, 2009).

Rewards can be extrinsic (tangible), such as financial incentives, or intrinsic, such as pleasure or satisfaction (Deci, Koestner, & Ryan, 1999). The first group can be further divided depending on whether the rewards were anticipated and whether they are conditional. There is a danger that if rewards are extrinsic and expected, they will hinder habit formation by reducing intrinsic motivation (Deci et al., 1999). While extrinsic rewards can still help to develop automaticity of the behaviour (Dickinson, 1985), they may not be feasible or practical in the long term and it might be difficult to distinguish whether the action is truly habitual or whether people are engaged just to receive the reward (Lally & Gardner, 2011). Thus, extrinsic rewards are likely to facilitate habit formation only when the reward is not a goal in itself and the behaviour offers other, ideally intrinsic, benefits to the person (Dickinson, 1985; Lally & Gardner, 2011).

In the context of medication habits, positive reinforcement may be difficult to achieve, as the reward may not be immediate, and thus may not become associated with the behaviour. Preventative therapies in particular do not provide any rewards, as the maintenance of the current health level and *the lack of negative effects* is the "reward". However, while positive reinforcement can be beneficial, it does not seem to be compulsory. No positive reinforcement was used in the habit formation study conducted by Lally et al. (2010) and yet their participants formed habits. As they were able to select habits they wanted to develop, it is possible that intrinsic motivation might be enough as long as the action is repeated regularly in a stable context.

Positive reinforcement, and even more so regular repetition and contextual cues, influence habit formation and can facilitate long-term changes in behaviour. As smartphones already have capabilities to support this process, the next section describes behaviour change and habit apps to better understand whether they could support the formation of medication habits.

2.3.3 Apps for behaviour change and habit formation

Smartphone apps have a potential to support behaviour change and habit formation (Klasnja & Pratt, 2012). Users already have access to apps designed to help them make long-lasting changes in their life and develop new healthy behaviours, although it is not clear how effective these apps are. One factor that improves effectiveness of interventions is their theoretical grounding, as it helps to select the right behaviour change techniques (Webb, Joseph, Yardley, & Michie, 2010). However, the existing technology tends to be either based on inappropriate theoretical constructs that do not support habit formation or not grounded in any theory at all. For example, an analysis of 127 health and fitness apps showed that the majority of them lacked theoretical content (Cowan et al., 2013). Similarly, a content analysis of descriptions of 3,336 paid health and fitness apps largely failed to identify theory-based approaches to supporting the change in behaviour (West et al., 2012). In both studies, apps that were based on theory focused primarily on supporting initial stages of the behaviour change process and provided options that helped to teach skills, track progress, or record actual behaviour. Habit formation was not supported.

The lack of theoretical grounding is an issue not only for commercial apps. Free et al. (2013) conducted a systematic review of 26 mobile health behaviour change interventions developed by researchers. They focused specifically on studies that used mobile technologies (mobile phones, smartphones, and other hand-held devices) as the primary platform for the intervention. Only seven studies reported using behaviour change techniques (e.g. 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.

(a) UbiHealth Garden (b) Mindless Change

Figure 2.1: Examples of behaviour change apps developed by HCI researches: UbiFit Garden and Mindless Change. Reproduced from Consolvo, Klasnja, et al. (2008) and Vainio et al. (2014).

Apps developed by HCI researchers are no different. While they tend to be informed by the literature, they are not based on habit formation research and instead focus on tracking, self-monitoring and social support (Klasnja, Consolvo, & Pratt, 2011). For example, UbiFit Garden (Consolvo, Klasnja, et al., 2008; Consolvo, Libby, et al., 2008) represents users' physical activity with flowers that are displayed on an interactive wallpaper on their mobile phone (see Figure 2.1a). Different types of flowers symbolise different types of activity (e.g. walking, cardio exercises, strength training), and butterflies indicate activity goals that have been met. The app's main goal is to keep users motivated and to encourage them to cultivate the garden by taking care of themselves. A more recent example of a behaviour change app is Mindless Change (Vainio et al., 2014). The app helps users set goals and uses avatars to personalise the experience and maintain the motivation (see Figure 2.1b). However, despite its name, it does not facilitate the development of automatic behaviour, nor does it encourage the use of contextual cues. While both apps support regular repetition, neither supports habit formation.

HCI research (e.g. Consolvo, McDonald, & Landay, 2009; Oinas-Kukkonen & Harjumaa, 2009) has proposed requirements for designing behaviour change technologies. While some of the design guidelines are valid (apps should be useful, give users control, and should not interrupt their everyday life or cause them to feel uncomfortable), they also emphasise the need to maintain interest with an app over time. This highlights the perceived importance of sustained engagement and the weakness of current apps' designs: their effectiveness depends on regular and prolonged interaction (Oinas-Kukkonen, 2012). However, this approach is not effective in the long term: once self-monitoring stops, the target behaviour tends to return to its initial levels (Klasnja et al., 2011; Kopp, 1988; Nelson, 1977). Moreover, users tend to abandon apps (Shevchik, 2013; Web, 2011) and once they stop regularly engaging with them, they can also stop engaging with the new behaviour (Renfree et al., 2016).

To address the limitations of existing behaviour change and habit formation technologies, Pinder, Vermeulen, Beale, & Hendley (2015) proposed a new approach: targeting the nonconscious systems and facilitating automatic responses. They argue that this could be achieved by triggering instincts, e.g. exercise games such as Zombies, Run! (Six to Start, 2011) elicit fear to make people run faster; or by goal priming (Aarts, Custers, & Veltkamp, 2008), e.g. showing information about desirable behaviours. However, while these are promising approaches that could support behaviour change in general through mobile phones, they are not relevant in the context of medication-taking.

Medication habits are ingrained in people's everyday lives and people already take advantage of existing routine events and cues that surround them. Behaviour change and habit apps could support this, as they are designed with regular repetition in mind and have capabilities to reinforce contextual cues (e.g. through plan reminders; see Prestwich & Kellar, 2014; Prestwich et al., 2009, 2010). However, the specific functionality they offer has not been investigated yet (at the time of writing there were no published functionality reviews of habit formation apps), and the lack of theoretical grounding implies that they do not facilitate the use of routine events and contextual cues. A different approach is needed, one that accounts for conscious remembering of a new regimen and habit formation in the longer term.

2.4 Towards better medication adherence apps

As smartphones have become ingrained in people's lives (Ofcom, 2015; Ventä et al., 2008) and apps are increasingly used to deliver health interventions (Free et al., 2013), phones have a potential to provide smarter adherence support and to help people develop medication habits. However, despite their capabilities, the support apps offer is limited. They largely focus on reminding people to take their medications at a specific time (Gal et al., 2015; Heldenbrand et al., 2016), which echoes the design of adherence interventions that also tend to be centred around timed reminders (Haynes et al., 2008; Vervloet et al., 2012). Moreover, adherence apps, as well as behaviour change apps designed to help people form new habits, are based on the premise that as long as users regularly use the app, they will continue to stay adherent, ideally indefinitely. High rates of forgetfulness show that this premise might be false.

We need a new approach—one that takes into account people's existing practices. Remembering to take medications initially relies on prospective memory, but with time may turn into a habit—both stages can be supported by routine events and other cues (Henry et al., 2012; Lally & Gardner, 2011; Park & Kidder, 1996; Verplanken, 2005). And indeed, research conducted with older adults shows that people often take advantage of daily routines and contextual cues to help them take their medications on a regular basis and prevent forgetting (Insel & Cole, 2005; O'Quin et al., 2014; Palen & Aaløkke, 2006; Tordoff, Simonsen, Thomson, & Norris, 2010). While it is not clear whether younger populations use the same remembering strategies, the literature suggests that these approaches could be beneficial to everyone who needs to adhere to a long-term regimen. Similarly, contextual cues are one of the main factors that facilitate the development

of new habits (Lally & Gardner, 2011). Therefore, by taking advantage of contextual cues that are already in use, apps could help people to both remember a new regimen from the start and turn it into a habit over time, ensuring sustained long-term adherence.

The following chapters present a series of studies conducted to understand how smartphone apps can support the creation of reliable routine-based remembering strategies that lead to the formation of medication habits. Designing apps that provide this type of support requires a better understanding of existing remembering strategies and specific cues used by people in their everyday life, outside the interventions. In addition, it is important to understand how the support for daily routines and contextual cues is currently implemented (if at all) in existing apps, as their strengths and limitations can inform the design of the new solution. My work focuses primarily on preventative therapies, as they are the most difficult to remember: there are no internal reminders and the goal is often to maintain the *status quo*. As a result, they can provide insights that will inform the design of a technology that takes advantage of external cues and existing behaviours.

Chapter 3

Exploring remembering strategies

This chapter:

- ❖ Presents an online survey that explores remembering strategies developed by 929 women who take oral contraception.
- ❖ Compares women's strategies with the results of two surveys conducted with 164 participants representing two distinct regimens: 83 parents remembering their children's antibiotics and 81 older adults with chronic conditions.
- ❖ Highlights the role of daily routines as the main component of remembering strategies and the low level of technology use across all three regimens.

Preliminary results have been published in [C.2, W.1, W.2, J.3]. *Combined full results of all surveys have been published in* [J.1].

Prospective memory and habit research suggest that relying on daily routines and other contextual cues can be an effective remembering strategy that supports medication management and can lead to the formation of medication habits. However, while studies conducted with older adults provide evidence that this is indeed the case (e.g. Insel & Cole, 2005; McGee-Lennon et al., 2011; O'Quin et al., 2014; Palen & Aaløkke, 2006), it is not clear whether existing research can be generalised to inform the design of adherence apps aimed at other populations and regimens.

In this chapter I present three online surveys that investigate strategies that support adherence to different types of medications. The first survey explores remembering strategies used by women

taking oral contraception (Survey I), as the Pill represents a long-term single-dose habitual preventative regimen. In addition, the lack of symptoms makes remembering more challenging. This user group is also likely to use smartphone apps: women aged 20-24 are the most likely to take oral contraception (FPA, 2007) and 90% of 16-24 year olds in the UK own a smartphone (Ofcom, 2015). As younger people are more willing to use adherence apps (Davies, Kotadia, Mughal, Hannan, & Alqarni, 2015), remembering strategies reported by women can inform the design of an adherence app that supports medication habits.

To validate the findings and allow for generalisations, next I describe two surveys focusing on more complex regimens. They investigate remembering strategies developed by parents to remember their children's antibiotics (representing a short-term multi-dose regimen that is often accompanied by symptoms; Survey II) and by older adults to manage their chronic conditions (representing a long-term multi-medication multi-dose regimen; Survey III). Comparing and contrasting the strategies reported by all three groups can help to better understand the role of daily routines and contextual cues in supporting medication-taking, informing future technologies. The chapter ends by highlighting the importance of routine events in medication management and emphasising the marginal role of smartphone apps as memory aids across regimens.

3.1 Remembering habitual regimens

Several studies have been conducted to investigate how women remember oral contraception and what are the reasons for their non-adherence, e.g. Aubeny et al. (2002, 2004); Martin, Slade, Sheeran, Wright, & Dibble (2011); Rosenberg & Waugh (1999); Rosenberg, Waugh, & Meehan (1995). However, existing research does not investigate remembering strategies used by women as part of their everyday life, outside research and clinical context. Neither does it look at their use of self-selected technology: while studies like Hou et al. (2010) evaluated the impact of technology during interventions aimed at increasing adherence to the Pill regimen, at the time of writing there were no studies that evaluated technologies selected by women themselves. Therefore, this study aimed to:

(i) Identify the strategies women develop to ensure they take the Pill on time and the circumstances in which these strategies fail;

(ii) Investigate what memory aids and technologies, especially smartphone apps, they use and how effective they are; and

(iii) Understand what role routines play in remembering long-term habitual regimens.

By highlighting the most important factors supporting habitual regimens, the findings will later inform the design of medication adherence apps that support people's everyday behaviour. Based on the research presented in Chapter 2, I assumed that more women would rely on daily routines and other contextual cues than on technology to help them remember their medications, and that this would be an effective strategy.

I used an online survey to gather the data. This method makes it easier to reach a large number of participants from across the country, including people with different experiences and varied lifestyles (Cairns & Cox, 2008). Of course it is difficult to control who responds to a survey (Rogers et al., 2011) and thus the distribution channels should be selected with care. However, as the target population for this study was rather large (the Pill was the primary contraception method for 47% of 1.2 million women who attended NHS community contraceptive clinics in 2012; Health & Social Care Information Centre, 2013), this was of a lesser concern. Online surveys also tend to be biased towards participants who use technology, which in this case was desirable, as one of the objectives was to understand what devices or apps women use to help them remember the Pill. By their nature, surveys rely on self-reports and when talking about adherence, people may not always be honest or accurate (Myers & Midence, 1998; Wagner & Rabkin, 2000). However, patients perceive forgetfulness as more socially acceptable than admitting intentional non-adherence (Atkins & Fallowfield, 2006; Unni & Farris, 2011) and their reports of forgetting are often accurate (Cramer, 1991). Since the study focused on forgetting and the goal was to identify remembering strategies—not to calculate exact adherence rates—the survey and self-reports were deemed a reliable source of data.

3.1.1 Method

Participants

In total, 971 women completed the survey. The majority of respondents (76%) were aged 18-25 years old, 21% were 26-36 years old. Most of them (73%) were in a relationship: dating, cohabiting, married or in a civil partnership; 27% were single. Nearly all respondents were childless (98%) and 84% were students; 81% reported that their life was busy at the time they completed the survey. A third of respondents had been taking the Pill for 3-5 years and 24% had been taking it for 1-2 years. The majority (80%) were on the 21/7 regimen (21 days followed

by seven Pill-free days) and only 17% were on the continuous regimen. Over a half (61%) could take the Pill up to 12 hours late and 12% had to take it within a 3-hour window each day.

Procedure

The survey was advertised on social networks, online forums, and among UCL students and staff. As an incentive for completing the study, participants were entered into a raffle with a chance to win one of three £25 Amazon vouchers.

Materials

The survey that was used to collect the data can be found in Appendix A. Its start page included an informed consent form and only those participants who agreed to participate were able to proceed. They were also free to withdraw at any time by closing their web browser's window. The survey consisted of three main parts. The first part included 18 questions that investigated how women remembered their contraception pills, and how often and why they forgot. The second part included the standardised 16-item self-report Prospective and Retrospective Memory Questionnaire (PRMQ; Crawford, Smith, Maylor, Della Sala, & Logie, 2003; Smith, Della Sala, Logie, & Maylor, 2000) and its results were later used to eliminate participants with memory issues or those with exceptional prospective memory who could skew the results. PRMQ questions were modified to fit into the survey form, although care was taken to ensure that the meaning of each question was not changed (see Appendix A). The third part of the survey collected demographic information and regimen details.

Analysis

Participants' PRMQ scores were compared with the control group from Crawford et al. (2003). Forty-two participants whose scores fell outside two standard deviations from the control group's score were excluded from analyses; analyses reported below are based on responses of 929 women. I used descriptive statistics to analyse the main trends and to identify types of cues used by participants, and Chi-square tests for independence to calculate differences in the effectiveness of daily routines and technology used by participants. For analyses with more than two categorical variables, Crammer's V was used to describe the effect size instead of the phi coefficient.

3.1.2 Findings

Survey I: Oral contraception. Remembering long-term single-dose regimens.

The majority of women reported relying on daily routines (61%) or said they simply "tried to remember" (52%) to take the Pill (see Figure 3.1). There was a large overlap between these two groups: 58% of women who simply remembered also said it was part of their daily routine, and 49% of women who selected daily routines also said they simply tried to remember. Remembering strategies reported by participants were linked to routine events such as waking up (33%), going to sleep (28%) or eating breakfast (6%). Women also reported keeping their pills by the bed (52%), in a bag (19%), in the bathroom (10%), or with their make-up (6%); the location (e.g. bathroom) and associated items (e.g. a purse) provided additional cues. The vast majority of respondents (90%) indicated that names of the days printed on the packaging were useful.

A quarter (24%) of women mentioned using some sort of technology as a reminder. The most common device was their phone's alarm clock (19%). Fifty-four women reported using smartphone apps (generic reminders or medication reminder apps) and 17 of them indicated that they would not be able to remember the Pill without them. This suggests that the remaining 37 women (68%) did not see them as crucial and might have used them as a backup. This is supported by the fact that 25% of women who reported the use of technology (N=223) also said that Pill-taking was part of their routine.

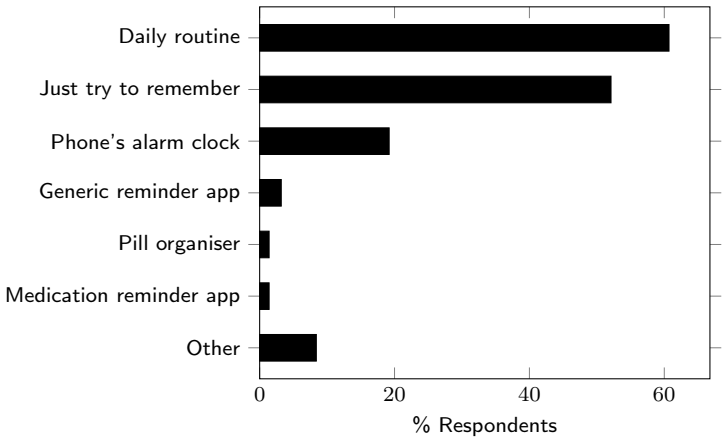
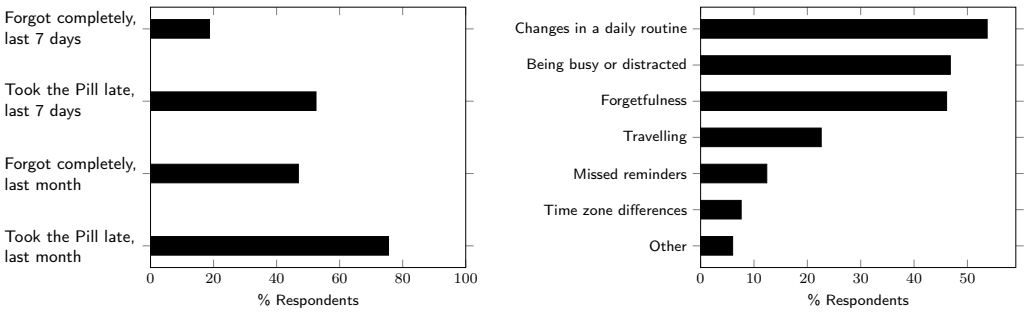


Figure 3.1: Memory aids used by women to help them remember the Pill (N=929). Multiple answers were allowed.



(a) Forgetting the Pill

(b) Reasons of forgetting

Figure 3.2: Scale of forgetting the Pill and main causes reported by participants (N=929). Figure (a) shows the percentage of participants who reported forgetting at least once when answering each question; last month figures include the week preceding the survey. Figure (b) shows the main causes of forgetting; multiple answers were allowed.

Forgetting the Pill

Several questions explored how often participants forgot the Pill (see Figure 3.2a). Respondents were asked how often they completely forgot the Pill and how often they took it late. "Forgetting completely" meant not taking the Pill on a given day at all and "being late" meant taking it later than required 12 or 3 hours, or simply later than usual, although this was not explicitly defined. Nineteen per cent of survey respondents said that during the week preceding the survey they completely forgot the Pill at least once and 53% reported taking it late. Similarly, for the month preceding the survey (including last week), nearly half (47%) reported completely forgetting the Pill at least once and 75% reported taking it late.

Reported causes of forgetting (see Figure 3.2b) highlighted the central role of routines and their context-dependence. Changes in the daily routine (54%), as well as anticipated disruptions to everyday life, such as travelling (23%) or time zone differences (8%), were reported as reasons for missing the Pill. As other reasons of forgetting, respondents reported being busy and distracted (47%), simply forgetting (46%), and missing reminders (12%).

A Chi-square test for independence was conducted to investigate whether women who took the Pill for longer forgot less often (see Table 3.1). There were no significant associations between the duration of the Pill regimen and missing doses completely. There was, however, a significant association between the duration of use and taking the Pill late: women who were taking the Pill for less than two years reported taking it late in the past week more often compared to the rest of survey respondents, although the effect size was small ($\chi^2(1,929)=13.22$, $p=.01$, Cramer's V=.12). Similarly, women who were taking the Pill for less than five years reported being late in

Table 3.1: Associations between the duration of the Pill use and incidents of forgetting, based on Chi-square tests for independence (N=929). Forgetting numbers show percentage of participants who reported forgetting at least once; last month figures include the week preceding the survey.

		Completely forgot at least once		Took the Pill late at least once	
Duration of the Pill use	N	Last week	Last month	Last week	Last month
Less than a year	150	18%	47%	61%	75%
1-2 years	225	20%	48%	59%	81%
3-5 years	304	20%	47%	50%	78%
6-10 years	192	15%	44%	45%	66%
Over 10 years	58	21%	50%	47%	74%
$\chi^2(1,929)$		3.16	1.14	13.22	14.69
p		.53	.89	.01	.005
Cramer's V		.06	.04	.12	.13

Statistically significant at $p<.05$

the past month more often than women who were taking it for longer ($\chi^2(1,929)=14.69$, $p=.005$, phi=.13).

As medication-taking is a habitual task, it was assumed that women who relied on routines would forget less often. Chi-square tests for independence were conducted to investigate how effective relying on routines was. The results showed that women for whom Pill-taking was part of their daily routine (N=565) reported forgetting less often than women who did not rely on routines (N=364); the results were statistically significant for forgetting the Pill completely and taking it late, with $p<.001$ and small effect sizes. Results of all analyses are summarised in Table 3.2.

A similar analysis was conducted to compare women who reported using apps or alarm clocks (N=210) with those who did not use any technology-based memory aids (N=719). While fewer

Table 3.2: Associations between the reliance on routines to support remembering and incidents of forgetting, based on Chi-square tests for independence (N=929). Forgetting numbers show percentage of participants who reported forgetting at least once; last month figures include the week preceding the survey.

		Completely forgot at least once		Took the Pill late at least once	
	N	Last week	Last month	Last week	Last month
Rely on routines	565	14%	41%	44%	69%
Don't rely on routines	364	27%	56%	67%	86%
$\chi^2(1,929)$		23.8	17.1	46.7	35.8
p		.000	.000	.000	.000
phi		-.16	-.14	-.23	-.20

Statistically significant at $p<.05$

Table 3.3: Associations between the use of technology to support remembering and incidents of forgetting, based on Chi-square tests for independence (N=929). Forgetting numbers show percentage of participants who reported forgetting at least once; last month figures include the week preceding the survey.

		Completely forgot at least once		Took the Pill late at least once	
	N	Last week	Last month	Last week	Last month
Use technology	210	22%	48%	61%	80%
Don't use technology	719	18%	47%	50%	74%
χ^2(1,929)		1.79	.09	7.29	2.72
p		.22	.76	.01	.10
phi		.04	.01	.09	.06

Statistically significant at $p<.05$

women who use technology reported forgetting the Pill completely during the week preceding the survey compared to non-users, the differences were not statistically significant ($\chi^2(1,929)=1.54$, $p=.215$, phi=.044 for forgetting during the past week and $\chi^2(1,929)=.09$, $p=.76$, phi=.013 for forgetting during the past month). Women who used reminders reported taking the Pill late more often than those who did not use technology, and in this case the result was statistically significant ($p=.007$) for the week preceding the survey. Results of these analyses are summarised in Table 3.3.

The presence of a routine and the use of technology were related to the duration of use: the longer women were taking the Pill, the more ingrained in their daily routine it became and the less they relied on technology-based reminders (see Figure 3.3). A Chi-square test for independence was used to check associations between the reliance on routines and the duration of Pill use.

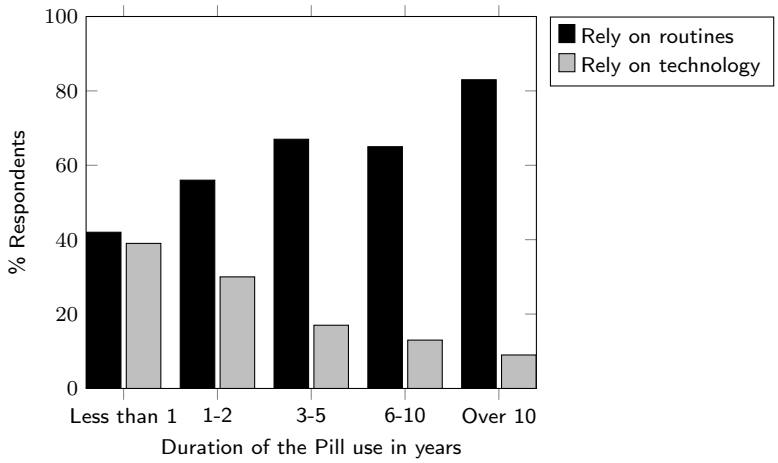


Figure 3.3: Reliance on routines and technology-based reminders among women who have been taking the Pill for different time periods.

Survey respondents were divided into two groups: women who indicated that the Pill was part of their daily routine and women who did not mention routines at all. The test showed that the association was significant, although with a small effect size ($\chi^2(4,929)=42.2$, $p<.001$ and Cramer's V=.21), suggesting that the longer women were on the Pill, the more likely they were to say it was part of their daily routine. Similarly, for the second test women were divided into those who indicated they used some sort of technology to support their memory and those who did not select any. Again, the association between the presence of technology and the length of the regimen was significant, with a modest effect size ($\chi^2(4,929)=52.7$, $p<.001$ and Cramer's V=.24), indicating that the reliance on technology was negatively correlated with the duration of Pill use: the longer women took the Pill, the less likely they were to rely on technology.

To compare the routine group and the technology group together, a Chi-square test for independent was conducted. Participants were divided into two groups: those who used technology and those who relied on routines; participants who belonged to both groups (N=51) were excluded from this analysis. The test revealed a significant difference in the duration of the Pill use among women using technology-based reminders (N=159) and those for whom the Pill was part of a daily routine (N=514). The result was in favour of the routine group ($\chi^2(4,673)=58.5$, $p<.001$) with a medium effect size (Cramer's V=.30), indicating an association between the length of the regimen and the presence of routines.

3.1.3 Conclusions

Survey results showed that incorporating the Pill into a daily routine was an effective strategy. Women for whom the Pill was part of their daily routine, who attached it to existing events (e.g. waking up), and who took advantage of the location of blister packs (e.g. kept them by the bed or in a bag) reported forgetting less often than the rest of participants. However, while the strategies they used can make it easier to remember (Johnson, 2002; Park & Kidder, 1996) and help to minimise occurrences of memory lapses (Barber et al., 2005), they introduce new vulnerabilities. And indeed, even though survey results showed that routines were associated with a reduced number of incidents of forgetting, women still forgot. These results are in line with the literature that shows how fragile routines can be (e.g. Barber et al., 2005; Bargh, 1994; Einstein et al., 1998) and how strongly they rely on the context (Wood et al., 2005): once the routine changes or is disrupted and the usual cues are not available, the support it provides disappears, even when the change was anticipated.

The same number of women who recently started the Pill regimen reported relying on routines and using alarm clocks and apps. However, women who have been taking the Pill for longer reported using technology less often compared to those who reported relying on routines, and the difference was bigger the longer they were taking the Pill (see Figure 3.3 on page 60). The need for reminders at the beginning of the regimen is supported by previous research. For example, in an evaluation of an oral contraception card providing timed reminders (Lachowsky & Levy-Toledano, 2002), the decision to assign women to reminder and non-reminder group was left to the doctor. As a result, predominantly young women starting to take the Pill for the first time—who might not have had a developed Pill-taking routine—were given the card and it helped them remember better. These trends suggest that technology might be the most useful at the beginning, before the routine is fully developed. However, too few women reported using technology and relying on routines at the same time to draw any definitive conclusions on the relationship between these two strategies.

Only a fraction of participants reported using apps, despite belonging to the age group that is the most likely to download them (Ofcom, 2015). It could be argued that it was so because smartphones have become ubiquitous only in recent years; however, the majority of respondents have been taking the Pill for less than five years, including a quarter who have been doing it for less than two. This suggests that they either were not aware of available apps or did not want to use them. Given that the results showed no benefits of using technology, available apps might not be fit for purpose. A review of contraception reminder apps suggests that this might be the case, as the apps seem to be no better than simple alarm clocks: they do not support daily routines and provide inflexible reminders that often cannot be postponed (Gal et al., 2015).

Overall, the results show that reliance on routines is beneficial for habitual regimens. Women's remembering strategies are similar to those of older adults living in care homes reported in the adherence literature (Insel & Cole, 2005; McGee-Lennon et al., 2011; O'Quin et al., 2014; Palen & Aaløkke, 2006), even though their regimen and circumstances are different. This suggests that some strategies may be universal. Therefore, to better understand the similarities between different regimens and the role of routines and other contextual cues in everyday medication management, the next section presents two surveys conducted with participant groups representing more complex regimens.

3.2 Remembering complex medication regimens

Two surveys were conducted to investigate the similarities between a simple long-term habitual regimen and more complex regimens. Parents remembering their children's antibiotics (Survey II) and older adults with chronic conditions (Survey III) were selected, as their regimens differ significantly from the Pill regimen. While oral contraception is a long-term single-dose preventative regimen that is also habitual in nature, antibiotics regimens are short, involve multiple doses, and often symptoms of the illness (e.g. a fever) can provide additional cues that can remind about medications. On the other hand, older adults often have to remember to take multiple medications multiple times per day, both to relieve symptoms and as preventative measures.

Comparing strategies used across different regimens will help to understand the role of daily routines and contextual cues in medication management and to identify types of cues best suited for supporting habitual regimens. As both Survey II and Survey III use the same questions with minor modifications to match regimen of each participant group, I provide a combined method section, but report findings separately.

3.2.1 Method

Participants

Overall, 175 participants were recruited: 88 parents of children who took antibiotics within the past year, and 87 older adults with chronic conditions. Their details are summarised in Table 3.4.

Table 3.4: Information about 88 parents and 87 older adults who filled in Survey II and III.

	Survey II: Parents administering antibiotics	Survey III: Older adults with chronic conditions
Demographics	46% aged 35-44 years old, 32% aged 26-34 years old, 13% aged 18-25 years old and 10% aged 45-54 years old; 80% women; 36% students	57% aged 60-69 years old, 23% aged 70-79 years old, 18% aged 80-89 years old and 1% over 90 years old; 79% women; 86% retired; 68% living with at least one family member and 24% living alone
Regimen	42% reported that children had to take 3 doses per day, 32% had to take 4 doses, and 26% had to take two doses	Reported taking up to 12 pills per day (average=4, SD=2.3); 64% took medications twice and 32% three times per day
Background	85% were the person primarily responsible for remembering antibiotics; 53% of children were under 3 years old & 19% were 4-6 years old when they took antibiotics	All were diagnosed with at least one chronic condition, including hypertension (47%), diabetes (39%), arthritis (30%), and high cholesterol (28%)

Procedure

To reach parents whose children take antibiotics (Survey II), an online survey was distributed through a mailing list among UCL staff and students, posted on social networks, and advertised via leaflets in nurseries and primary schools in South London. As an incentive, participants were offered a chance to enter a raffle to win one of three £25 Amazon vouchers.

Survey III was part of an international collaboration funded by the UBI-HEALTH Network grant and was conducted with Dr Marcela Rodriguez from Universidad Autónoma de Baja California (UABC) in Mexicali, Mexico, who organised data collection. It was conducted in Mexicali and participants were recruited by contacting relatives and friends, and by visiting local public centres that provide older adults with healthcare and social services, with which Dr Rodriguez made an *a priori* collaboration agreement. Participants were approached face-to-face, with interviewers (UABC students) filling in the survey on a tablet computer; they were not offered any incentives for participation.

Materials

Both surveys were based on Survey I described earlier (see page 56) to ensure data can be reliably compared across regimens. Small modifications were made to account for differences in regimens and personal circumstances. Survey III data was collected in Spanish and a validated Spanish version of PRMQ (González-Ramírez & María Eugenia Mendoza-González, 2011) was used. Survey II is available in Appendix B and Survey III (translated into English) is available in Appendix C.

Analysis

I conducted all analyses. PRMQ scores were calculated for each survey and compared with the control group from Crawford et al. (2003). Participants whose scores fell outside two standard deviations from the control group's score were excluded. Survey III results were translated into English. In the end, the data of 83 parents and 81 older adults were included in the analyses.

The format of a question investigating remembering strategies ("What do you use to help you remember to take your pills?"; see Appendices A-C) differed between the surveys to match the data collection method: in Survey I and II it was a multiple answers question, but in Survey III it

was open-ended. Two researchers not involved in this research and I independently matched the open-ended answers with survey categories. For 75 entries (86%) all raters were in agreement. For 11 entries (13%), 2 out of 3 raters were in agreement, and their answers were used. In one case there was no agreement between the raters and the best category was selected after a discussion ("a clock" was filed under "Other" as it wasn't clear whether the participant meant paying attention to actual time or used reminders).

As in Survey I, I used descriptive statistics to analyse the main trends and to understand types of cues participants used, and Chi-square tests for independence to calculate differences in the effectiveness of daily routines and technology used by participants.

3.2.2 Findings

Survey II: Antibiotics. Remembering short-term multi-dose regimens

Responses from 83 participants were analysed. When asked about specific remembering strategies, the majority of parents reported that they simply "tried to remember" and therefore did not use any memory aids (see Figure 3.4). However, they still relied on contextual cues: they reported keeping antibiotics in the kitchen (85%), most often inside the fridge or a kitchen cabinet (74%); 12% reported keeping antibiotics in a visible place. For a quarter of participants, remembering antibiotics was part of their daily routine, and a similar number reported using some sort of technology to support their memory, usually their mobile phone's alarm clock. A third of respondents (33%) also said their children were involved in remembering.

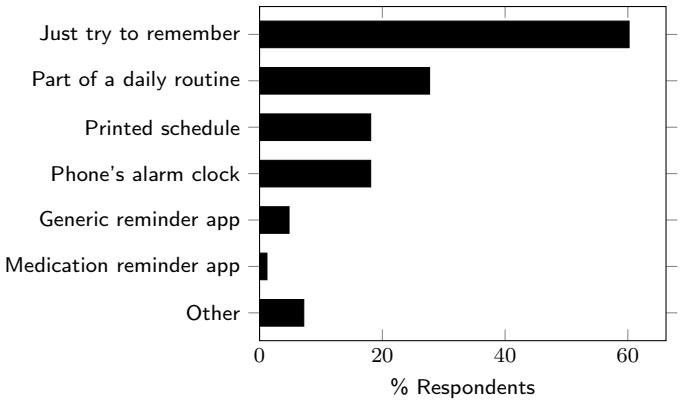


Figure 3.4: Memory aids used by participants to remember antibiotics (N=83). Multiple answers were allowed.

Nearly half of respondents (43%) said that fitting antibiotics into their daily routine was difficult or very difficult, mainly because of too many daily doses and having to care for more than one child. The age of the child was also a factor, as it is difficult to manage evenly spaced doses when the child is young and parents have to follow a specific daily routine that may not be compatible with the regimen. In a few cases respondents reported difficulties with managing antibiotics when multiple people and locations were involved (e.g. home and nursery), as it was harder to remember when the last dose was administered and who was responsible for the next one. In addition, 11% of participants also mentioned general issues related to childcare, e.g. the child being asleep when the dose was due, leaving medications at the nursery, or issues with synchronising antibiotics with meals.

Participants reported forgetting to give the medication on time 1-2 times (58%) or 3-4 times (19%) last time their child took antibiotics. Assuming an average of three daily doses need to be taken for a week (a typical length of a course of antibiotics), there are 21 opportunities to forget. It means that 58% of respondents reported missing 5-10% of doses and 19% of participants reported forgetting 15-20% doses. Four respondents reported forgetting five or more times. Even though 19% said that they were not late with a single dose the last time their child took antibiotics, only one person said that in general they never forget.

A Chi-Square test for independence was conducted to investigate the association between the presence of a routine and missing at least one dose. Participants who reported relying on routines (N=23) also reported forgetting less often than other participants (N=60), although the result was not significant ($\chi^2(1,83)=.34$, $p=.56$, phi=.10). Another Chi-square test was conducted to investigate the associations between the use of technology and incidents of forgetting, and while generally respondents who reported using technology (N=20) forgot less often, the result was also not statistically significant ($\chi^2(1,83)=1.15$, $p=.29$, phi=-.15). As the majority of participants were women (80%), I conducted the same analyses to test for gender differences in selected strategies or incidents of forgetting; however, the results were not statistically significant.

Survey III: Older adults. Remembering long-term multi-dose regimens

Responses from 81 participants were analysed. They reported taking their medications before sleep (57%), in the morning after waking up (48%) or with meals (27% of participants took their medication after breakfast and 31% after lunch); for 82% the time was prescribed by their doctor. Nearly a half of participants (46%) reported keeping their medications by the bed and 43% kept

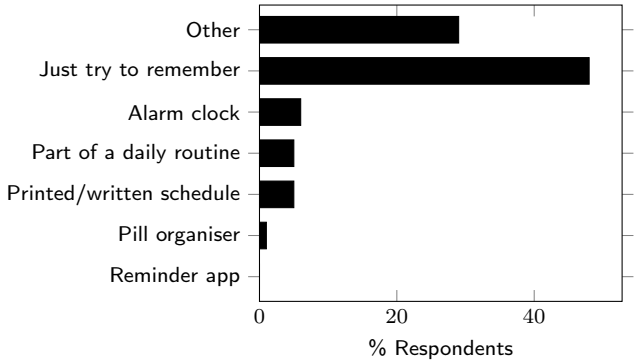


Figure 3.5: Memory aids used by older adults to help them remember their medications (N=81). Multiple answers were allowed.

them in the kitchen (22% in a cabinet and 21% on a table). In addition, 24% of participants reported keeping them in a bag or a wallet. Overall, 69% of respondents reported relying only on routine events, 20% combined routine actions with specific time and 12% took their medications at a specific hour. However, when asked directly about what helped them remember, only 5% explicitly mentioned routines (see Figure 3.5). Forty-two participants (48%) reported that they did not use anything to help them remember, even though they kept medications in places that made remembering easier (e.g. by the bed, in the kitchen) or took them in conjunction with routine events (e.g. before going to sleep, after waking up). Only five participants reported using alarm clocks as reminders and none reported using apps.

The majority of participants reported that they did not forget their medications at all during the week or the month preceding the survey (74% and 51%, respectively); 52% of participants reported that overall they rarely forgot and 32% said they never forgot. When asked about main reasons for forgetting, participants reported being busy and distracted (42%), simple forgetfulness (40%), and changes in the routine (25%).

To explore the relationship between remembering strategies and forgetfulness, participants were divided into those who reported relying on routines or keeping medications in visible places (N=17) and those who reported using other strategies (N=64). The result of Chi-square test for independence was not statistically significant for instances of forgetting in the past week (χ^2(1,81)=1.69, p=.19, phi=.18) or in the past month (χ^2(1,81)=.364, p=.55, phi=.097), indicating that the presence of contextual cues did not make any difference. Given that the majority of participants reported not using anything to help them remember (N=42), another Chi-square test was conducted to compare them to the rest of participants (N=39). The results were not statistically significant for forgetting in the past week (χ^2(1,81)=1.47, p=.23, phi=.163), but were

significant for the past month ($\chi^2(1,81)=5.43$, $p=.02$, phi=.28), indicating that participants who reported not using any cues forgot less often. However, even though they said they did not use any memory aids, answers to other questions showed that they did take medications in response to routine events or used other contextual cues.

Even though the majority of participants were women (79%), the results of analyses exploring gender differences in selected strategies or incidents of forgetting were not statistically significant.

3.2.3 Conclusions

The remembering strategies reported by parents and older adults were similar to those reported by women in Survey I: participants tended not to use technology and primarily relied on everyday routines, physical objects serving as visual cues, and the location of medications. However, despite the general similarities, there were small differences in the use of cues across regimens.

Even though the course of antibiotics is too short to be turned into a routine in itself (the standard length of an antibiotics treatment is 7-10 days; Michael, Hodson, Craig, Martin, & Moyer, 2003), parents reported relying on routine events: the majority of them "simply tried to remember" or used existing routine events as triggers to action. In addition, while antibiotics were not always visible, participants reported keeping them in places where they still could serve as visual cues, e.g. in the fridge, even if that visibility was not intentional. This is a reasonable approach, as cues that become visible at the right time (e.g. opening the fridge and seeing antibiotics that need to be taken with meals) are more effective than cues that are visible all the time (Vortac et al., 1995). Despite the complexity of antibiotics regimen and known difficulties with remembering multiple daily doses (Kardas, 2002), not many participants reported the use of technology. Perhaps they did not see the benefits of reminders (relying on them was not associated with reduced rates of forgetting) or it was not possible to set reminders that match the regimen and the realities of caring for a young child.

On the other hand, the lack of technology use among older adults was not surprising. Only 0.7% of older adults in Mexico used a smartphone in 2014 (eMarketer, 2015) and overall older adults are significantly less likely to rely on reminders compared to younger populations (McGee-Lennon et al., 2011). In line with existing research, Study III participants reported relying on daily routines and keeping medications in visible places (Dalgaard et al., 2013a; Palen & Aaløkke, 2006; Verdezoto & Olsen, 2012). However, the majority of them did not see themselves as using

any cues at all: their medication management strategies were so ingrained in their daily lives that they often did not recognise them as such. The way they planned when to take their medications and where to keep them provided prompts to action, and in their mind they simply remembered on their own. Such ingrained reliance on contextual cues in this case could be explained by a more structured daily life of older adults, who tend to have higher levels of temporal organisation compared to other age groups (Orbell & Verplanken, 2010). It also suggests that they might have developed a habit and their behaviour became automatic, which would explain the lack of awareness of what cues were actually prompting them (Bargh, 1994; Orbell & Verplanken, 2010).

Conducting Survey III face-to-face might have influenced its results. While it helped to reach older adults, they might not have wanted to openly admit they were non-adherent. However, as people perceive forgetfulness as more socially acceptable than admitting intentional non-adherence and may report it instead (Atkins & Fallowfield, 2006; Unni & Farris, 2011), reported forgetting rates are likely to be accurate. The change of format also led to changing the remembering strategies question from pre-defined multiple choice into an open-ended one in Survey III. While remembering strategies in general were similar and it was possible to map open-ended answers onto the categories from Survey I and II, there was a difference in the number of people who reported relying on routines. As routines were explicitly mentioned on the list of potential remembering strategies in online surveys, participants might have selected them because they were prompted to think about them. Survey III participants were not given that prompt and instead provided specific strategies. However, as other questions investigated the wider context and not just strategies directly reported by participants, the findings are still valid.

3.3 Discussion

The aim of this chapter was to understand the extent of reliance on daily routines and technology in everyday medication management in order to inform the design of medication adherence apps that are grounded in people's day-to-day behaviours. The studies presented above investigated strategies developed to remember three distinct regimens. Oral contraception was selected to represent a single-dose long-term habitual medication regimen, and the remembering strategies developed by women were compared with strategies used by parents administering their children's antibiotics (short-term, multi-dose regimen) and older adults with chronic conditions (long-term, multi-dose, multi-medication regimen).

The results of all surveys showed that relying on daily routines was an integral part of participants' remembering strategies. The results were in line with previous studies conducted with older adults (Insel & Cole, 2005; O'Quin et al., 2014; Palen & Aaløkke, 2006; Tordoff et al., 2010), which suggests that these strategies are universal for all age groups and should be accounted for by adherence technologies. While salient event-based tasks in general are easier to remember, regardless of age (Rendell et al., 2011), the role of routines can vary across regimens. For women, the act of taking the Pill was a routine in itself; parents relied on existing daily routines as triggers to action, as the regimen was too short to allow for formation of a dedicated routine; and older adults' remembering strategies were so ingrained in their day-to-day life that they believed they "simply remembered" on their own. This confirms that routines can support medication-taking at different stages of the habit formation process: initially, routine events serve as triggers to action (similar to remembering short-term regimens such as antibiotics); with time they start to drive the behaviour (remembering the Pill); and once the habit forms, the behaviour becomes automatic (older adults' habits ingrained in their daily life). They can be both prospective memory and habit cues.

As reliance on contextual cues makes remembering medications easier (Johnson, 2002; Park & Kidder, 1996), helps to develop a habit over time (Lally & Gardner, 2011; Neal et al., 2012), and minimises occurrences of memory lapses (Barber et al., 2005; Park & Kidder, 1996), it was assumed that reliance on routines would be more effective than using technology-based reminders. It turned out to be true only for women taking the Pill, possibly due to differences in sample sizes. Even though the trend was the same for parents and older adults (those who reported that taking medications was part of their routine forgot less often than those who did not mention routines), the differences were not statistically significant. Moreover, despite being associated with lower forgetting rates, reliance on routines was not perfect: participants still forgot. Routine behaviours depend on the context and environment (Dolan et al., 2012; Wood et al., 2005), which explains why so many participants reported changes to the routine as main causes of forgetting. As it is impossible to eliminate situations that lead to routine changes, either deliberate (e.g. holidays) or unexpected (e.g. oversleeping), adherence technologies could provide necessary support. However, participants tended not to use apps.

The small number of women who reported using apps came as a surprise: given their age, they were the most likely to own a smartphone and install apps (Ofcom, 2015). Similarly, it was expected that parents would use technology, mainly due to complexity of antibiotics regimen

and difficulties with remembering multiple daily doses (Kardas, 2002), but again it was not the case. These trends are supported by research published by Davies et al. (2015) after this study was conducted: 54% of members of the general public who responded to their questionnaires (N=400, 55% aged over 40 years old) reported relying on daily routines as a way of remembering their medications, 10% reported using reminders, and only 1.5% reported using apps; similarly, 47% of students (aged 18-29 years old; N=333) reported relying on daily routines and only 3% used apps. The low app uptake might be explained by several factors: the lack of clear benefits of using the apps compared to other strategies, good enough support provided by simple alarm clocks, or difficulties in setting up reliable reminders that can match one's regimen. This suggests that available apps might not be fit for purpose, although with just a fraction of participants using them, it is difficult to draw any strong conclusions.

In theory, with their ubiquity and popularity, smartphone apps are a promising platform for delivering adherence interventions (Klasnja & Pratt, 2012) that could provide support for situations when the routine changes. However, even though hundreds of apps can be easily installed by anyone with a smartphone, it is not clear what functionality they offer and how they support remembering; academic research evaluating their features is scarce. At the time of writing no one has examined medication reminders in detail and the number of studies published recently (Gal et al., 2015; Heldenbrand et al., 2016; Morrissey et al., 2016) suggests an interest in the area and a need for clearer information. Similarly, while several habit formation apps exist that were designed specifically to help people repeat their behaviour every day, it is not clear whether they are based on habit research and whether they could support the development of medication habits. Given that behaviour change apps in general lack theoretical grounding (Cowan et al., 2013; Free et al., 2013; West et al., 2012), the same can be assumed about habit formation apps.

To address this gap and to understand how well smartphone apps support medication-taking and what could be improved, the next chapter evaluates the functionality of existing medication reminder apps and habit formation apps to identify features that could support medication habits. Understanding the strengths and limitations of available solutions will inform the design of adherence apps that make use of people's existing routines.

Chapter 4

Evaluation of existing smartphone apps

This chapter:

- ❖ Presents a functionality review of 229 medication reminder apps and an analysis of 1,012 user reviews to understand how apps currently support medication-taking.
- ❖ Describes a review of features available in 115 habit formation apps and their theoretical grounding to investigate how they could support medication habits.
- ❖ Highlights the limitations of existing apps and proposes an alternative approach.

The studies presented in this chapter have been published in [C.1, C.2] *and contributed to* [J.2].

As smartphones are ubiquitous and personal (Ofcom, 2015; Ventä et al., 2008), they are a great platform for delivering adherence interventions (Fjeldsoe et al., 2009; Klasnja & Pratt, 2012) and have a potential to support the formation of medication habits that facilitate long-term adherence. However, even though hundreds of apps are available, the results from Chapter 3 suggest that people do not use them: only 1% of women taking oral contraception and 2% of parents remembering their children's antibiotics reported using medication reminder apps. Instead, the majority of participants reported relying on daily routines; their low reported rates of forgetting suggest that this was an effective strategy. The lack of clear benefits of using the apps raises questions regarding their utility and the extent to which they meet users' needs.

To understand how existing apps currently support medication-taking and whether they could facilitate long-term adherence, in this chapter I analyse their functionality and users' attitudes

towards them. First, I review the features available in dedicated medication reminder apps to understand how they support memory and daily routines. To understand the reasons for low uptake reported in the previous chapter and to investigate whether the apps meet users' needs, I then analyse user reviews of the most popular apps. Next, I focus on the functionality provided by habit formation apps, i.e. apps designed specifically to help people regularly repeat a new behaviour and turn it into a habit, as they could inform the design of better adherence apps. The chapter ends with a discussion of existing apps' limitations, highlighting the need for further investigation into the process of habit development to understand how factors that support it could be implemented through an app.

4.1 Medication reminder apps

There are several ways of reviewing health apps: from broader app store searches, through reviewing apps' descriptions, ratings and reviews, to piloting the apps and eliciting feedback from users (Boudreaux et al., 2014). In this context, a functionality review was deemed to be the most relevant, as it can directly inform the design of future adherence apps by highlighting existing features and their limitations. In addition, as user reviews can provide insights into usability, functionality, and efficacy (Boudreaux et al., 2014), they help to establish whether the reviewed apps meet users' needs. Customer review analyses were used in the past to understand attitudes of users and features they request (Iacob & Harrison, 2013) as well as their opinions about functionality extracted from negative comments (Iacob, Veerappa, & Harrison, 2013; Khalid, 2013). The approach described below was inspired by the aforementioned studies.

4.1.1 Method

To understand how adherence apps currently prevent forgetfulness, medication reminder apps—as opposed to general adherence apps—were selected for the study as reminding is a standard approach in preventing unintentional non-adherence (Vervloet et al., 2012). The review was conducted in February 2013. As 86% of new smartphones purchased in the previous year (2012) had been iOS and Android devices (MobiThinking, 2013), apps available in the UK versions of Apple iTunes Store (Apple Inc., n.d.) and Google Play (Google, n.d.) were included in the analysis. Free and paid apps, and full and limited ("lite") versions were included in the review and counted separately, because they offered different functionality. Similarly, apps available in both

stores were treated as separate apps, as due to operating system differences their functionality and available types of notifications differed. Apps for tablet computers, generic reminder apps, and other health support apps were excluded.

Prior to the main analysis, a list of common features was prepared based on the first 25 apps found in each store after searching for "medication reminder". Identified features were grouped into categories and used later to aid data collection. During the main data collection stage, "medication reminder", "pill reminder", "contraception reminder", and "birth control reminder" were used as search keywords. This allowed me to identify a wide range of medication reminders suitable for long-term medication regimens, and to investigate the reasons for low app uptake highlighted in the contraception survey from Chapter 3.

In total, all searches returned 1,125 results (307 in Apple iTunes Store and 818 in Google Play), most of which were irrelevant (e.g. generic reminders, vet apps). Many apps appeared in multiple searches as each keyword had to be used separately because of technical limitations of both app stores. In the end, 229 medication reminder apps met the inclusion criteria (123 for iPhones and 106 for Android phones, including 15 available for both platforms). Details of each app available on its app store page were recorded, including app's name, user ratings, number of user reviews, and the presence of feature categories identified during the initial analysis. Features not fitting into the predefined categories were also noted and later grouped to create additional categories.

Next, the most reviewed apps were identified for user review analysis. Only apps from Google Play were selected as due to technical limitations it was not possible to copy comments from the iTunes App Store application. To ensure a wide range of apps were analysed, apps identified during the functionality review were divided into four categories based on their functionality:

- *Simple reminder apps*, i.e. apps that offer basic functionality needed to take medications every day, such as reminders or a snooze option;
- *Advanced reminder apps*, i.e. apps that primarily provide reminders, but with additional options supporting remembering, such as refill reminders or time zone support;
- *Personal medication management apps*, i.e. apps that support adherence and provide additional features that support adherence and help users to manage their health and manage relationships with healthcare providers; and
- *Family medication management apps*, i.e. apps that allow users to monitor adherence and support health of multiple users, e.g. children or elderly parents.

The top 10 most reviewed apps from each category were selected, resulting in 40 apps being analysed in total (see Appendix D for the list of analysed apps). For each app, 50 reviews were recorded; if an app had fewer than 50 reviews, all available reviews were noted. Before data collection, all reviews were sorted by "Helpfulness" (other sorting options provided by Google Play were "Rating" and "Newest"), to ensure that positive and negative opinions as well as new and old reviews were included. Content of each review was copied into a separate row in a spreadsheet, and codes summarising features and issues mentioned in the review were added.

Thematic analysis (Braun & Clarke, 2006) was used to make sense of the data. Each review was classified in terms of its general sentiment (positive, negative, neutral) and its type (general praise, complaints, comments on functionality, feature requests, other). They were grouped into clusters of common themes, and main categories were extracted. The analysis was done separately for feature requests, positive functionality reviews, and negative functionality reviews. Initial codes were added to each review, describing the functionality and related issues mentioned by the authors; even though inductive analysis was originally planned, codes closely resembled functionality categories identified earlier. Next, codes describing feature requests and functionality comments were selected for further analysis. They were copied on post-it notes for ease of manipulation and later grouped into clusters of common themes. The main categories, with identified themes and underlying codes, can be found in Appendix D.

4.1.2 Findings

Functionality

Amongst 229 identified apps, 197 apps (86%) were generic medication reminder apps, while 32 apps (14%) addressed specific conditions or regimens, mainly contraception (25 apps). Identified feature categories are summarised in Figure 4.1 and are described in more detail in Table 4.1.

Nearly all identified apps (97%) offered timed reminders. Eight apps either did not have reminders listed on the app description page or did not provide them due to version limitations. The majority of apps (83%) supported multiple medications; contraception reminders and lite versions were often limited to a single daily dose. A third of apps (33%) imposed limitations on alert scheduling, e.g. by allowing only one alert per medication per day or not supporting time intervals such as alerts every X hours or X days. Only 39 apps (17%) offered an option to postpone (or "snooze") a reminder.

Table 4.1: Functionality of medication reminder apps (N=229).

Features category	Description	No. apps	% Apps
Reminders	Timed alerts and notifications reminding to take medications at a specified time	221	97%
Multiple medications support	Ability to set reminders for multiple medications or multiple doses of the same medication	189	83%
Flexible scheduling	Reminders supporting different types of regimens, e.g. every other day, every X hours, on selected days only	154	67%
Medication history	Medication log that includes past regimens or information about taken/missed doses	86	38%
User notes and calendars	User's comments, e.g. whether the medication should be taken with food, information about side effects; sometimes in a form of a calendar	60	26%
Refill reminders	Stock control and reminders	59	26%
Medication pictures or icons	Visual prompts helping to identify which medicine to take	47	21%
Multiple users support	User accounts with separate medication history and reminders for each user	42	18%
History/regimen sharing	An option to share medication history, e.g. via email	41	18%
Customisable alert types	Different types of alerts to select: pop-ups, status icons, flashing light, sound reminders, etc.	40	18%
Snooze	Repeated reminders, an option to postpone alerts	39	17%
Customisable reminder sounds	A library of sounds, an option to choose own sounds	39	17%
Health provider details	Doctor's contact details with a map; list of local pharmacies with their details and maps	37	16%
Medication information	Drugs database, additional information about the medications: dosage, side effects, etc.	32	14%
User's health information	Information about user's allergies or conditions	26	11%
Password protection	An option to restrict access to the app with a password or a passcode	25	11%
Notifications for other people	Automatic text message or email alerts to others when a medication dose is missed; emergency contact numbers	19	8%
Backup and synchronisation	Medication history and reminders schedule backups, data synchronisation across multiple devices	19	8%
Appointment reminders	A diary with doctor's appointment details and reminders	18	8%
Data export	An option to export medication history and regimen in different file formats	17	7%
One-off medication tracking	Tracking of medications taken "as needed", e.g. painkillers	15	7%
Missed doses tracking	Automatic tracking of missed doses and highlighting them in the medication log	14	6%
Adherence charts and statistics	Statistics and charts showing missed doses, adherence rates, medication costs, etc.	12	5%
Time zone support	An option to always use user's home time zone to support timely medication-taking when travelling	10	4%
Mood changes and side effects tracking	An option to record information about mood and reactions related to each medication	8	4%
Smart silencing	An option to disable reminders when not needed, e.g. during sleep hours or pill-free weeks	7	3%
Deals and prices	Medication discount coupons, deals, and medication pricing information (mainly US apps)	7	3%
Overdosing protection	Dose tracking and automatic alerts when the daily limit has been reached	5	2%
Adherence rewards	Incentives and points for consistent medication-taking	4	2%

Some apps provided additional personalisation features: customisable alerts allowing users to select different types of notifications such as pop-up messages, status updates or flashing lights (18%); customisable sounds (39%); and an option to add medication pictures to help with recall (21%). Over a third of apps (38%) allowed users to check their medication and regimen history, and export the data (7%) or email it to others (18%). Some apps (7%) provided options to add and track medications taken "as needed", e.g. painkillers, which were also included in the medication log. Six per cent of apps automatically tracked missed and late doses, highlighting them in the history report, and 5% offered statistics and charts describing usage trends, adherence rates, and sometimes even estimated treatment costs. In addition, 11% of apps, mainly contraception reminders, provided password protection, and 8% offered an option to back up the data or synchronise it across multiple devices.

Many apps offered additional features that aimed to support memory: refill reminders (26%); user notes and a calendar view with medication times (26%); a database with medication information

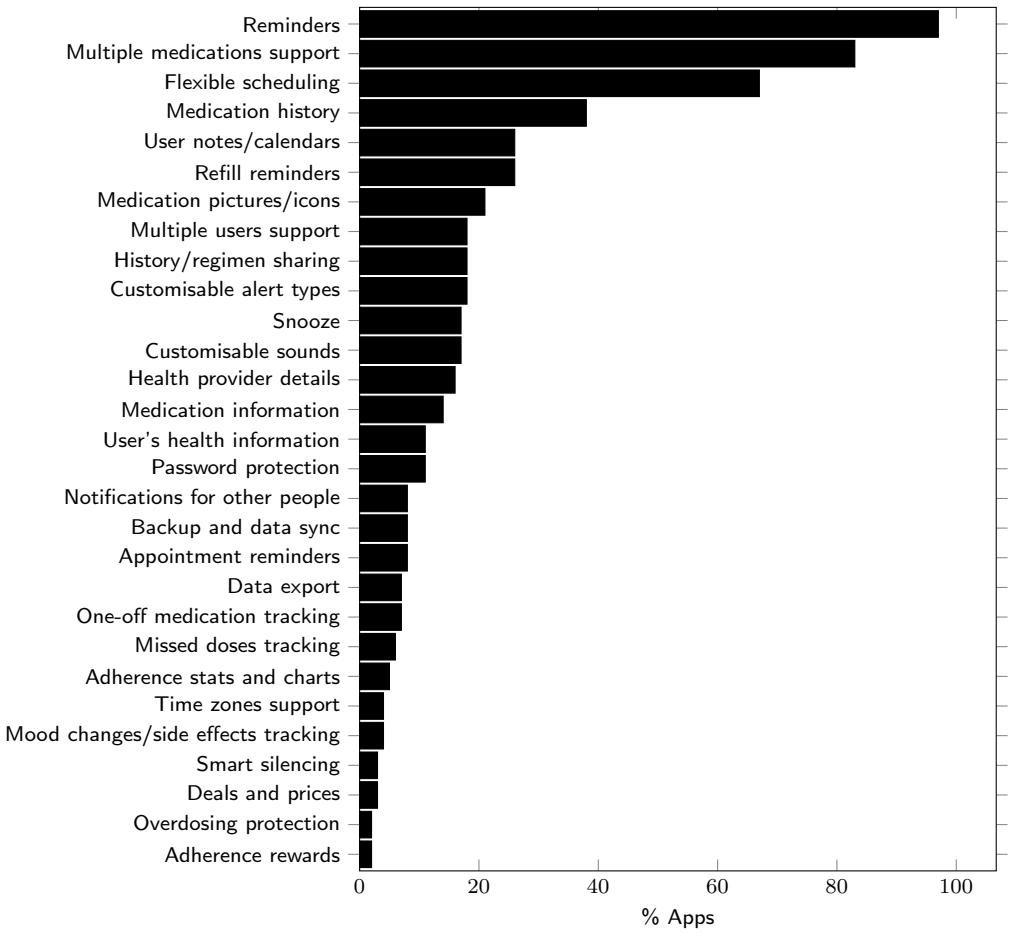


Figure 4.1: Functionality of medication reminder apps (N=229).

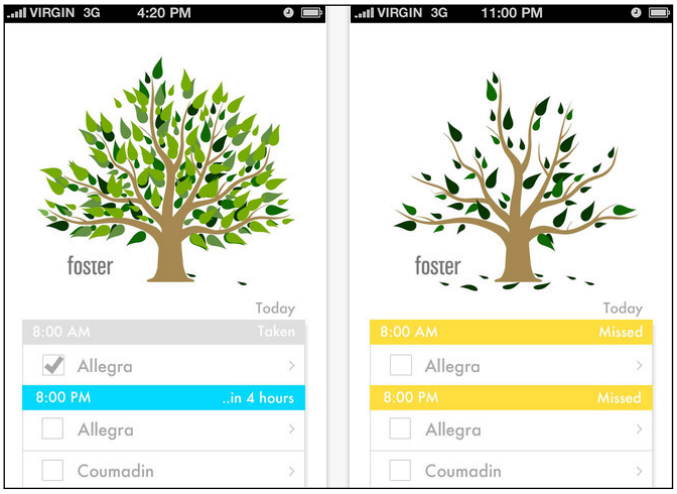


Figure 4.2: *Foster – Pill Reminder*, a medication reminder that encourages regular medication taking. A tree is healthy when pills are taken on time (left) and starts losing leaves with missed doses (right).

e.g. dosage and side effects (14%); or an option to alert other people about missed doses (8%). Less common features included time zone support to ensure medication is taken at the right time when travelling (10 apps); smart silencing to ensure alerts do not go off when user is asleep or during a Pill-free week in oral contraception regimens (seven apps); the ability to track mood and side effects after taking each dose (eight apps); and overdosing protection with alerts informing when a daily limit of a medication (e.g. painkillers) has been reached (five apps). More complex apps also stored user's health information, e.g. their allergies or blood type (11% of apps) or healthcare provider and pharmacy details (16%), and provided treatment cost estimates and discount codes for medications (3%). Doctor's appointment reminders were available in 18 apps.

Only four apps (2%) provided options supporting habit formation and regular medication-taking. Foster App (Thryve, n.d.; Figure 4.2) encouraged continuous use by making users responsible for a tree (similar to UbiFit Garden described on page 50). To take care of it, they had to take medications—recording the doses "waters" the tree; if a dose is missed, the tree loses its leaves. The other three apps (Dr. Heimer (Galicia, n.d.), MED-ASSIST (Team xBots, n.d.), Reminder RX (Locust Tech Inc., n.d.)) rewarded users with points that could be compared or shared with friends, or redeemed into vouchers and exchanged for other apps.

Twenty-five identified reminder apps were dedicated oral contraception reminders (see Figure 4.3 for a summary of their functionality). They all offered timed reminders, although only eight (32%) provided a snooze option. Flexible scheduling that could help to adjust the reminders to a daily routine was available in 11 apps (44%). Three apps provided smart silencing that stopped

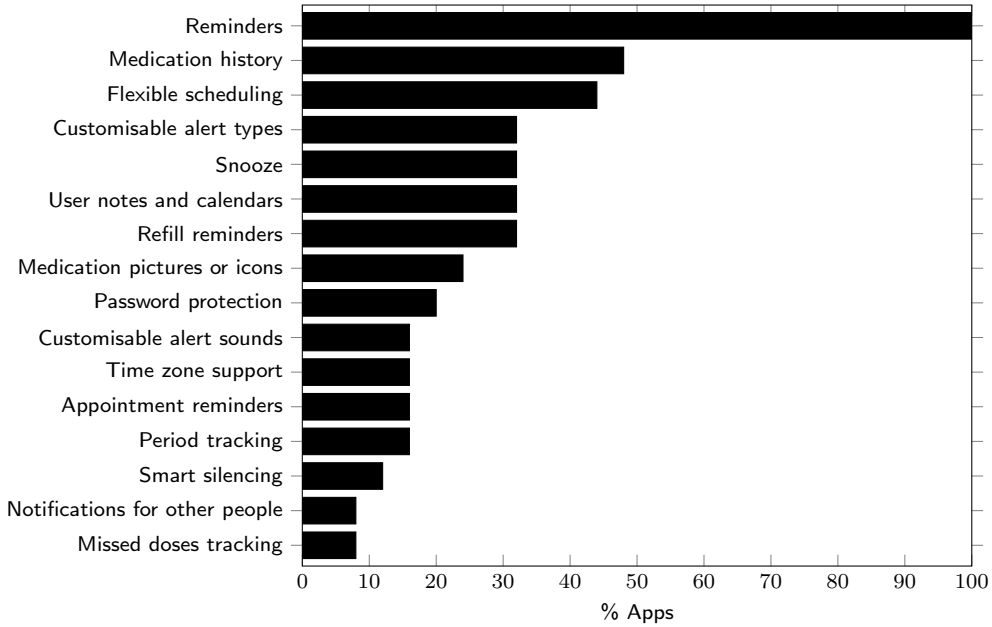


Figure 4.3: Functionality of oral contraception reminder apps (N=25).

reminders during the Pill-free period. Eight apps allowed users to select the most convenient alert type and four to change sounds. Six apps allowed women to select a picture of a blister pack representing their regimen to help them track pills and check if they were taken. Four apps provided time zone support, helping users to take the Pill on time when travelling. Twelve apps provided medication logs, and one app automatically tracked late and missed doses. Eight apps provided a calendar and allowed users to add notes. Additional features that could help to remember and manage the contraception regimen included refill reminders (eight apps), doctor's appointment reminders (five apps), and automatic notifications for other people, e.g. a partner (two apps). Five apps provided password protection to support privacy.

User reviews

In total, 1,012 reviews were collected: 291 reviews of simple medication reminders (29%), 392 of advanced medication reminders (39%), 112 personal medication management apps (11%), and 217 family medication management apps (21%). Based on the overall sentiment and the content of each review, user comments were divided into two main groups: general comments presenting users' attitudes towards the apps and comments mentioning specific functionality. Over half of the reviews (595, or 59%) fell into the latter category and could be further divided into descriptions of existing functionality (42% of all reviews) and "feature requests" (17%) in which

users demanded specific changes or wished certain options were available. The remaining 417 reviews (41%) were general praise comments (e.g. *"So far it's worked like a charm!"*), complaints (2%; e.g. *"Really unhelpful app"*), or other miscellaneous comments (1%; e.g. *"I have to take meds every 6 hours from having a wisdom tooth pulled, & I have a horrible memory. So hopefully this helps."*). Further analyses were conducted on 595 reviews that mentioned specific functionality.

User preferences

Even though feature requests, positive functionality reviews and negative functionality reviews were analysed separately (see Appendix D for details), the results of all three analyses showed that the most important features and characteristics of a medication reminder app were reliable reminders, customisation, usability, and positive user experience.

Reliable and customisable alerts were the most important feature. The customisation was especially important for users on regimens that are complex, e.g. multiple medication or multiple doses per day; or irregular, e.g. an oral contraception regimen with Pill-free weeks.

> *"I have one med I take every 3 days, this app had no problem letting me schedule that, other apps did!"* – Review #737

> *"All 4 of my boys are either taking some of the same and some different vitamins and/or medications than each other at this time, and this app helps me keep track of who took what at what time and when the next dose is due.* [...] *I can even set an alarm to remind myself to make sure the next dose is on time for each child."* – Review #800

> *"I need weekday alarm rules and weekend rules. Some meds I take every day, and some are every other day."* – Review #659

> *"I have a med that I take every other day and there is no way to designate that in this app."* – Review #161

Users often complained when reminders did not work as expected, were not customisable, did not support a specific regimen, or simply did not provide the snooze option:

> *"My alerts have not gone off a single time since* [the] *installation on* [my phone]. *Why did I give you my money?"* – Review #201

> *"Ignores option to not alarm continuously and overrides global mute. Not good in a meeting!"* – Review #458

In general, users expected the apps to offer functions that help them with their regimen. Due to their limited functionality, many simple medication reminders were seen as lacking and useless:

> *"Uninstalling. Seems to do nothing more than what I can get my alarm to do. In fact, my alarm is better as I can snooze it if I'm not around my medicine"* – Review #392

Users appreciated the support of reminders in situations when their routine changed and liked alerts that were visible until they took their medication:

> *"Love this app! I like how the pill icon stays in notification bar until you confirm you took the pill. Never miss my meds!"* – Review #143

> *"I only take one medication, but on days where my routine changes, I often forget to take it. This app has definitely been extremely helpful."* – Review #380

Customisation also allowed users to select relevant, meaningful, and discreet alerts that not only helped them remember and provided notifications appropriate for a given situation, but also protected their privacy.

> *"So lucky to have found this app. I used to never remember to take any pills. This app makes it easy to remember, and it's non-invasive, no pop-ups. There is an alarm (that you can put on vibrate) and you just click 'yes' when you've taken the pill."* – Review #305

> *"It's useful and doesn't just flash a message across my screen in an embarrassing way."* – Review #318

Because of the issues with stability, apps were often seen as unreliable. Users frequently complained that apps would sometimes stop working, lose data and the alert schedule after software updates, or freeze their smartphone. Smaller incidents such as alerts that occasionally did not work or confusing functionality also reduced users' trust.

> *"I love this app when it works but there have been multiple times where it just doesn't go off. Then I had to uninstall and download again because it said alarm in 364 days?!"* – Review #52

> *"Worked great, but now it seems that every time there's an update my alerts are deleted. May look for a different app."* – Review #488

4.1.3 Conclusions

The identified apps provided functionality of varying complexity: from simple reminder alerts to smart silencing and medication tracking, to general health management options. Many apps were nothing more than SMS alerts or alarm clocks packaged as medication reminders and could be easily replaced by smartphone's default functions with no loss to the users. More complex apps expanded the alarm clock's functionality by allowing users to check whether a medication was taken, and by providing features such as time zone support and smart silencing that could help to manage medication-taking in situations when the routine changes. However, regardless of the complexity or functionality provided, all apps focused on timed reminders: their main purpose was to remind users to take medications at a specific time. As the snooze option was rarely available, using the apps could increase the likelihood of forgetting, as users are expected to react immediately so that the reminder is not forgotten (Cramer, 1991).

These results are supported by newer studies that strengthen the reliability and validity of my work. Heldenbrand et al. (2016) identified 367 unique adherence apps and conducted a thorough analysis and user-testing of the top 100 highest-ranking apps. Among them, 23 apps failed to produce reminders, failed to install correctly, or needed special access codes. The remaining 77 apps were evaluated in detail, which revealed their simplistic design: while 70% provided reminders, only 47% allowed users to customise them and fit them into a daily routine; less than a half (45%) provided a snooze option. A review of 39 dedicated oral contraception reminders confirmed these trends as well: while 32 apps (82%) provided reminders, they were also inflexible and only 14 apps (36%) allowed users to postpone them (Gal et al., 2015). Users seem to be aware of these limitations (e.g. see Review #392 on page 82), which could explain why so many survey participants from Chapter 3 reported using alarm clocks, but not apps.

The results show that flexible reminders and customisation are features liked and desired by users. Flexibility and customisation are also features recommended by HCI researchers: they make reminder apps accessible and effective (Silva et al., 2009), and could help to adjust them to an existing routine and increase users' sense of personal agency (Sundar, Bellur, & Jia, 2012). However, they are rarely available. Moreover, despite generally not meeting users' needs, medication reminder apps seem to be designed to encourage users to rely on them, even though overreliance on external cues can be associated with more omission errors (Einstein et al., 1998) and can lead to dependency, which—given the issues with stability and reliability—can increase the likelihood of forgetting if a reminder fails.

Overall, the results also highlight disparities between the functionality offered by medication reminder apps and the prospective memory and habit literature. While the research suggests that reliance on daily routines as triggers to action is an effective remembering strategy (Guynn et al., 1998; Park & Kidder, 1996), apps focus on timed reminders. Even dedicated contraception reminder apps ignore the habitual nature of long-term regimens, despite the fact that for many women taking the Pill is part of their daily routine. To understand how this support could be provided, the next study evaluated the functionality of dedicated habit formation apps.

4.2 Habit formation apps

The review of medication reminder apps showed that they did not support daily routines and instead primarily provided timed reminders, even though it is easier to remember tasks linked to daily events. As routines can also support habit formation—and long-term regimens are habitual in nature—habit formation apps could provide insights into how routine support could be implemented in adherence apps.

Several reviews of general behaviour change apps have been conducted (e.g. Cowan et al., 2013; West et al., 2012), but the focus was on their grounding in theory. However, as behaviour change theories tend to focus on intentional behaviour and neglect habits (see page 43), the lack of grounding in behaviour change theory does not necessarily mean that the apps could not support habit formation. Therefore, below I present a review of apps designed specifically to help people fit a new behaviour into their daily routine and turn it into a habit. To understand how they support habit formation, I review their functionality and their grounding in habit research.

4.2.1 Method

The keyword "habit" was used in the UK version of Apple iTunes Store (Apple Inc., n.d.) and Google Play (Google, n.d.). 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: habit cessation apps, general behaviour change apps, food and activity trackers, exercise routines, books about habits, and research apps that require registration codes. Apps for tablet computers and apps not available in English were also excluded. In the end, 115 apps were identified: 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 that were later used in the main data collection phase. Their presence was noted for each of the 115 identified apps. 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 the development of new habits, each feature was coded for whether it supports the factors influencing this process: contextual cues, implementation intentions, and positive reinforcement (see page 45 for details).

Since habit formation is a part of the wider behaviour change process, features were also matched with corresponding behaviour change techniques from Behaviour Change Techniques Taxonomy version 1 (BCT Taxonomy, 2014; Michie et al., 2013). Based on the Taxonomy, I extracted a list of techniques that could be delivered by smartphone apps. Next, I matched the items from the list with recorded app functionality. To validate the results, matching techniques were presented as a list to two other researchers who were asked to independently select up to three techniques that could be supported by each feature.

4.2.2 Findings

Functionality

Figure 4.4 summarises 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 behaviour.

Apps also provided features that explicitly 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, the apps allowed them to add notes

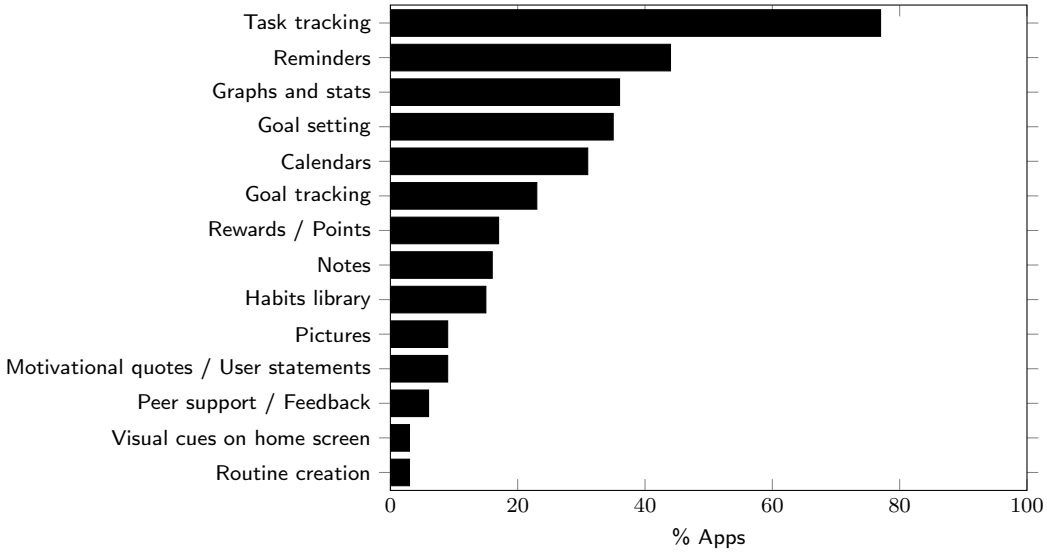


Figure 4.4: Functionality of habit formation apps (N=115).

(16%) and pictures reminding of the task (9%), and enter statements about the goal or read motivational quotes (9%). Some apps (15%) provided a habit library, 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. Habit Clock (HabitClock, n.d.) and The Fabulous (The Fabulous, n.d.) provided a step-by-step guidance to help users develop a morning routine made of predefined activities (e.g. wake up, meditate, eat breakfast, write for an hour). Habitual Free (Davis, 2013;

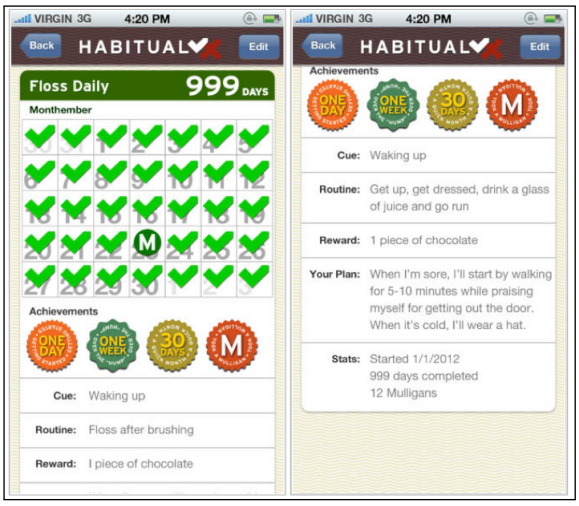


Figure 4.5: *Habitual Free*, a habit formation app that requires users to specify a cue, a new routine and a reward.

see Figure 4.5) was the only app that 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. eating a piece of chocolate). However, tracking the behaviour was still the main feature.

Grounding in behaviour change and habit research

Table 4.2 presents identified app features and matches them with corresponding elements supporting habit formation and behaviour change techniques. The majority of apps focused on supporting self-monitoring: tracking own behaviour and receiving feedback. Users were able to record the time they completed the task, view how many times they did it in the past without any breaks, or track their progress towards goals.

Table 4.2: Functionality of habit formation apps with corresponding factors supporting habit formation and behaviour change techniques (N=115). Apps marked with *i* are available for iOS and with *a* for Android phones.

Functionality	% Apps	Habit formation elements	Behaviour change techniques	Example apps
Task tracking	77%	-	Self-monitoring, Feedback on behaviour	Daily Habit[a]
Reminders	44%	-	Prompts / cues	Healthy Habits[i]
Graphs & stats	36%	-	Feedback on behaviour and its outcomes, Self-monitoring	Way of Life[i]
Goal setting	35%	-	Goal-setting	HabitFlow[a]
Calendars	31%	-	Feedback on behaviour, Self-monitoring, Goal-setting	Habit Calendar[a]
Goal progress tracking	23%	-	Feedback on outcomes of behaviour, Self-monitoring	Strides[i]
Rewards & points	17%	Positive reinforcement	Rewards & incentives	Habit RPG[ia]
Notes	16%	-	Prompts / cues	Any Habit[i]
Habits library	15%	-	Goal-setting, Action planning	The Fabulous[a]
Pictures	9%	Cues	Prompts / cues, Positive self-talk, Rewards & incentives	The Habit Factor[ia]
Motivational quotes & own statements	9%	Positive reinforcement	Positive self-talk, Rewards & incentives	Good Habit Maker[1]
Peer support & feedback	6%	-	Social support, Feedback on behaviour	Lift[ia]
Visual cues on home screen	3%	Cues	Prompts / cues, Feedback on behaviour	3 Week Habit[a]
Routine creation	3%	Implementation intentions	Action planning, Goal-setting	Habitual Free[i]

Out of elements that support habit formation, positive reinforcement features were the most common, available in 23% apps. Only a few apps provided relevant features that could support contextual cues and daily routines. Fifteen apps provided features that could serve as cues to action, such as memorable pictures or icons, but they did not facilitate the use of parts of the enviroment as cues. Explicit routine support and features that help to select meaningful cues to action and form implementation intentions were available in only three apps.

4.2.3 Conclusions

Contrary to the existing research that highlights the lack of apps' theoretical underpinnings (Cowan et al., 2013; West et al., 2012), features of all apps could be matched with corresponding behaviour change techniques, mainly those promoting self-monitoring. Self-monitoring is often used in behaviour change interventions (Free et al., 2013) as it helps people to understand their behaviour, set realistic goals, monitor progress, and maintain motivation (Bandura, 1991). However, it does not help to form associations between the task and the environment, nor does it support the development of automaticity. Moreover, it is effective only if the tracking continues: once it stops (e.g. when the app stops working or a user gets bored), the behaviour can revert to pre-intervention levels (Klasnja et al., 2011; Kopp, 1988; Renfree et al., 2016). This emphasises a lack of understanding of how habits form and what role they play in supporting long-term changes in behaviour. It also highlights a tension between developers' need for app engagement and users' need to develop a habit that, if successful, will lead to them abandoning the app.

The apps also provided features that help to maintain motivation, such as positive reinforcement, goal setting, rewards and incentives, and positive self-talk. While high motivation can help to start a new behaviour and initiate regular repetition, its influence decreases with time (Neal et al., 2012; Wood & Neal, 2007) and extrinsic rewards can hinder the development of automaticity (Deci et al., 1999). Only five out of 14 identified feature categories could be matched with factors that influence the development of new habits and only one of them—routine creation—could help users to find the right trigger event. This shows that, apart from three examples, the existing habit apps do not provide features that support habit formation and cannot inform the design of medication adherence apps that facilitate the development of medication habits.

4.3 Discussion

The survey results from Chapter 3 showed that people tend to take their medications together with existing routine tasks, such as eating meals or getting ready in the morning. They also highlighted the lack of technology use across all regimens, even among young adults, which suggests that existing apps might not be fit for purpose. Therefore, the goal of this chapter was to investigate how existing apps currently support medication-taking and whether habit formation apps provide functionality that could facilitate the formation of medication habits.

The results showed that the support provided by apps was indeed inadequate. The functionality review of 229 medication reminder apps showed that features that could help people make medications part of their daily routine were unavailable. The apps mainly provided timed reminders that often could not be postponed, and as a result they did not differ much from SMS reminders or simple alarm clocks available on every mobile phone. With only 18% of them providing customisable alerts, they took a "one size fits all" approach, disregarding the fact that medication-taking routines are personalised and unique to each individual (Johnson, 2002). The analysis of user reviews of the most popular apps emphasised this need for personalisation and showed that users wanted and valued flexible reminders that could be customised and fit into their routines. The review of 115 habit formation apps showed that they did not make use of existing routine events and other contextual cues, even though cues are key to developing a new habit (Lally & Gardner, 2011). Moreover, by providing self-tracking features and timed reminders, the apps encouraged regular interactions, helping users to develop a habit of using the app, but not necessarily the habit they initially set out to develop.

These results highlight the lack of understanding of the behaviours the apps are supposed to support. On the surface, providing reminders sounds like a good strategy for helping people to remember their medications or to repeat the same behaviour every day. However, in the context of maintaining adherence over a longer period simple reminders are not enough. Existing apps are not grounded in prospective memory and habit formation research that highlights the importance of event-based tasks and contextual cues (Gollwitzer, 1999; Guynn et al., 1998; Lally & Gardner, 2011; Park & Kidder, 1996; Verplanken, 2005). They also neglect the common strategies people use to remember their medications (see Chapter 3 and existing studies conducted with older adults, e.g. Palen & Aaløkke, 2006). Instead, the apps facilitate continued engagement with technology and teach people to rely on it, which can have a negative effect on remembering:

people who are expected to be reminded are more likely to forget (Einstein et al., 1998; Schæfer & Laing, 2000). Moreover, since apps are often unreliable and can easily break, they increase the chances of forgetting even further, as reliance on technology often means that the behaviour stops once the app's support is removed (Renfree et al., 2016).

The limitations of existing apps and the need for routine support call for a new approach; however, the existing focus on reminders might influence users' attitudes towards any new solution. While people acknowledge the role of routines in medication-taking (see for example Review #380 on page 82), they do not consider apps to be a tool that could help to create or maintain them. They expect the apps to provide flexible reminders that are appropriate for their daily routines, but they do not see the lack of explicit routine support as a problem, nor do they ask for it in their feature requests. This suggests that people may not expect that technology could do more than simply remind that something needs to be done—after all, regular reminders are all that is available and all they know (see other reviews of adherence apps, e.g. Choi et al., 2015; Heldenbrand et al., 2016; Morrissey et al., 2016; van Kerkhof et al., 2016).

Nevertheless, the focus of the apps should shift from simple reminders that users learn to rely on completely, to a smart assistive technology that helps them create their own personalised routines. Instead of passively reminding to take medications at a specified time, the technology could be seen as an assistant that leads users towards developing a new behaviour. To support the formation of medication habits, apps should help users associate their medications with an existing routine event. The reviews analysis highlighted users' preference for customisation, which emphasises their need for being in control. To address it, the routine creation should take that into account and allow users to select a regular event that best fits their schedule and their needs. In theory, this could be done explicitly by asking users to specify their existing routine or providing a list of examples to choose from (as was demonstrated by Habitual Free and two other apps that help to form routines; see page 86); or implicitly by simply letting them know that people in general find it easier to remember their medications when they take them right after a regular task, e.g. eating breakfast or brushing their teeth (an approach similar to educational campaigns aimed at reducing intentional non-adherence, e.g. Haynes et al., 2008). In practice, however, it is not clear which approach would be best or how to implement it effectively.

To improve existing apps and provide habit support grounded in research and people's daily practices, we need to understand how individual factors influencing habit formation (repetition, contextual cues, positive reinforcement; see page 45) could be supported through an app. More-

over, given that reminders are a common feature in adherence and habit apps, that people expect to have access to scheduled notifications, and that plan reminders illustrate that reminders can effectively reinforce implementation intentions and support behaviour change (Prestwich & Kellar, 2014; Prestwich et al., 2009, 2010), it is also important to investigate what impact reminders have on the formation of new habits. This would allow us to establish what types of cues should and could be supported by apps, and would later inform the design guidelines for implementing this support. Therefore, the next chapter investigates how regular repetition, contextual cues and positive reinforcement could be supported through a mobile technology. It also explores the influence of timed reminders on facilitating the development of automatic behaviour.

Chapter 5

Developing habits in the real world

This chapter:

- ❖ Presents a 4-week experimental study conducted with 133 participants to explore the role of different types of cues and positive reinforcement in the development of automaticity.
- ❖ Describes a 12-week follow-up study conducted with 209 participants that builds on the results of the first study.
- ❖ Highlights the gaps in the habit formation literature and the need for better understanding of what constitutes "good cues" and what factors support their selection.

The first study presented in this chapter has been published in [C.1]. *The second study was presented at 2nd Behaviour Change Conference: Digital Health and Wellbeing and an extended abstract with a summary of the results was published in* [E.1].

Medication surveys from Chapter 3 confirmed that turning medication-taking into an event-based task and relying on routine daily events as triggers to action can be an effective strategy for staying adherent—more effective than using reminders. Yet, as reported in Chapter 4, reviews of medication reminder and habit formation apps showed that apps do not leverage existing routine behaviours, nor do they facilitate the formation of dedicated medication routines. Instead, they provide reminders that often require immediate response, even though event-based tasks are easier to remember (Einstein & McDaniel, 1996; Park & Kidder, 1996). Features that could support long term regimens and the formation of medication habits are generally unavailable.

Medication-taking is a habitual task and habits are an important part of a daily routine: they drive the behaviour and, as it becomes automatic, help to maintain it over longer periods (Lally & Gardner, 2011; Verplanken, 2005). The existing literature highlights the importance of consistent repetition, contextual cues, and positive reinforcement as factors supporting habit formation (Lally & Gardner, 2011); however, it is not clear how they can be effectively supported through a mobile technology. Previous studies investigating habit formation have focused on understanding how long it takes for the new behaviour to become automatic (Lally et al., 2010), what strategies people develop to support that process (Lally et al., 2011), or what point in the routine is the most effective as a trigger to action (Judah et al., 2013); how this theory could be implemented in practice has not been explored.

For technologies to be effective, they need to be grounded in theory as it allows to identify appropriate behaviour change techniques that have the greatest impact (Webb et al., 2010). Yet, the analysis of habit formation apps reported in the previous chapter showed their lack of theoretical basis. Understanding how the theory could be translated into specific features is crucial to ensuring that an app will effectively support habit formation. Therefore, in this chapter I present two studies that investigated how contextual cues and positive reinforcement delivered via mobile technology could facilitate the development of automaticity in the real world, and compare this approach to standard timed reminders commonly used in adherence and habit formation apps. The first study, described in the next section, focuses on mechanisms of developing automatic behaviours when forming a new habit is not an explicit goal, which helps to test the theory and assess the effectiveness of different types of cues. The second study is described next. It builds on the results of the first study by investigating how the process differs in a naturalistic setting, i.e. when people want to form a habit and can select their own cues.

The results of both studies highlight the limitations of the current understanding of how habits form. Even though the literature suggests that contextual cues can support prospective remembering and habit formation (Lally & Gardner, 2011; Park & Kidder, 1996), the studies demonstrate that not all cues can effectively support both at the same time. As the existing theories do not explain what constitutes an effective cue and what factors influence its selection, it is difficult to translate the theory into specific features that could be delivered through a mobile phone. Therefore, this chapter ends with a discussion of limitations of habit research and outlines the steps that need to be taken before habit support can be effectively implemented.

5.1 Investigating the role of contextual cues, reminders and positive reinforcement

Grounding technology-based behaviour change interventions in theory enhances their effectiveness by helping to identify theoretical constructs that need to be targeted (Webb et al., 2010); in the context of habit formation, these are the factors supporting the development of automaticity. For a habit to develop, the behaviour needs to be consistently repeated in the presence of stable contextual cues (Gardner et al., 2012; Wood & Neal, 2007). The repetition can be facilitated with reminders (Tobias, 2009), but this is not enough: the task requires a stable context so that the environment starts to drive the behaviour. While any part of the environment can be a cue (Lally & Gardner, 2011; Neal et al., 2012; Wood & Neal, 2009), using routine events as triggers to action might be the most effective: in a sequence of actions, each step prompts the next (Botvinick et al., 2009; Graybiel, 1998; Verplanken, 2005). Routine events also support prospective remembering (Park & Kidder, 1996), which can ensure regular repetition from the start. In addition, providing positive reinforcement can support the process of habit formation as even small successes increase the feeling of satisfaction and can strengthen the habit (Aarts et al., 1997; Lally & Gardner, 2011).

Based on the research summarised above, it was assumed that relying on routine events as triggers to action would be more effective than relying on reminders, and receiving positive reinforcement could support habit formation and consistent repetition; combining both should then be the most effective. Therefore, the following hypotheses were formed to investigate the role of different types of cues and positive reinforcement in the process of habit formation:

Hypothesis 1: Participants who use routine events as cues will be more adherent and will report higher levels of automaticity compared to participants who use different cues.

Hypothesis 2: Participants who receive positive reinforcement will be more adherent and report higher automaticity compared to participants who do not receive positive reinforcement.

Hypothesis 3: Participants who use routine events as triggers to action and also receive positive reinforcement will be the most adherent and will report the highest automaticity compared to other participants.

A longitudinal experimental study design was selected as the most appropriate method for testing the hypotheses. As habits take time to develop (from 18 to estimated 254 days, with median of 66 days; Lally et al., 2010), the study had to last at least a few weeks. Experimental design

was chosen as it ensures more rigour and confidence in findings (Rogers et al., 2011) and allowed me to compare in a structured way the individual factors that influence the process of habit formation with standard reminders.

5.1.1 Method

Participants were asked to report via text message what they had for lunch every day for four weeks. Lunch was selected as a trigger event as it is a familiar task that takes place every day. To be able to focus on the mechanisms of habit formation, to reduce potential biases, and 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 which type of cue can help to turn the act of sending text messages with lunch descriptions into an automatic action, and thus which cues should be supported by an app that facilitates habit formation. As simple tasks become automatic faster than complex tasks, some even in 18 days (Lally et al., 2010), it was assumed that sending an SMS was simple enough to make it possible to observe an increase in automaticity in only four weeks. Participants were informed of the real focus of the study in the debrief email.

Participants

Overall, 133 participants signed up for the study. They were recruited on social networks and through leaflets distributed on UCL campus (see Appendix E for the recruitment questionnaire). They were 18-55 years old (mean age: 25 years old, SD=5.8), 81% were women, 82% were students. Participants who finished the study received a £5 voucher in recognition of their SMS costs and a summary of their lunch patterns. They were also entered into a raffle with a chance to win one of five £25 Amazon vouchers.

Design

The study used 3 × 2 between-subject design: cue (none, SMS reminder, lunch) × positive reinforcement (none, SMS), which resulted in six conditions. SMS reminder represented a standard timed reminder, while lunch was selected to serve as a trigger event (contextual cue). Dependent variables were automaticity, adherence and response time. Automaticity was the most important factor as it is associated with habit strength (Gardner et al., 2012; Lally et al., 2010; Verplanken

& Orbell, 2003). Adherence, defined as consistency in sending SMS reports, was measured to track repetition. Response time was measured to investigate how soon after the cue participants reported their lunches.

Participants were randomly assigned to conditions that varied in terms of type of cue and positive reinforcement. There were 22 participants in each condition, 23 in the Control group. The conditions are summarised in Table 5.1 and described below.

Table 5.1: Independent variables and study conditions.

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

No cues (Control) group. Participants were simply 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 ("Please let me know what you had for lunch") 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 finished lunch (implementation intention), which served as a trigger event. As it is easier to remember tasks that take place after a routine action (Judah et al., 2013), the "after" instruction was emphasised ("Think of your last bite as a sign it's time to send your lunch report" and "Make sure you send the text right after you finish eating") to ensure sending the report was associated with the trigger event. No positive reinforcement was provided.

No cues and positive reinforcement (N&PR) group. Cues to action were not specified (as in the Control group), but after sending a lunch report participants received an automated confirmation message that provided positive reinforcement (e.g. "Great, thank you!", "You're great!", "Awesome!"). The messages were inspired by examples from Fogg (2012). They were sent with a delay to make it less obvious that they were automatic.

Reminder and positive reinforcement (R&PR) group. Participants received reminders in the afternoon and positive reinforcement messages in response to their SMS reports.

Trigger and positive reinforcement (T&PR) group. Participants were instructed to send text messages after lunch and received positive reinforcement messages.

Materials

As developing a full app for study purposes would have been premature at this point, text messages were used to interact with participants through their phone. They were managed by Twilio (Twilio Inc., n.d.). The service provided a platform for receiving and storing text messages, and allowed to create text message reminders and send automated confirmation messages. Two Twilio mobile numbers were used: the first provided custom, randomly selected confirmation messages (was used by N&PR, R&PR and T&PR groups) and the second number had automated responses switched off (was used by Control, Reminder and Trigger groups). IronWorker (Iron.io, n.d.) was used to host Twilio reminder code and to handle scheduled text message reminders. All messages sent and received by Twilio were stored on their server and logs were later exported as a comma separated file (CSV). Stored data included the content of the message, its date and time, and participants' mobile numbers.

Weekly summary emails were managed by MailChimp (Rocket Science Group, n.d.). At the end of each week lunch reports exported from Twilio were converted into a MailChimp compatible format and imported to their server, and emails with a summary of weekly lunches were sent to all participants. MailChimp was also used to distribute emails with instructions at the beginning of the study, the final questionnaire at the end, and the debrief email.

The Self-Report Habit Index questionnaire (SRHI; Verplanken & Orbell, 2003) was included in the final survey to measure habit strength. However, in the end only a validated subset of SRHI questions (Self-Report Behavioural Automaticity Index – SRBAI; Gardner et al., 2012) was used in the analysis as it is limited to questions that specifically focus on automaticity of behaviour: ("Behaviour X is something...") 1. "I do automatically", 2. "I do without having to consciously remember", 3. "I do without thinking", and 4. "I start doing before I realise I'm doing it". Questions were presented on a 7-point Likert scale with answers ranging from "Strongly Agree" to "Strongly Disagree". Scores ranged from 4 to 28 points, with higher scores indicating higher self-reported levels of automaticity.

Procedure

The study started in November 2013. Participants were asked to report each day via SMS at what time they had lunch and what they ate. 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; different times were selected to account for changes in a daily routine.

Before the study had started, participants received emails with condition-specific instructions, lunch report examples, and assigned Twilio numbers to which they were supposed to send their lunch reports (see Appendix E for details). On the first day of the study they received an email reminding them their Twilio number and instructions.

Every Monday all participants received emails with a summary of their lunches from the previous week; the goal was to provide implicit reminders and keep participants engaged with the study. At the end of the study participants received a link to the final survey that explored how they remembered to send text messages and how difficult it was. The survey also included the full SRHI questionnaire. After submitting their responses, each participant received a debrief email that explained the main objective of the study and included vouchers.

Due to technical issues, for the fist two weeks of the study positive reinforcement messages were sent randomly i.e. participants in PR, R&PR, T&PR groups received them in a response to some of their text messages, but not all. The issue was fixed and for the rest of the study they received confirmations for all their lunch reports. Overall, throughout the study 88% participants from these conditions received at least 75% of confirmations they were supposed to receive. I discuss the implications in the study conclusions on page 109.

Pilot study

To test all procedures and technology, 18 academics and PhD students (16 of them not familiar with the main objective of the study) reported their lunches for 10 days. The recruitment questionnaire, emails to participants, and the content of SMS reminders were edited based on feedback to clarify the instructions. Updates to the text messaging code accidentally introduced the technical issues mentioned earlier. Pilot participants also pointed out that the presence of the researcher in the office often prompted them to send lunch reports. As a result, care was taken later to ensure participants did not know anyone involved in the study.

Analysis

For the purpose of this study, an "effective intervention" was defined as one characterised by a low number of missed lunch reports, high self-reported automaticity of the behaviour at the end of the study, and a low variation in time intervals between the base time (lunch time or reminder time) and the lunch report time, in particular during the final week.

Automaticity of behaviour was assessed using SRBAI scores. A weekly adherence rate was calculated for each group based on the number of text messages received each week divided by the number of text messages expected in that time period. The number of text messages expected was calculated by multiplying the number of participants in each group by seven. Two-way between-subject analyses of variance were used to explore the impact of cue type and positive reinforcement on automaticity and adherence. Changes in automaticity and adherence over time were explored using mixed between-within analyses of variance. To explore how participants remembered to send lunch reports, the frequency of memory aids mentioned in open-ended answers to the final surveys was counted and illustrative quotes extracted; the main trends were presented using descriptive statistics.

The variation of lunch times was calculated as a difference in minutes between reported lunch time or the time of a reminder and the time when an SMS from a participant had been received. As Twilio used Pacific Daylight Time (PDT), all time stamps had to be converted into Greenwich Mean Time (GMT) to match participants' time zone. Time variation of each report was used to determine weekly averages for all conditions.

To investigate how response time changed throughout the study, the difference between the time of the SMS and the base time was calculated in minutes for each lunch report. Base time was defined as the time of the reminder (Reminder and R&PR conditions) or reported lunch time (all other conditions). Based on response time, lunch reports were divided into four groups: "immediate reports" sent within five minutes after the base time (including reports sent before the base time, e.g. those reporting lunch in advance or sent before the reminder), "after lunch reports" sent within an hour from the base time (based on the assumption that lunch breaks usually last 30-60 minutes), "late reports" sent 1-12 hours after the base time (assumed to be sent on the same day as lunch), and "forgotten reports" sent over 12 hours after the base time (i.e. sent the next day). The response time categories were used to calculate the time variation per condition.

Among participants who completed the study, 77% were women. To rule out the influence of gender on automaticity and adherence, independent samples t-tests were conducted. There were no significant results.

5.1.2 Findings

Ninety-six participants (72%) completed the study and were included in the final analysis. Six participants withdrew from the study, 22 stopped sending messages after two weeks and were assumed to have dropped out, and seven did not respond to the final survey and their data had to be excluded. Another two participants had to be excluded as their messages for the first week of the study were lost. No one had to be excluded due to low adherence rates. The fewest participants dropped out from the R&PR and Reminder groups (two and four, respectively), while the Trigger and Control groups lost nine participants each (41% and 39%, respectively). Figure 5.1 shows drop out rates for each condition.

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 groups sent

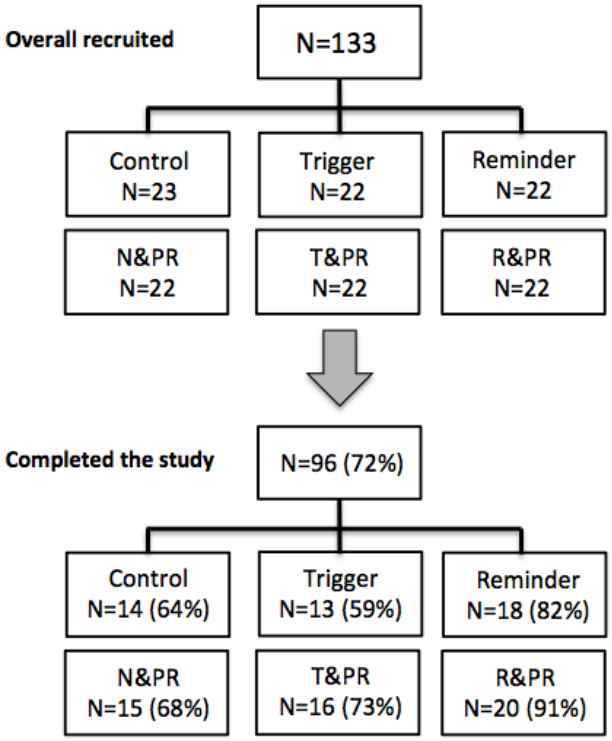


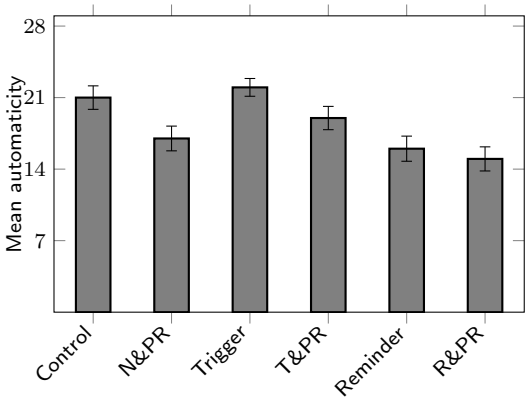
Figure 5.1: Number of participants from each condition who completed the study.

the most (on average 26 and 27 messages per person respectively), while participants from the T&PR group sent the fewest (on average 19.5 messages per person).

Impact of cues and positive reinforcement on automaticity

Automaticity measured with SRBAI scores was used to assess the strength of the texting habit; the scores are summarised in Figure 5.2. 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 it was 17 (SD=4.7, N=15). Participants from both reminder conditions reported the lowest automaticity levels: the Reminder group's score was 16 (SD=5.2, N=18) and R&PR's was 15 (SD=5.3, N=20).

To test the hypotheses, a two-way between-subjects ANOVA compared all cue types to each other and explored the impact of cue type and positive reinforcement on automaticity (see Figure 5.3). There were significant main effects for cue type ($F(2,90)=10.65$, $p<.001$, partial $\eta^2=.19$) and positive reinforcement ($F(1,90)=6.39$, $p=.013$, partial $\eta^2=.07$), the latter indicating that automaticity was higher for conditions *without* positive reinforcement (mean=19, SD=5.2, N=45 vs. mean=17, SD=5.1, N=51). The interaction between these two factors was not statistically significant ($F(2,90)=1.32$, $p=.27$, partial $\eta^2=.03$). For cue type, a 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.



Condition	N	Mean	SD	Min	Max
Control	14	21	4.3	12	28
N&PR	15	17	4.7	11	28
Trigger	13	22	3.2	17	26
T&PR	16	19	4.6	10	28
Reminder	18	16	5.2	9	28
R&PR	20	15	5.3	7	28

Figure 5.2: Automaticity scores per condition based on SRBAI results (N=96). Scores range from 4 to 28 points, higher scores indicate a stronger habit.

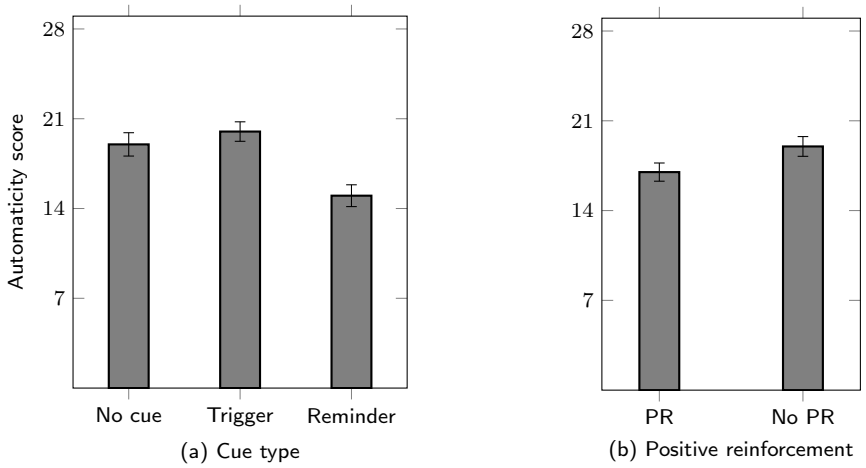
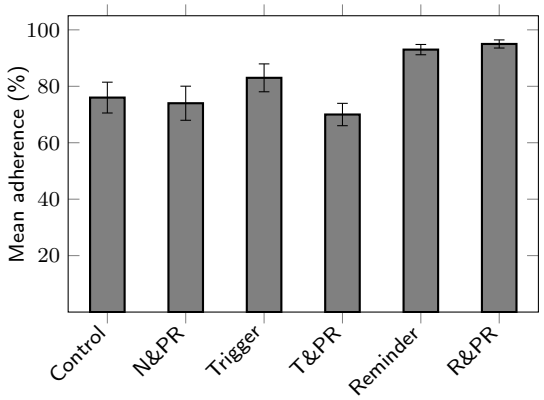


Figure 5.3: Mean automaticity scores for (a) cue type and (b) presence of positive reinforcement (N=96). Higher values indicate higher automaticity, max=28.

Impact of cues and positive reinforcement on adherence

Adherence rates were calculated to understand how consistently users repeated their behaviour. They are summarised in Figure 5.4. Adherence of 71% was an equivalent of reporting lunches every day on weekdays only. Overall, participants from the Reminder and R&PR groups were the most adherent with the adherence of 93% (SD=8%) and 95% (SD=6%) respectively, while the T&PR had the lowest average score (mean=70%, SD=16%), although it was still high.

To test the hypotheses, the influence of type of cue and positive reinforcement on adherence rates was evaluated using a two-way between-subjects ANOVA. There was a statistically significant main effect for cue type: $F(2,90)=15.46$, $p<.001$, partial $\eta^2=.26$, but not for positive reinforcement: $F(1,90)=1.94$, $p=.17$, partial $\eta^2=.02$. There was no significant interaction ($F(2,90)=1.87$,



Condition	N	Mean	SD	Min	Max
Control	14	76%	20%	29%	100%
N&PR	15	74%	23%	25%	100%
Trigger	13	83%	18%	36%	100%
T&PR	16	70%	16%	36%	96%
Reminder	18	93%	8%	68%	100%
R&PR	20	95%	6%	79%	100%

Figure 5.4: Adherence scores per condition (N=96). Adherence of 71% is an equivalent of reporting lunches every day on weekdays only.

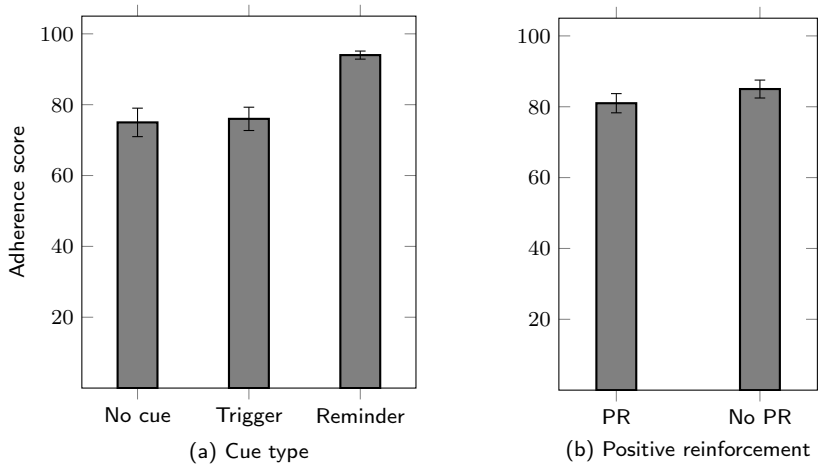


Figure 5.5: Mean adherence scores for (a) cue type and (b) presence of positive reinforcement. Adherence of 71% is an equivalent of reporting lunches every day on weekdays only. N=96.

p=.16, partial η^2=.04). A Bonferroni post-hoc test showed a 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). Scores are shown in Figure 5.5.

To assess the impact of each condition on adherence over time, a mixed between-within subjects analysis of variance was conducted. There was no significant interaction between cue type and time (Wilk's Lambda=.93, F(6,176)=1.08, p=.37, partial η^2=.04) or reinforcement and time (Wilk's Lambda=.97, F(3,88)=1.02, p=.39, partial η^2=.03). There was a substantial main effect for time (Wilk's Lambda=.73, F(3,88)=10.8, p<.001, partial η^2=.27), with all groups showing a decline in adherence over four weeks (see Figure 5.6). The main effect comparing all cue types

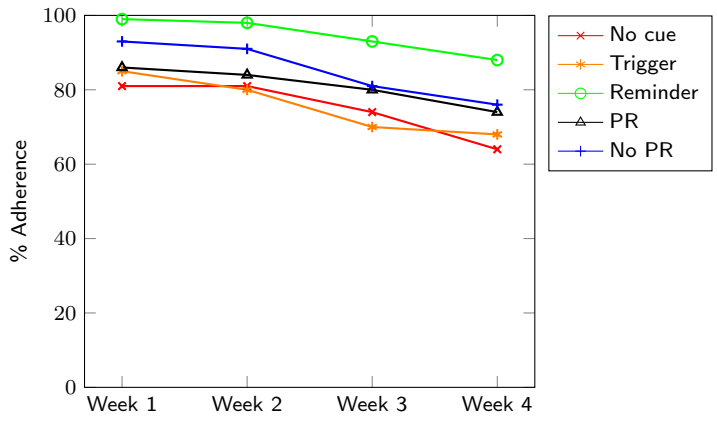


Figure 5.6: Change in adherence rates over time for different cue conditions (no cue, trigger event, reminder) and positive reinforcement (PR, No PR). N=96.

was also statistically significant with a large effect size ($F(2,90)=15.5$, $p<.001$, partial $\eta^2=.26$), suggesting differences in effectiveness of each condition in supporting adherence. Participants in the reminder conditions were the most adherent. There was no significant difference between conditions that received positive reinforcement and those that did not ($F(1,90)=1.8$, $p=.18$, partial $\eta^2=.02$).

Impact of cues on response time and consistency of repetition

In total, 2,455 lunch reports were received (including SMS and reports sent via email by participants unable to send a text at the time). After messages with no lunch time (e.g. with time of lunch missing or stating that there was no lunch that day) were excluded, 2,372 lunch reports were analysed. Overall, 26% of lunch reports were "immediate", 33% were sent within an hour ("after lunch"), 34% were "late" and 6% were labelled as "forgotten". Figure 5.7 shows the prevalence of each type of the report by cue type and positive reinforcement. Nearly half of participants from reminder groups responded immediately (45%) and only 1% of their reports were classified as "forgotten". Trigger groups reported the highest volume of forgotten lunch reports (13%).

To test the hypotheses and assess the impact of a type of cue and positive reinforcement on response time throughout the study (consistency of repetition), a mixed between-within subjects ANOVA was conducted on average weekly scores of 89 participants who were active throughout the whole study. "Forgotten" reports were excluded from the analysis. As the assumption

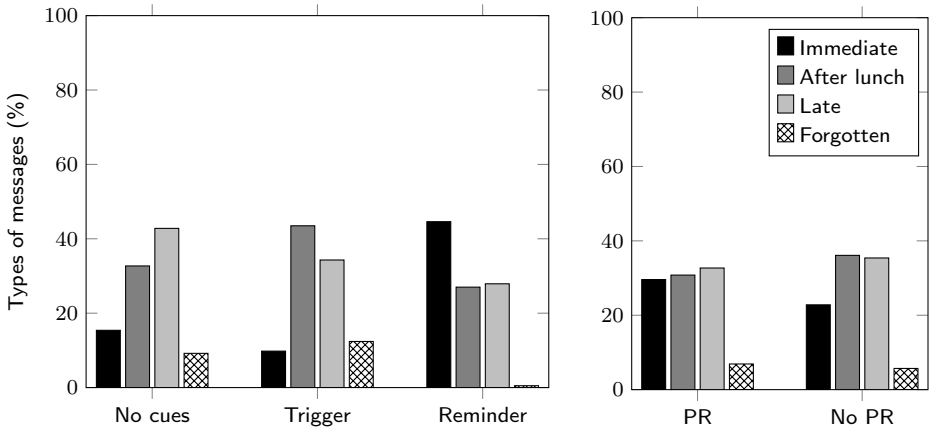


Figure 5.7: Types of lunch reports per condition by response time: sent within 5 minutes of receiving a reminder ("immediate"), sent within 30-60 minutes ("after lunch"), sent within 1-12 hours ("late"), and sent after 12 hours or later ("forgotten").

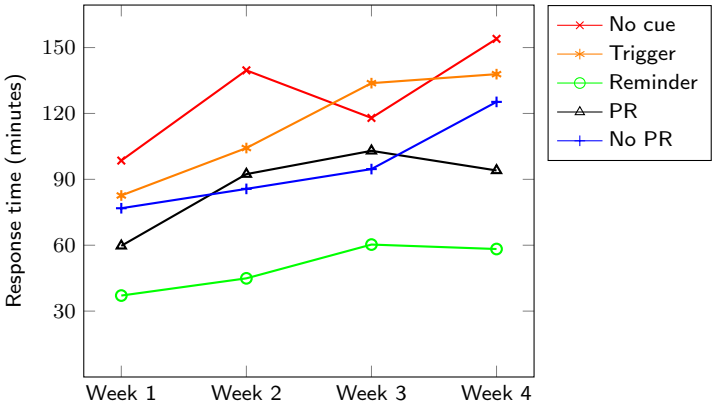


Figure 5.8: Average response time by condition (N=89). Reports sent 12 hours or later after the base time are excluded.

of homogeneity of variances was violated, more conservative value of p=.001 was used to assess significance. There was no significant interaction between the condition and time (Wilk's Lambda=.88, F(6,162)=1.73, p=.12, partial η^2=.06) or positive reinforcement and time (Wilk's Lambda=.903, F(3,81)=2.89, p=.04, partial η^2=.09), which suggests that the point in the study had not influenced response time. There was a large main effect for time (Wilk's Lambda=.73, F(3,81)=10.15, p<.001, partial η^2=.27), with most groups showing an increase in response time during the study (see Figure 5.8). The main effect comparing different types of cues was significant with a large effect size (F(2,83)=15.3, p<.001, partial η^2=.27), highlighting that reminder conditions recorded the fastest response time throughout the study.

Some participants reported their lunches without waiting for reminders: 10 participants from the Reminder condition (59% of this group) and 15 from the R&PR condition (75%). On average, they sent their reports seven times throughout the study (SD=6) before receiving reminders. Eight participants did so for at least a third of their reports, with one person responding to the reminder only twice and sending all other messages right after lunch before receiving SMS.

Remembering strategies

Eighty-nine participants answered the final survey that explored how they remembered to send lunch reports. The majority of participants who received SMS reminders named them as their main cue to action (16 participants from the Reminder condition and 13 from the R&PR), although two users reported using additional reminders: a note on a hand and a daily alarm.

Seven participants from N&PR and five from the Control group reported using reminders. Across all conditions, participants generally reported using phone alerts, notes, and calendars as additional memory aids; one person set a wallpaper on their phone with the words "send lunch report" to see it while using the phone. Previous lunch reports also served as reminders, as participants saw them when composing and receiving other messages. Eleven participants reported relying on a trigger event: the lunch itself, going to bed, or eating breakfast (the latter served as a reminder to report previous day's lunch). Eleven participants (from all conditions but Control) reported that sending text messages had become a "habit":

> *"For the first two weeks, it is more like an interesting thing to do. Then it becomes a kind of habit so I don't forget doing it."* – P58

> *"I just got into the habit after setting reminders in my diary for the first week"* – P124

Fifty-nine participants reported that remembering to send lunch reports was easy, mainly because they received SMS reminders (22 responses), developed a routine (11 responses), or relied on external reminders such as alerts or to-do lists (11 respondents). Six participants said they were motivated: they wanted to send the reports and be good study participants. Another six said that remembering was easy because their memory was good.

Among participants who reported that remembering to send the reports was difficult, 20 said that the main reason was being busy or distracted, and 14 reported that it was not part of their daily routine or it did not fit into their everyday schedule. Eight participants said they simply could not remember, including one participant who explained that lunch was not an important meal during the day, which made it harder to remember about the reports. Two participants who used their own reminders said that since they often had lunch with colleagues, it was too easy to dismiss the reminder and then forget about the report.

5.1.3 Conclusions

The aim of the study was to investigate the role of different types of cues and positive reinforcement in the process of habit formation. Based on the habit research, it was expected that relying on routine events as triggers to action would effectively support the development of automaticity (Botvinick et al., 2009; Graybiel, 1998; Verplanken, 2005). This hypothesis was supported: participants who reported relying on trigger events recorded higher automaticity levels than those who received reminders. Open-ended answers to the final survey confirmed that the presence of

a routine made remembering easier. However, participants who were using trigger events as cues tended to forget more often compared to participants from other conditions.

Relying on reminders was linked with lower forgetfulness: participants from reminder groups recorded the highest adherence and the fastest response time during the study. Open-ended answers showed that SMS reminders made remembering easy and participants who did not receive them often relied on self-selected cues and own reminders. However, reminder conditions reported the lowest automaticity scores. High automaticity of behaviour is associated with habit strength (Gardner et al., 2012; Lally et al., 2010; Verplanken & Orbell, 2003), and its low level suggests that while reminders were effective at reminding about the task and keeping participants engaged with the study, they did not help them to develop a habit. This is contrary to the assumption that reminders could support habit formation as long as their effect decays with the same speed as the habit develops (Tobias, 2009). Since automaticity scores for participants using reminders were lower than for those using no cues at all, and all adherence scores declined with time, it could be argued that in this case reminders might have hindered habit development and their effectiveness could decrease with time without facilitating habit formation.

Positive reinforcement was expected to support the development of automaticity regardless of the type of cue (Aarts et al., 1997; Lally & Gardner, 2011). However, the opposite was true: groups without it reported higher automaticity. As the messages were rather enthusiastic (e.g. "Awesome!", "You're amazing!"; inspired by Fogg, 2012), some participants might have found them annoying. Moreover, since they were automated (although delivered with a delay), they might have been perceived as not genuine. Unfortunately, the final survey did not explore participants' attitudes towards them. Technical issues also might have had an impact on the results, but these seem unlikely to explain why these messages had the small but opposite effect to the one predicted. Indeed, as the role of positive reinforcement in habit formation is to support repetition, the aim of these messages 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 participants' goal. Intrinsic motivation could explain the lack of effect of these messages: as participants were interested in understanding their eating habits, the motivation was already present and no support was needed.

Overall, it was expected that a combination of a trigger event and positive reinforcement would be the most effective method of habit formation as it incorporated all factors supporting habit formation (Lally & Gardner, 2011); it turned out to be the worst. Participants from the T&PR

condition reported automaticity levels no better than the control group and forgot the most often: they had the lowest adherence, which decreased over time, and the longest response time, which increased over time. This suggests that while event-based cues support the development of automaticity, it might develop too slowly to make this approach effective on its own and some level of reminder support might be desirable.

Limitations

The results also highlighted limitations related to the context of use. To form a habit, the task needs to be repeated in a stable context (Gardner et al., 2012; Wood & Neal, 2007), and routine events serving as triggers to action provide a stable cue that prompts the next step in a sequence (Botvinick et al., 2009; Graybiel, 1998; Verplanken, 2005). Therefore, lunch was chosen as a trigger event, as it is a simple, regular task that is often a part of a daily routine. However, while it takes place every day, participants reported eating at different times and in different environments. This lack of consistency influenced the stability of contextual cues and might have interfered with the process of habit formation.

The task selected for the study might have also influenced the outcomes, as it could be considered 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. The increase in automaticity of their behaviour emphasises the benefits of event-based cues and suggests that cues may be even more effective when the task is meaningful and people are trying to develop a new, desirable habit.

Technical issues with positive reinforcement experienced during the first two weeks of the study also might have had an impact on the results. Despite them, I decided to analyse the full study data because most participants received most of the messages. Removing participants who had not received all text messages from the dataset would have made it difficult to compare positive reinforcement conditions with others. It would also require limiting the data from the whole study to two weeks only, which is too short a period to measure the impact on habit formation. Moreover, the remaining data would have been confounded by existing texting practice as the study had already been running for two weeks.

Even though participants responding to trigger events reported higher automaticity scores compared to those relying on a reminder, they did not develop a habit and were the most forgetful. Perhaps if the study lasted longer than four weeks and participants were able to select their own cues to action the effectiveness of triggers would increase. Therefore, to evaluate the effectiveness of different types of cues in a more realistic context and to address the limitations discussed above I conducted a follow-up study. It is described in the next section.

5.2 Follow-up study: Understanding habit formation in a more realistic context

The results of the study reported above suggest that while relying on trigger events supports the development of automaticity of behaviour, it does not prevent forgetfulness—even though the presence of a routine should also support prospective remembering (Park & Kidder, 1996). However, the study design had limitations related to the context of use that might have influenced these outcomes: the length of the study, the task, and available cues. Therefore, to ensure that theory was tested in the right context, a follow-up study was designed to address these limitations.

The previous study ran for four weeks because simple tasks can become automatic in as little as 18 days (Lally et al., 2010); therefore, one month was deemed enough to observe an increase in automaticity. This assumption was confirmed. To validate the results over a longer period and test habit support in more realistic circumstances, the follow-up was extended to 84 days. This time period matched the length of the seminal study conducted by Lally et al. (2010) that investigated the time needed for a new behaviour to become automatic.

The task was also changed to make the process more realistic. In the previous study, it was somewhat arbitrary as participants did not know that they were developing a habit. This allowed me to focus on factors supporting the development of automaticity, but made the situation less realistic. As people who use habit formation apps know what they are for and want to develop new habits, the follow-up study made it clear that the goal was to start a new healthy behaviour. Participants were able to choose a task they would like to turn into a habit, although this choice was limited to two daily tasks (drinking water or meditating) to retain control over study conditions. Suggested tasks were listed on the recruitment questionnaire to help participants make an informed choice from the start.

Eating lunch was used as a cue to action in the first study. While in theory it is a routine event, in practice the context in which it took place varied. Moreover, the cue was assigned to participants and they were not able to change it, even when it was ineffective. Therefore, to make the context more realistic, participants in the follow-up study were assigned to general cue conditions (e.g. *a* routine event) and were able to define their own specific cues within these limits. They were also free to change these cues if needed.

In addition, even though routine events serving as cues are the most effective (Botvinick et al., 2009; Graybiel, 1998; Verplanken, 2005), the broader environment in which the habit develops can also provide contextual cues (Neal et al., 2012; Verplanken et al., 2008; Wood et al., 2005). Therefore, a new hypothesis was formed and tested together with the hypotheses from the first study (see page 95):

Hypothesis 4: Participants who use a routine event that occurs in the same location as trigger to action will be more adherent and report higher levels of automaticity compared to participants who use different cues.

The content of positive reinforcement messages also changed. The enthusiastic messages inspired by Fogg (2012) were replaced with simple acknowledgements that aimed to facilitate repetition.

5.2.1 Method

Participants were asked to repeat a healthy behaviour for three months. Every day, they had to report via SMS the time they completed their task. To ensure that the task was meaningful and participants were working towards a habit they would like to develop, before signing up they were given a choice between two simple tasks: a daily meditation habit (focusing on one's breath for less than a minute) or drinking water (one glass). These tasks were selected because they are simple and do not require any specialised tools or resources, which reduces the effort required to complete them every day.

Participants

Overall, 209 participants signed up for the study. They were recruited on social networks and through leaflets distributed on the campus; none of them had participated in the previous study. They were 18-58 years old (mean age=27, SD=7.6); 68% were women, 74% were students. 56%

selected meditation and 44% drinking water as their task. For their participation, they were offered a chance to be entered into a raffle to win one of three £50 vouchers or one of three £25 vouchers (see Appendix F for the recruitment questionnaire).

Design

The study used a 4 × 2 between-subject design based on the previous study. 'Stable context' (a combination of a trigger event and a location) was added as another cue type, resulting in eight conditions: cue (none, SMS reminder, trigger event, stable context) × positive reinforcement (none, SMS). Dependent variables were automaticity, adherence, and response time. There were 26 participants in each condition; 27 in the "no cues with positive reinforcement" group. Study conditions are summarised in Table 5.2 and described in detail below.

Table 5.2: Independent variables and study conditions.

Positive reinforcement	Cue			
	None	SMS reminder	Trigger event	Stable context (trigger event & location)
None	Control group	Reminder group	Trigger group	SC group
SMS confirmation	N&PR group	R&PR group	T&PR	SC&PR group

No cues (Control) group. Participants were told to meditate or drink a glass of water once every day and to report straight away at what time they did it. No cues were specified in the instructions. Participants did not receive any confirmation messages.

Reminder group. Participants received daily text messages reminding them to do their chosen task and report at what time they did it. They were able to choose at what time they would like to receive the reminders. They did not receive any confirmation messages.

Trigger group. Participants were asked to form their own implementation intentions and complete their task after something they already do, e.g. "meditating briefly after finishing morning coffee" or "drinking a glass of water after finishing eating lunch". They were explicitly told that attaching a new habit to an existing routine event could help with remembering as the routine could serve as a trigger. They were asked to report the time they did their task and after what routine event they did it.

Stable context (SC) group. Participants were given the same instructions as the Trigger group, but also had to include a specific location in their implementation intentions, e.g.

"meditating briefly in the bathroom after brushing the teeth in the morning" or "drinking a glass of water after coming to the kitchen after waking up". They were told that performing the task in the same location helped to develop a habit. They were asked to report the time they did the task, after what trigger event, and in what location.

No cues and positive reinforcement (N&PR) group. Participants were given the same instructions as the Control group. They received a positive reinforcement messages after sending each task report. Messages from the previous study were used, although the list of responses was reduced to simple confirmations, e.g. "Great, thank you!", "Noted!".

Reminder and positive reinforcement (R&PR) group. Same as the Reminder group, participants had to select a time for SMS reminders. They had to complete the task when reminded and to report at what time they did it. They received positive reinforcement.

Trigger and positive reinforcement (T&PR) group. Participants were given the same instructions as the Trigger group and received positive reinforcement.

Stable context and positive reinforcement (SC&PR) group. Participants were given the same instructions as the SC group and received positive reinforcement.

Materials

The same technologies were used as in the previous study: text messages were managed with Twilio (Twilio Inc., n.d.), SMS reminders were scheduled using IronWorker (Iron.io, n.d.), and MailChimp (Rocket Science Group, n.d.) was used to manage communication with participants. See page 98 for details.

Self-Report Behavioural Automaticity Index (SRBAI; Gardner et al., 2012) was used to assess automaticity levels at the end of Week 6 and Week 12. Its four questions were presented on a 7-point Likert scale with answers ranging from "Strongly Agree" to "Strongly Disagree".

Procedure

The study started in May 2014. The study procedure closely resembled that from the previous study (see page 98). Participants were asked to send daily text messages for 84 days reporting at what time they completed their chosen task. Some conditions also had to report their trigger

events and the location where they completed the task. Each message's arrival time and its content were recorded.

Before the beginning of the study, participants received emails with condition- and task-specific instructions and their assigned Twilio numbers. Participants from both reminder conditions were able to choose one of the predefined reminder times: 8am, 2pm or 9pm; the default time was 8am. They were free to change the time slot at any point during the study. Similarly, participants who had to complete their task after a trigger event or in a specific location were free to change them at any point and select contextual cues that better matched their daily routine.

One day before the study started, participants received an email reminding them of study instructions. At the end of each week, participants in all conditions received an email reminding how long until the end of the study, providing words of encouragement and showing their progress (adherence in the previous week); the role of the email was to keep participants engaged and motivated. Halfway through the study (at the end of Week 6) participants received a link to an online questionnaire that included the SRBAI questions.

A week after the study ended, all participants received a link to the "end-of-study" survey. The survey was based on the previous study, although to address its limitations, it also explored how participants remembered to send daily text messages and included questions about the usefulness of confirmation messages, attitudes towards the study, and SRBAI questions. After submitting their responses, participants received a debrief email. Raffle winners received vouchers in separate emails. Three months after the study ended, participants who had indicated earlier that they would be happy to answer any follow-up questions, received an email with a link to a short questionnaire investigating whether they continued to repeat their task every day. Study materials (instructions, questionnaires, emails, etc.) can be found in Appendix F.

Analysis

Automaticity and adherence were analysed the same way as the previous study (see page 100). SRBAI scores were measured at the end of Week 6 and Week 12. Mixed between-within subjects ANOVA was used to investigate how automaticity and adherence scores changed over time. Response time was not analysed this time, as the effort required for the analysis was disproportionate to the insights the data could provide.

Among participants who completed the study, 64% were women. To rule out the influence of gender on automaticity and adherence, independent samples t-tests were conducted; the results were not statistically significant. Similar analyses were conducted to explore the influence of a task and showed that participants who selected drinking water reported significantly higher automaticity compared to those who selected meditation (mean=18, SD=5, N=49 vs. mean=14, SD=6, N=66; $p<.001$) and higher adherence (mean=73%, SD=20%, N=49 vs. mean=63%, SD=24%, N=66; $p=.02$); the implications are discussed in study conclusions on page 123.

Pilot study

The study was piloted with eight participants recruited at UCL and on social networks; none of them participated in the previous study or its pilot. The pilot lasted 10 days and on the 5th day participants received the "Week 6" email with the questionnaire. Study instructions and final survey questions were clarified based on the pilot feedback.

5.2.2 Findings

In total, 115 participants (55%) completed the study: 29 withdrew, 50 were removed after 4-5 weeks of inactivity, and 15 participants did not submit the end-of-study survey and their data had to be excluded. Eighteen participants (69%) dropped out from the SC group within the first month, possibly due to complex or too rigid instructions; reasons for such a large drop-out rate and its implications are discussed in study conclusions. Among participants who completed the study, 66 were doing daily meditation and 49 were drinking a glass of water. Flow diagram in Figure 5.9 shows the number of participants from each category who completed the study and those who later responded to the follow-up survey.

Impact of cues and positive reinforcement on automaticity

SRBAI scores were used to measure the automaticity of habitual tasks selected by participants. Figure 5.10 shows automaticity scores at the end of the study. The T&PR (mean=16, SD=6, N=14) and SC&PR (mean=17, SD=4.9, N=15) groups reported the highest scores. The lowest automaticity was reported by participants from the SC group (mean=12, SD=6.9, N=6).

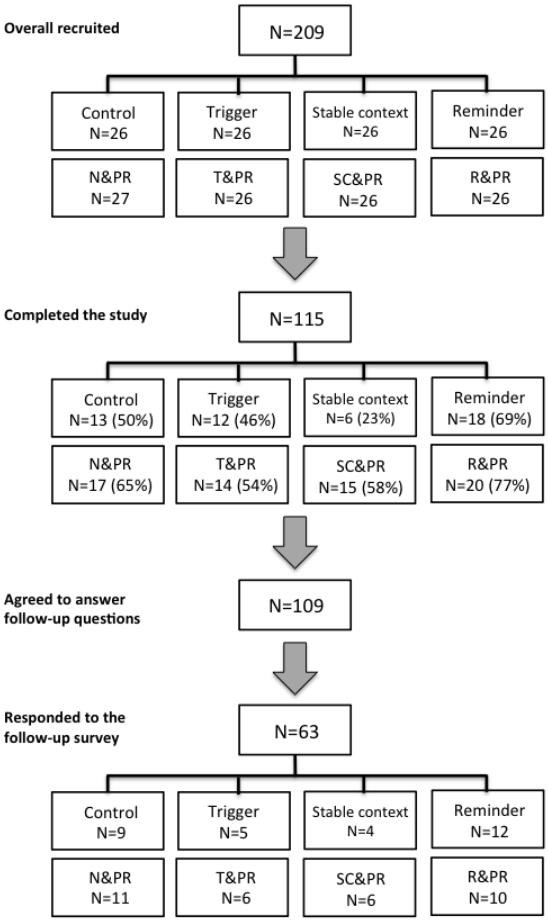
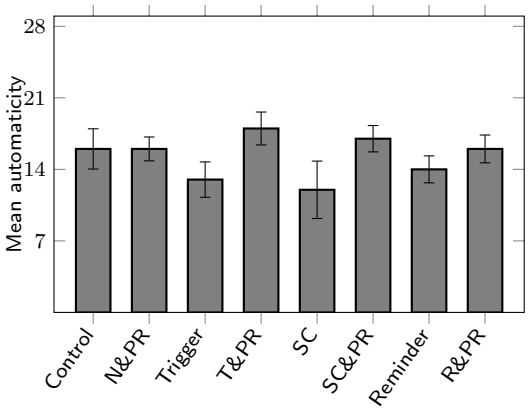


Figure 5.9: Number of participants who completed the study and responded to the follow-up survey.

To test the hypotheses, a two-way between-subjects ANOVA compared all cue types to each other and explored the impact of cue type and positive reinforcement on automaticity. The interaction between cue type and positive reinforcement was not statistically significant ($F(3,107)=.75$,



Condition	N	Mean	SD	Min	Max
Control	13	16	7.1	4	28
N&PR	17	16	4.8	7	23
Trigger	12	13	6.0	4	27
T&PR	14	18	6.0	6	28
SC	6	12	6.9	4	21
SC&PR	15	17	4.9	9	25
Reminder	18	14	5.6	7	24
R&PR	20	16	6.1	7	24

Figure 5.10: Automaticity scores per condition (N=115). Scores range from 4 to 28 points, higher scores indicate a stronger habit.

p=.53, partial η^2=.02). There was no significant main effect for cue type (F(3,107)=.48, p=.69, partial η^2=.01), but there was for positive reinforcement (F(1,107)=6.15, p=.015, partial η^2=.05), the latter indicating that participants who received positive reinforcement reported higher automaticity levels compared to those who did not receive it (mean=16.6, SD=5.5, N=66 vs. mean=14, SD=6.2, N=49).

Automaticity was measured at the end of Week 6 and Week 12 (see Figure 5.11) and a mixed between-within subjects ANOVA was conducted to investigate how SRBAI scores changed over time for groups with different types of cues and positive reinforcement. As 18 people did not fill in the Week 6 questionnaire, they were excluded. Data from only 97 participants was included in the analysis. There was no significant interaction between the type of cue and time (Wilk's Lambda=.96, F(3,89)=1.14, p=.34, partial η^2=.04) or between positive reinforcement and type of cue (Wilk's Lambda=1, F(1,89)=0.4, p=.85, partial η^2=.00). There was a substantial main effect for time (Wilk's Lambda=.885, F(1,89)=11.53, p=.001, partial η^2=.115), with all groups showing an increase in automaticity (although the increase was marginal for location-dependent cues). The main effect comparing different cue types was not significant (F(3,89)=.06, p=.98, partial η^2=.002); neither was the main effect comparing positive reinforcement types (F(1,89)=3.89, p=.051, partial η^2=.042). These results suggest no difference in effectiveness of each condition in supporting the increase in automaticity. However, no cue and trigger groups reported the highest increase in scores between Week 6 and Week 12 (2.4 and 2 respectively), while it increased by 1.5 for reminder and by 0.4 for stable context groups.

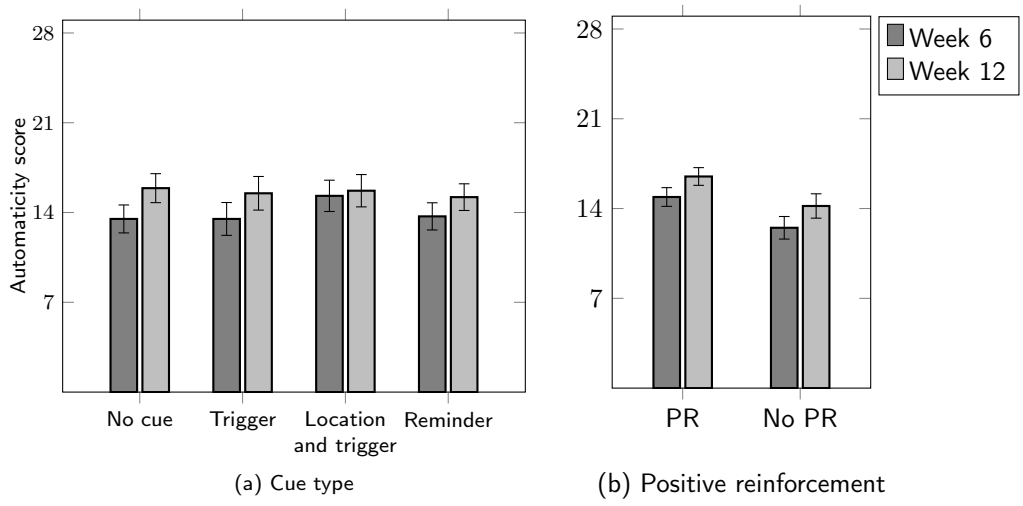
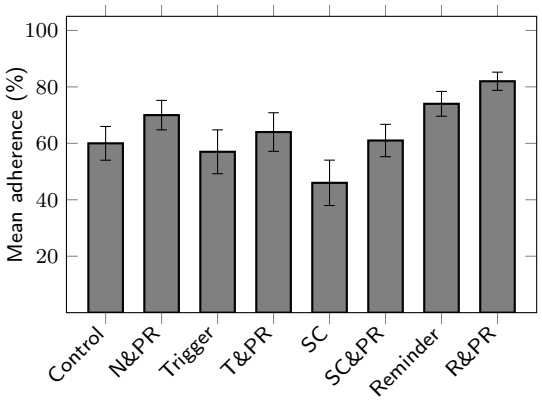


Figure 5.11: Mean automaticity scores at the end of Week 6 and Week 12 by (a) cue type and (b) positive reinforcement. Higher values indicate higher automaticity, max=28. Participants who did not submit Week 6 questionnaire are excluded. N=97.



Condition	N	Mean	SD	Min	Max
Control	13	60%	22%	27%	94%
N&PR	17	70%	22%	12%	95%
Trigger	12	57%	27%	12%	99%
T&PR	14	64%	26%	13%	94%
SC	6	46%	20%	26%	80%
SC&PR	15	61%	22%	29%	100%
Reminder	18	74%	19%	29%	96%
R&PR	20	82%	14%	42%	100%

Figure 5.12: Adherence scores per condition (N=115). Adherence of 71% is an equivalent of reporting lunches every day on weekdays only.

Impact of cues and positive reinforcement on adherence

Adherence was measured to assess how well participants remembered to repeat their healthy behaviour of choice. Figure 5.12 summarises adherence rates for all conditions; adherence of 71% is an equivalent of reporting lunches every day on weekdays only (five days a week). The R&PR and Reminder conditions recorded the highest adherence (82% and 74%). Surprisingly, N&PR also recorded high overall adherence of 70%. SC (46%) and Trigger (57%) did the worst, while their equivalents with positive reinforcement did better (SC&PR recorded 61% and T&PR recorded 64%), although they did not differ much from the Control group (60%).

To test the hypotheses, a two-way between-subjects ANOVA was used to evaluate the influence of the type of cue and positive reinforcement on adherence rates. There was a statistically significant

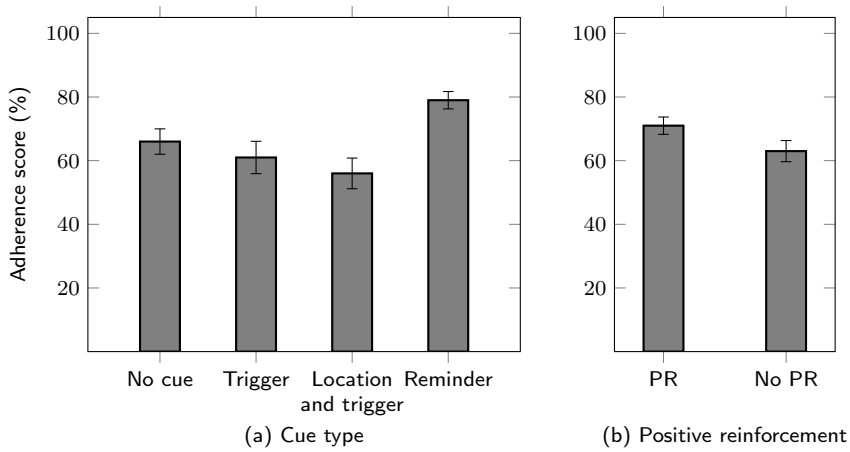


Figure 5.13: Mean adherence scores for (a) cue type and (b) positive reinforcement. Adherence of 71% is an equivalent of reporting lunches every day on weekdays only. N=96.

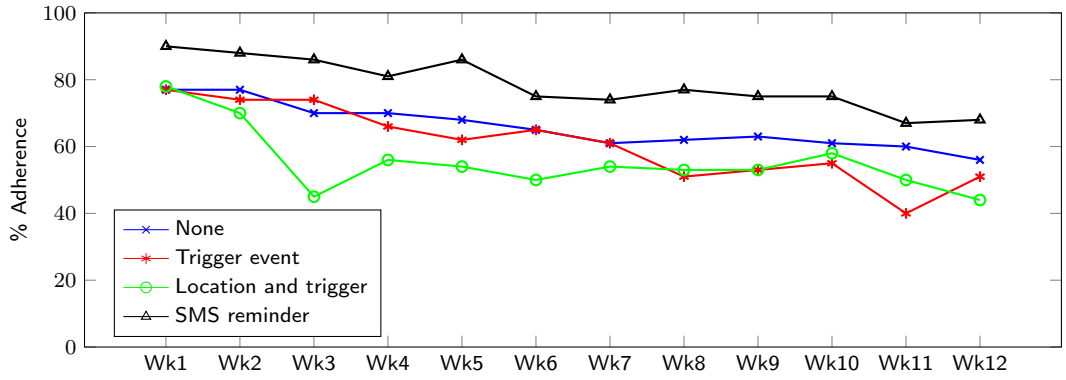


Figure 5.14: Change in adherence rates over time for different cue types (N=115).

main effect for cue type (F(3,107)=6.87, p<.001, partial η^2=.161) and for positive reinforcement (F(1,107)=5.9, p=.017, partial η^2=.052). There was no significant interaction (F(3,107)=.126, p=.95, partial η^2=.004). A Bonferroni post-hoc test showed significant differences only for reminders (mean=79%, SD=17%, N=38) vs. trigger events (mean=61%, SD=26%, N=26; p=.008) and reminders vs. location & trigger (mean=56%, SD=22%, N=21; p=.001). Figure 5.13 shows mean adherence scores by cue type and positive reinforcement.

To assess the impact of each type of cue and positive reinforcement on adherence over time a mixed between-within subjects analysis of variance was conducted. There was no significant interaction between the type of cue and time (Wilk's Lambda=.727, F(33,286)=.99, p=.48, partial η^2=.101) and positive reinforcement and time (Wilk's Lambda=.89, F(11,97)=1.086, p=.38, partial η^2=.11). There was a substantial main effect for time (Wilk's Lambda=.52, F(11,97)=8.14, p<.001, partial η^2=.48), with all groups showing a decline over time (see Figure 5.14). The main effect comparing types of cues was statistically significant with a large effect size (F(3,107)=6.87, p<.001, partial η^2=.16), indicating that SMS reminders were the most effective. The main effect comparing conditions with and without positive reinforcement was also statistically significant with a very large effect size (F(1,107)=5.88, p=.017, partial η^2=0.52), showing that participants who received positive reinforcement were more adherent.

Influence of location

To understand the role of location as a cue, participants in SC and SC&PR conditions were asked to report where they meditated or drank water every day. Twenty-one of them (6 from SC and 15 from SC&PR) completed the study and their data was included in this analysis. The sample was too small for statistical analyses and only general trends are described in this section.

Seven participants had adherence equal or higher than 71% (an equivalent of reporting the task every day on weekdays only). The most successful participants reported making their task part of a morning or evening routine: drinking water with meals (mostly breakfast or dinner) and meditating while getting ready to sleep. For example, one participant who drank water with breakfast reported continuing to do so consistently during three different holiday trips.

Seven participants with the lowest adherence (30-39%) did not have a set routine. They mostly reported repeating the task in various places and at different times of day, and did not use consistent trigger events. Only three of them consistently reported the same location, although it was not a place where they went every day: a park, a train, or a gym.

Remembering strategies

One hundred and fifteen participants responded to the end-of-study survey sent a week after the main part of the study had ended. Over a half of them (68 participants, or 59%) reported that it was easy to remember to repeat their selected task during the study ("very easy" for 19% and "somewhat easy" for 40%), mostly because it was part of their routine (16 participants) or became automatic (8 participants). Nine participants reported that their selected trigger event prompted them and made remembering easier. Twelve participants reported that remembering was easy because they received reminders or set up their own. Among participants who found it difficult to remember (47 participants), 21 reported being busy, stressed, or distracted as the main reasons of forgetting, and 15 blamed changes in their daily routine. Nine participants reported that if they did not complete their task as soon as they remembered or as soon as they received a reminder, they would have forgotten. General lack of a fixed schedule (reported by seven participants) was also an issue. Five participants reported that while they remembered to complete the task, they often forgot to send a text message.

Thirty-eight participants received daily reminders at their preferred time (three participants changed the time during the study to a more convenient slot). Most of them (31 participants, or 84%) reported that reminders were useful or very useful in supporting their memory, even though they were sometimes "a little annoying" (P55) and arrived "often not at a convenient time" (P47). For five participants reminders made no difference and one person (P54) found them "useless", as they sounded more like a "command" than a reminder.

Seventy-nine participants (69%) went on holidays during the study, including 15 who were away more than once. Among them, 37 participants (47%) reported that remembering was difficult, mainly because their routine changed and they were distracted with holiday activities. Twenty-seven participants (34%) reported that it was easy to remember the task as it was relevant: participants who selected meditating said their holidays were relaxing and it was easier to find time for meditation, while those who selected drinking water often said that it was hot and they had to drink more water anyway. Three participants said that by the time they went on holidays the new task had become a habit and they were doing it automatically. Fifteen participants indicated that it was neither easy nor difficult to remember while on holidays, although their open-ended answers suggested that it was actually difficult: they were busy, distracted, their routine changed, they missed reminders, or did not remember to send their SMS reports.

When asked whether the task became part of their daily routine, the majority of participants (59%) agreed. When asked directly if they thought they developed a habit, 52% said yes. Whether participants perceived their behaviour as part of their daily routine or thought it became a habit was not related to the condition they were in. Chi-square tests for independence showed that there was no significant association between perceived routine or a habit and the type of cue (χ^2(3, n=101)=4.95, p=.175, Cramer's V=.22 and χ^2(3, n=115)=2.23, p=.53, Cramer's V=.14, respectively) or positive reinforcement (χ^2(1, n=101)=2.2, p=.14, phi=-.17 and χ^2(1, n=115)=3.65, p=.056, phi=-.196, respectively). However, an independent samples t-test showed a significant difference in actual automaticity scores (mean=18 for those who reported that the task was part of a daily routine vs. mean=10 for those who did not; t(99)=-8.15, p<.001), indicating that those with higher automaticity knew that the behaviour was a habit.

Throughout the study, 72 participants received positive reinforcement in the form of confirmation messages. Among them, 39 participants (55%) reported that the messages were useful, mainly because they helped them to stay motivated and engaged with the study ("it's good to be acknowledged" – P135, "it felt like I had achieved some small thing that day" – P191). In general, participants thought that messages were "cute" and "friendly", although one person said that at times they were annoying. However, over a third of participants (27, or 38%) reported that messages made no difference and they would have preferred reminders or more information on how to form the habit they were working on. Simple confirmations were "nice", but "after the first week they were pretty unnecessary" (P95). Five participants thought the messages were useless as they did not provide any valuable information.

Repetition after the study

As the end-of-study survey was sent a week after the study had finished, participants were asked whether they continued doing their chosen task every day during that week. Eighty-five participants (74%) reported repeating the task at least once during that week, including 24 participants (21%) who reported repeating their task every day. The majority of these 24 participants were from the N&PR group (eight participants, or 33%), R&PR group (five participants, or 21%), and the Control group (four participants, or 17%). Thirty-one participants (26%) did not repeat the task at all after the study had ended; they were from the same conditions as those who repeated the task daily and their numbers per condition were also the same.

To explore whether cue type and positive reinforcement influenced the number of repetitions during the week after the end of the study, two-way between-subjects ANOVA was conducted. Levene's test returned a significant result, suggesting that variance of the dependent variable across the groups was not equal, and as a result p=.01 was used to assess the significance levels of the analysis. There was no significant interaction between cue type and positive reinforcement (F(3,107)=.628, p=.59, partial η^2=.017). As a more stringent significance level had to be used, there were no statistically significant main effects for cue type (F(3,107)=2.95, p=.036, partial η^2=.076) or for positive reinforcement (F(1,107)=6.16, p=.015, partial η^2=.054), suggesting that none of them influenced participants' behaviour.

Three months after the study had ended, 109 participants who had indicated earlier that they would be happy to answer any additional questions received the follow-up survey; 63 participants responded (58%). Only 18 participants (29% of those who responded) reported that they were still doing their task regularly, even though at the end of the study 57 had expressed the intention to continue. Participants who were still repeating their tasks were mainly from no cues conditions (five from N&PR and four from the Control group), three each were from R&PR and SC&PR, and two each from Reminder and Trigger groups.

Among participants who stopped repeating the task (N=45), 26 (58%) reported stopping right after the study had ended, 16 (36%) reported continuing for a few weeks before stopping, and three (6%) reported stopping soon before the follow-up survey arrived. They reported that they did so because they had not enjoyed the task ("it was more of a chore" – P155); did not see any immediate benefits and lacked intrinsic motivation; or were busy and kept forgetting, so finally gave up and stopped trying.

Participants who continued with the task (N=18) were asked about their remembering strategies. Eight explicitly stated that the behaviour had become part of their routine and was a part of a sequence of tasks. Another eight participants reported getting used to repeating the task and feeling like they "had to" do it. In addition, three participants reported that they had started to carry a water bottle with them (and having it around had become a habit in itself). Four other participants reported that they had formed habits, although they were not daily habits: they still meditated a few times per week or drank water in a specific context.

5.2.3 Conclusions

The follow-up study investigated the process of habit formation in a more realistic context and to address the limitations of the "lunch study". As in the previous study, SMS reminders were the most effective in supporting adherence and the least effective in supporting the development of automaticity, although this time automaticity scores did not differ significantly between conditions. The analysis of scores over time showed that while time did indeed influence the results, there were no differences between conditions. In line with existing research, this shows that with enough consistent repetition, the automaticity can increase regardless of the type of cues used (Lally et al., 2010), although the type of cue seems to influence the speed of the increase. However, the increase in automaticity did not prevent forgetting. Moreover, the analyses of engagement with the task after the study showed that the study conditions or automaticity scores did not have impact on whether participants continued to meditate or drink water; it was more important whether the task fitted into their life.

In terms of positive reinforcement, the technical issues from the previous study were resolved and this time participants received all messages they were supposed to receive. As the content of messages had been overtly enthusiastic in the first study (Fogg, 2012), in the follow-up it was replaced with polite "thank you" messages that aimed to provide confirmation rather than elicit specific feelings. However, while conditions with positive reinforcement recorded better adherence and automaticity than their equivalents without it, due to several changes to the study design it is difficult to identify the main factor that has contributed to that improved result.

The task was also changed in the follow-up study. Participants were given a choice between two healthy habits: drinking a glass of water or meditating briefly every day. While these tasks were more meaningful for participants, they introduced new issues. First of all, the new tasks

were more difficult than sending lunch reports. They both required specific conditions (access to water, quiet time for meditation), although drinking water seemed to be easier as participants who selected this task reported higher automaticity and were more adherent. Second, task instructions might have been ambiguous as it was not specified when participants should drink water. As a result, participant were able to do it multiple times per day, which might have caused confusion as to which occurrence of the task they should report. Some participants who selected meditation had preconceived ideas of what a meditation session should look like and, for example, instead of focusing on their breath for 30 seconds as initially suggested, they wanted to meditate for five minutes while sitting cross-legged in a quiet room and listening to meditation tracks. This might explain why meditating was more difficult compared to drinking water and shows that tasks that already fit into one's day and do not require extra effort are easier to turn into habits. Finally, while in theory the tasks could be repeated every day, in practice they turned out to be heavily context-dependent. As a result, although participants did not develop a *daily* habit, some of them developed *a* habit, e.g. they started carrying a water bottle, meditating during their commute, or doing breathing exercises when stressed.

It was expected that repeating the task in a stable context, i.e. in response to a trigger event that takes place in the same location, would improve adherence and automaticity the most compared to other conditions as habits are heavily context-dependent (Verplanken, 2005). This hypothesis was not supported: stable context conditions lost the most participants and had the lowest adherence and automaticity scores. This may have been due to the fact that the definition of a stable context used in this study was too restrictive, resulting in complex instructions. This complexity, combined with the lack of positive reinforcement, could explain the high drop-out rate in the stable context condition. However, it should be noted that in the end the stable context turned out to *not* be as stable as expected: many people consistently reported different cues. In addition, contrary to the expected outcomes suggested by the literature (Neal et al., 2012; Verplanken et al., 2008; Wood et al., 2005), responding to routine actions that take place in the same location (but at different times) was less effective than responding to the same routine action in different contexts, e.g. during holidays. Therefore, the results suggest that when the wider context changes, the location itself is not that important and the choice of the trigger event plays a bigger role.

5.3 Discussion

Even though the theoretical grounding improves the effectiveness of interventions (Webb et al., 2010), the majority of habit formation apps are not grounded in habit research (see Chapter 4). Therefore, to test how habit theory could be used in practice to facilitate the development of automaticity in the real world, this chapter presented two studies that explored how contextual cues, timed reminders, and positive reinforcement support the process of habit formation.

The first study ("lunch study") focused on the mechanisms of developing automaticity. As a result, the participants were not aware that forming a habit was their goal, which allowed me to test the effectiveness of different types of cues. The second study ("healthy habits study") expanded the scope to investigate the role of contextual cues, including location, in a more realistic context. In this case participants were able to select a behaviour they would like to turn into a habit and cues that would support this process. The healthy habits study also addressed some of the limitations of the lunch study and aimed to validate its findings.

The lunch study showed that while reminders were effective at keeping people engaged, they hindered the development of automaticity: relying on event-based cues or no cues at all was more effective than relying on reminders. The presence of positive reinforcement did not affect the results. On the other hand, the healthy habits study confirmed that reminders were the most effective at supporting adherence; however, there were no significant differences across different types of cues in supporting automaticity—it increased with time for all conditions. Moreover, positive reinforcement was effective: participants who received confirmation messages forgot less often and reported higher automaticity at the end of the study. Contrary to the predictions, location as a contextual cue turned out to be ineffective.

The lack of significant results in the healthy habits study could be explained by its low statistical power. When the sample size of a study is large (i.e. in the order of N=100 per group), power should not be an issue; however, small numbers of participants per condition can lead to non-significant results due to insufficient power (Field, 2009; Stevens, 1996). And indeed, the total sample sizes used in the analyses were N=96 and N=115 for the lunch study and the healthy habits study, respectively. As a result, with six and eight conditions per study, the number of participants varied between N=20 and N=13 per group in the first study, and between N=20 and N=6 in the follow-up. While fewer participants are not an issue if effect sizes are high (Field, 2009), in the reported studies they were mostly small-to-medium. Therefore, power should be

acknowledged as a potential limitation, although this suggests that if more participants completed the study, the results of the follow-up might have further supported the initial results, especially given that the trends uncovered in cue analyses were similar.

The results also showed that studying the process of habit formation in a naturalistic setting is difficult, as habits take time to develop and several factors can influence the experience. Moreover, they highlighted the difficulty in translating theory into practice and supporting the development of new habits through a mobile platform.

5.3.1 Supporting habit formation through a mobile phone

The studies reported in this chapter used SMS to simulate how habit support could be delivered via mobile phone. I did not use an actual app, as at this point it was not clear how theory could be translated into specific features. With existing apps lacking theoretical grounding (see page 87), I had to start with the literature, focusing on repetition, contextual cues and positive reinforcement—the main factors supporting habit formation. However, even though both studies were informed by research, the underlying information turned out to be insufficient to effectively facilitate the development of new habits.

During both studies participants were exposed to different types of cues: SMS reminders with an immediate call to action, a pre-defined trigger event (lunch), self-selected trigger events, or self-selected trigger events in a specific location. It is worth acknowledging that even though 29 participants in the lunch study and 30 participants in the healthy habits study were assigned to "no cues" groups, it did not mean that they did not use any cues. While specific cues were not defined, participants still ended up relying on cues similar to those used in other conditions: phone alerts or trigger events. This should not come as surprise, as people's preferences, motivations and practical factors influence adherence and any steps taken towards staying adherent (Chapman et al., 2015; Horne, 2001), and thus participants might have used their default strategies or selected cues that they thought would work best in the context of these studies. It is therefore important to keep in mind that all participants used *some* cues and their effectiveness in supporting habit formation varied.

Table 5.3 summarises automaticity scores for all types of cues reported earlier in both studies. As the same SRBAI questionnaire was used, it allowed for a comparison of final scores. There was no difference in score between reminder groups, suggesting that the presence of reminders

Table 5.3: Automaticity scores from both habit formation studies by cue type and positive reinforcement. SRBAI scale: 7-28, the higher the score, the stronger the habit.

	Lunch study			Healthy habits study		
	N	Mean	SD	N	Mean	SD
No specified cues	29	19.10	4.9	30	16.17	5.8
Trigger event	29	20.17	4.1	26	15.88	6.3
Trigger event & location	-	-	-	21	15.24	5.8
Reminder	38	15.29	5.2	38	14.92	5.9
Positive reinforcement	51	16.88	5.1	66	16.59	5.5
No positive reinforcement	45	19.50	5.2	49	14.08	6.2

does not support the development of automaticity regardless of the length of the study. However, even though the healthy habits study lasted longer, participants from the lunch study reported significantly higher automaticity levels in no cue ($t(57)=2.09$, $p=.04$) and trigger ($t(42)=2.93$, $p=.005$) conditions compared to their corresponding conditions in the second study.

To understand these differences in automaticity we need to focus in more detail on the tasks and also the studies themselves. The literature shows that simple tasks become automatic faster than more complex actions (Lally et al., 2010); however, it turns out that not all simple tasks are equally simple. During the lunch study participants had to send a text message after having lunch. Given the popularity of smartphones and their personal nature (Ventä et al., 2008), it was safe to assume that participants would have a phone with them most of the time and texting would be a low effort task; the high number of participants who responded immediately supports this assumption. Moreover, when lunch was used as a cue, even though the task was artificial, the relationship between the trigger and the task was meaningful: participants had to remember to report their lunches because they wanted to learn about their food habits. The implementation intention (to send a text after eating lunch) was provided at the beginning of the study and then regularly reinforced through weekly emails that mentioned both lunch and texting, although that reinforcement was neither explicit nor intentional.

In contrast, the participants of the healthy habits study were able to select one of two simple tasks they would want to develop: drinking a glass of water or focusing briefly on breathing. While the tasks were simple, it became apparent that they required specific conditions: participants needed access to water and time to drink a whole glass, or needed to feel comfortable enough to close their eyes and focus on their breath. These tasks were short and easy, but required more planning than sending a text message. Moreover, to make the study more realistic and

allow participants to fit the behaviour into their daily routines, participants were assigned to conditions representing types of cues, not specific triggers. They were free to choose their own trigger events and change them if necessary. While this worked for some participants, it had a negative effect on others: as it was difficult to use the same trigger all the time, some participants started reporting different triggers. Lally et al. (2011) suggest that forming several variations of a desirable habit that rely on different cues each could help to deal with regular changes in context (e.g. doing yoga after work on workdays vs. in the morning on weekends). However, it could also lead to the formation of multiple independent habits that develop at a different speed, which might have been the case here. If true, this would explain the overall low automaticity scores of participants who were free to change their cues. This negative influence of variable cues became even more apparent with participants who had to select their own trigger and location, and it might have hindered habit development, as even small changes in context can affect task performance (Lally et al., 2011). In addition, unlike in the lunch study, the relationship between a chosen trigger and the task was not reinforced throughout the healthy habits study: as I did not know what triggers participants would use in the following week, weekly emails mentioned only the task, but not its trigger; an implementation intention was not provided. With this in mind, the differences in automaticity scores suggest that an occasional reinforcement of the association between the task and its trigger might be key in helping to develop a habit.

Table 5.3 also shows automaticity scores from both studies for conditions with and without positive reinforcement. The results of the lunch study showed that positive reinforcement made no difference, while the healthy habits study showed that confirmation messages were effective. However, in terms of raw SRBAI scores, participants from both studies who received positive reinforcement reported the same levels of automaticity (mean=17, SD=.66, N=51 in the first study vs. mean=16.6, SD=5.5, N=66 in the follow-up). In a sense, positive reinforcement was equally effective. This suggests that when the connection between the task and its trigger was not regularly repeated (as in the healthy habits study), positive reinforcement was required and indeed made a difference. In line with the literature, this means that positive reinforcement can support the formation of new habits (Gardner & Lally, 2013), although it is not always needed (Lally & Gardner, 2011).

5.3.2 Limitations of habit research

The differences in scores discussed above highlight the limitations of habit research that have implications for designing apps that support medication habits. The literature suggests that to form a habit, the new behaviour needs to be repeated in a stable context in the presence of contextual cues (Gardner et al., 2012; Wood & Neal, 2007). Anything can be a cue: preceding actions, location, objects, etc. (Ji & Wood, 2007; Lally et al., 2011; Neal et al., 2012; Verplanken, 2005; Verplanken et al., 2008; Wood & Neal, 2009; Wood et al., 2005), although relying on routine events as triggers to action might be the most effective (Botvinick et al., 2009; Graybiel, 1998; Verplanken, 2005). It was assumed that using implementation intentions and defining tasks as event-based would be enough to support habit formation and prevent forgetfulness, but the studies reported in this chapter did not support this assumption and highlighted the limitations of contextual cues in supporting adherence. It seems that while anything can be a cue, it is not clear what constitutes a *good* cue or how to find one that is the most appropriate.

Facilitating the formation of medication habits requires a better understanding of what cues can support both prospective remembering (so that adherence is high from the beginning of the regimen) and habit formation (so that automaticity develops with time) at the same time. It is also important to understand the process of cue selection and factors that influence it, as technology could leverage it. The results show that when given choice, people are not consistent and may frequently change their cues. Existing research suggests that often people are not aware of cues that drive their automatic behaviour (Orbell & Verplanken, 2010)—my results suggest that they may also not realise which cues they should select to support automatic behaviour; they may even be unaware that cues are important in the first place. Without addressing these limitations, any attempts to use the theory to support real-world behaviour are deemed to yield inconclusive results. Therefore, the next chapter presents two studies conducted to address the gaps in theory by identifying the characteristics of good remembering strategies and factors that influence their formation.

Chapter 6

Developing reliable remembering strategies

This chapter:

- ❖ Revisits datasets from online surveys (Chapter 3) and habit formation studies (Chapter 5) to understand the characteristics of good cues and effective remembering strategies.
- ❖ Presents a 3-week study that explores how people select remembering strategies when starting a new daily medication regimen.
- ❖ Shows that reliable remembering strategies are made of multiple clearly defined contextual cues and that selecting the right cues that fit into one's daily routine takes time and requires trial and error.

The results of the effective remembering strategies analysis have been published together with the survey results from Chapter 3 in [J.1].

Prospective memory research shows that tasks linked to routine events are easier to remember (Johnson, 2002; Park & Kidder, 1996) and survey results reported in Chapter 3 confirm that making medications part of a daily routine is a popular and often effective strategy. At the same time, habit research suggests that routine events used as triggers to action are the most effective in supporting the development of new habits (Botvinick et al., 2009; Graybiel, 1998; Verplanken, 2005). However, the results from Chapter 5 show that using routines as cues to action does not always support prospective remembering and habit formation at the same time. While routine events are better at facilitating habit formation compared to timed reminders (use of which can inhibit the development of automaticity), relying on them does not always prevent forgetting,

as habits take too long to develop to be useful in the short term. Habit literature implies that anything can be a cue as long as the behaviour is consistently repeated in its presence (Gardner et al., 2012; Wood & Neal, 2007), but as habit research does not take prospective remembering into account, it is not clear what types of cues can support this process from the start.

Moreover, the results from Chapter 5 also indicate that people do not know what cues are the most effective. When free to select their own triggers to action, people can be inconsistent, which implies that they may not understand the importance of good stable cues. While the existing research suggests that people often do not recognise what prompts their behaviour (Orbell & Verplanken, 2010) and may select suboptimal cues (Gardner et al., 2014), their decision-making process and factors that influence which cues they choose are not known. Understanding what drives their cue selection can inform the design of technologies that help people select the best cues and form reliable remembering strategies.

This chapter aims to address the limitations of habit research highlighted in the previous chapter by identifying the characteristics of good remembering strategies and investigating the factors that influence people's decisions to select specific cues. First, I revisit the data from medication surveys (Chapter 3) and habit formation studies (Chapter 5) to identify the most adherent participants; this allows me to investigate what cues they use and what components effective remembering strategies have in common. Next, I describe a 3-week field study that explores how people select cues and form remembering strategies for a new regimen. Finally, I discuss the findings. They show that reliable remembering strategies are made of multiple clearly defined contextual cues and that selecting the right cues that fit into one's daily routine takes time and requires trial and error. This helps to understand which cues should be supported by technology and how apps could facilitate the process of cue selection.

6.1 Retrospective analysis of effective remembering strategies

The results of both habit formation studies reported in Chapter 5 showed that not all contextual cues were equally effective: while they supported the increase of automaticity, they did not always prevent forgetfulness. This has consequences for remembering medication regimens, as people need to stay adherent from the start. Therefore, it is important to understand what types of cues—or broader remembering strategies that incorporate them—can support prospective

remembering and lead to the development of medication habits in the long term. The data from previous studies contains information that can provide insights: the responses of the most adherent participants from the medication surveys (Chapter 3) can help to identify effective real-world remembering strategies, while the data from the habit formation studies (Chapter 5) includes additional information about cues that are associated with both high adherence and high automaticity. Comparing and contrasting these datasets can help to establish the characteristics of reliable cues and effective remembering strategies.

6.1.1 Method

In total, the data of 654 participants was extracted for the analysis from medication surveys reported in Chapter 3 and habit formation studies reported in Chapter 5.

For the survey data analysis, responses of 578 participants were selected: 516 women taking oral contraception who reported not missing any pills at all during the month preceding the survey, equally adherent 46 older adults, and 16 parents who reported not missing any doses the last time their child took antibiotics. For each participant, the following information about their remembering strategies were extracted: location of medications, time to take them, reported strategies and cues, and additional free text comments provided by participants.

The selection of relevant data from habit formation studies was a two-stage process. First, 132 participants with adherence of 71% or higher (equivalent of repeating the task every day during work days) were identified, including 71 participants from the lunch study and 61 from the healthy habits study. Next, a subset of participants with automaticity scores higher than 16 (SRBAI scores range from 4 to 28 points, with higher scores indicating stronger habit; 16 is the middle point) was extracted: 43 participants from the lunch study and 33 from the healthy habits study. That included 24 participants from no cues conditions, 32 from reminder conditions, 22 from trigger conditions, and four from the stable context conditions. For each participant, their cue type and final survey answers explaining what helped them remember about the task and repeat it were recorded. In addition, for participants from the healthy habits study, information about reported trigger events, locations, and time of day were recorded.

Each dataset was analysed separately. To extract the characteristics of good remembering strategies and to identify the most effective cues, the frequency of each cue was counted and illustrative quotes were selected. The main trends are presented using descriptive statistics.

6.1.2 Findings

Surveys

The identified participants reported that they took their medications in response to routine actions (e.g. waking up, eating meals, brushing teeth; 88% of respondents selected for this analysis), kept them in specific locations (e.g. by the bed, on the kitchen table; 78%) and relied on meaningful objects serving as visual cues (e.g. kept medication boxes in a visible or meaningful spot, used pill organisers; 66%).

Two-thirds of participants (66%) reported creating additional cues by leaving medications in a visible place (e.g. on a bedside table) or in a meaningful place related to their routine (e.g. inside a make-up box). Over a quarter (27%) reported that even though they used visual cues or relied on routines, they also used other safeguards such as relying on phone alerts or other people (partners, children) to remind them about medications.

Over half of the participants (55%) reported using all three types of cues at the same time and a further 25% used a combination of two; 8% of participants reported relying only on routines without specifying other types of cues. No one reported relying on location or visual cues only.

Only 6% of participants (35 women taking oral contraception) reported using reminders as their sole remembering strategy. Other participants who used reminders used them in conjunction with daily routines (reported by 13% participants) or with visual cues (12%). For them, it was often an additional safeguard.

> *"Even though I have a reminder on my phone, I tend to remember without it – I only use it just in case"* – Respondent #24, Oral contraception survey

Participants also reported taking steps to ensure that they have access to medications at the right time: 21% of participants reported keeping their pills in a wallet, bag or purse—somewhere where the pills would be at hand if they forgot to take them at the usual time. Three participants also modified their daily routines to allow for checks whether they had already taken the medication. Overall, 27% of participants used multiple strategies, often combining extra cues with ensuring that medications are available in a few different places.

Habit formation studies

Only participants from the trigger and stable context conditions in the healthy habits study were explicitly asked to report their cues (N=9); everyone else's cues were extracted from open ended answers to the final surveys. As a result, it was impossible to identify primary cues for 14 participants: seven did not provide any information about their remembering strategies and another seven said that the behaviour had become part of their daily routine, but did not provide any details. Among the remaining 62 participants, 31 (50%) reported relying on contextual cues: specific routine events (42%, or 26 participants), visual cues such as a water bottle or previously sent SMS visible on the phone (10%), and location (11%). Seven people also reported relying on memory or internal cues, e.g. they remembered to drink water when they felt hot or thirsty, although none of them said it was their only strategy. However, regardless of the type of cue, participants used it consistently throughout the study and the only exception were six participants who started with reminders (either their own or SMS reminders), but at the end reported that they mainly relied on trigger events such as getting up or eating dinner.

Nine participants reported that routine events they responded to were linked with specific locations (7 participants) or objects (2 participants). However, three participants whose routines were linked to broader locations like "my office" reported difficulties with remembering about the task while their routine changed. In contrast, those who selected specific locations such as "bed" (as opposed to "my room") did not report these issues.

> *"When my routine stayed constant, I usually drank water at the same times every day – right after I woke up, or right after I got to work. But when I spent a few days away on holiday, or did something unusual on the weekend, I often forgot"* – Participant #176, Healthy habits study, Control condition

> *"Once I got into a routine it was easy, for example I would do it on the bus into uni. However if I wasn't taking transport that day then it would be more difficult to remember, especially weekends."* – Participant #172, Healthy habits study, T&PR condition

Twenty-eight participants reported using reminders as their primary cue, although 20 of them were from reminder conditions and thus were supposed to receive phone notifications. Among remaining eight participants, six were from no cue conditions and two from trigger conditions. However, 13 participants from reminder conditions reported that they mainly relied on contextual cues. That included five participants who said the task had become part of their routine or turned into a habit, and two participants who reported responding to trigger events.

> *"*[I'd report it] *Right after lunch or reply to the reminding text message"* – Participant #69, Lunch study, R&PR condition
>
> *"I always tried to drink a glass of water after dinner"* – Participant #167, Healthy habits study, R&PR condition

The majority of participants from the habit studies dataset (N=76) were either provided a specific cue such as reminders or lunch as a trigger (43 participants, or 57%) or instructed to select routine events (9 participants, or 12%), while 24 participants from no cues conditions were free to select their own remembering strategies. Among them, 12 participants made it a part of their daily routine (although only nine provided details of these routines), six set up their own reminders, and two used objects as visual cues. Three participants did not provide details of how they remembered and one person explicitly reported not having any strategy.

6.1.3 Conclusions

The aim of the retrospective analysis of the datasets from previous studies was to identify cues associated with the most effective strategies reported by participants, i.e. strategies that support remembering from the start and can lead to the formation of a habit. Surveys reported in Chapter 3 provided examples of effective strategies for maintaining high adherence, while the analysis of the data from Chapter 5 identified cues that support the development of automaticity while preventing forgetfulness.

The results showed that relying on daily routines, meaningful objects and meaningful locations as cues were the most common remembering strategies used by the most adherent participants, while creating visual cues and keeping medications at hand were the most common strategies for preventing forgetfulness. These cues were often interconnected: keeping medications on the bedside table combines an object with location, while taking pills with breakfast in the kitchen combines a routine with location and an object. These cue combinations were often further reinforced by extra safeguards, e.g. by additional back-up reminders or keeping spare pills in a bag. However, these connections were less prominent in the habit studies data, possibly because the dataset was much smaller and not all details were provided, e.g. 31 participants mentioned routines, but only 26 specified what routine events triggered their behaviour and only nine described where that routine took place or whether any additional objects were used as cues.

Survey participants also reported using technology together with other cues and only a small proportion of the most adherent participants reported using it as their sole memory aid; often reminders were just an additional safeguard. The combination of reminders with contextual cues in the healthy habits dataset was less common. Many participants reported other factors as their main cues and mainly participants from reminder conditions relied on reminders as their only cue. This suggests that contextual cues alone were sufficient in most cases.

However, while the retrospective analysis helped to identify the components of effective remembering strategies that support long-term adherence, there was not enough evidence that the same strategies could lead to the formation of medication habits. Even though the cues extracted from habit formation studies were similar to those reported in medication surveys, more participants relied on reminders and fewer reported relying on combinations of cues. This might have been a result of task and study differences: although the tasks were similar (taking the pill requires as little effort as sending an SMS or meditating for less than a minute), survey participants reported real-life strategies developed to remember their medications, while remembering to send lunch reports, meditate briefly or drink a glass of water were tasks selected for experimental studies that explored specific behaviours. Moreover, in habit formation studies only a small number of participants were specifically asked to describe their cues and as a result the analysed information about cues might be incomplete.

The next section describes a situated study with interviews that focuses specifically on cues and characteristics of good strategies. It explores how people form remembering strategies when they start a new medication regimen, what factors influence this process, and what combinations of cues are the most effective. Exploring what cues people select and how they form new strategies also helps to validate the findings of the retrospective analysis, as the data from medication surveys was mainly extracted from established routines. Looking at the process of routine formation from the start provides a richer understanding of how cues fit into people's everyday life. The results will clarify what cues are the most effective and thus should be supported by adherence apps that facilitate the formation of medication habits. This will help to understand how this support should be provided to match people's decision-making processes and take advantage of factors that influence them.

6.2 Developing remembering strategies

The habit formation studies described in the previous chapter showed that when people are free to select their cues, they are often inconsistent—and this lack of cue stability can sometimes reduce the effectiveness of their strategies. And indeed, as described in the previous section, the retrospective analyses of remembering strategies reported by the most adherent participants from Chapter 3 and Chapter 5 showed that consistent cues were the most effective. Moreover, these participants tended to rely on remembering strategies based on routine events linked with a location and an associated object that can serve as a visual cue. However, while the results provide insights into what types of cues or cue combinations appear to work in supporting adherence and the development of automaticity, they require validation and a richer understanding of how such cues fit within a wider context of starting a new medication regimen.

To design apps that help to form remembering strategies that both support adherence and facilitate habit formation, it is important to understand how people select effective strategies and what factors influence this process. Medication surveys explored established behaviours, while habit formation studies focused on tasks designed to investigate and measure specific aspects of the process of habit formation; none explicitly focused on cue selection. To address this gap, I conducted a 3-week field study with semi-structured interviews. This method of investigation was well suited for exploring how people develop new medication routines and what influences their decisions: studies set in a naturalistic setting help to generate rich data on people's everyday behaviours (Rogers et al., 2011) and semi-structured interviews allow researchers to further explore the topic and identify new themes (Cairns & Cox, 2008). The details of the study and its results are described in the following sections.

6.2.1 Method

To understand how people select cues and form remembering strategies for a new daily medication regimen, 39 participants were asked about their general and intended remembering strategies, given a box of vitamin C tablets to take daily for three weeks, and later interviewed about their experience and the effectiveness of strategies they developed.

Participants

UCL students who wanted to start taking vitamin C tablets were recruited through social media and leaflets distributed on the campus (see Appendix G for the recruitment questionnaire). The student population was selected to match the demographics of participants from the oral contraception survey described in Chapter 3. Both male and female students were recruited to allow for a wider range of potential remembering strategies, as young men do not take birth control pills and thus are less likely to have an established daily medication regimen.

Thirty nine participants signed up for the study. They were 18-43 years old (mean=23 years, SD=3.7); 20 were male (51%). The majority were undergraduate students (20 participants); 17 were studying STEM subjects (Science, Technology, Engineering and Maths). Six participants reported currently taking long-term medications (contraceptive pills, medications for chronic conditions, herbal supplements), 17 had taken long-term medications in the past, six only had experience with short-term regimens (flu medications, antibiotics, painkillers), six have not taken any medications since moving out from their parents' house, and three said they had no relevant experience at all. SRBAI scores of four participants who were currently taking medications indicated that this behaviour was already automatic. Participant details are reported in Table 6.1.

Materials

Vitamin C tablets were chosen for the study as they represent a simple single-dose single-medication regimen (similar to oral contraception) and because they had been used in previous studies exploring how people remember new behaviours (Sheeran & Orbell, 1999) or form habits (Judah, 2015). Moreover, vitamin C provides several health benefits (Grosso et al., 2013): it protects the cells and supports the maintenance of connective tissue (NHS Choices, 2015) and taking vitamin C supplements is associated with quicker recovery from colds or milder symptoms (Douglas & Hemila, 2005; Hemilä, 2007), which made it beneficial to participants as the study was conducted during a flu season. As taking less than 1,000mg of vitamin C supplements is unlikely to cause any harm (NHS Choices, 2015), 200mg tablets available over the counter in a high street pharmacy were used in the study (Boots, n.d.). They were chewable and did not require access to water, and were selected to make participants' task as simple as possible. The study was approved by UCL Ethics Committee, project ID: 7459/001.

Table 6.1: Details of participants who completed the study. Participants' current medication regimens that were already automatic (i.e. with SRBAI scores over 20 out of 28) are marked with an asterisk. P37 did not attend the second interview and was excluded from the analysis.

#	Gender	Age	Education	Field of study	Medication experience
P1	F	19	Undergraduate	Social Sciences	Childhood; fish oil, herbal medicines
P2	M	20	Undergraduate	STEM	Short-term; antibiotics
P3	M	20	Undergraduate	Medicine & Pharmacy	No experience
P4	M	29	MSc student	Social Sciences	Long-term; supplements, post-surgery
P5	F	20	Undergraduate	Social Sciences	Long-term; the Pill
P6	M	21	Undergraduate	STEM	Childhood; vitamin C, multivitamins
P7	M	19	Undergraduate	Business & Finance	Childhood; vitamin C
P8	M	27	MSC student	STEM	Long-term; vitamin C
P9	F	22	Undergraduate	STEM	Currently taking; homeopathic pills
P10	F	19	Undergraduate	STEM	Currently taking; the Pill*
P11	M	21	Undergraduate	STEM	Short-term; antibiotics
P12	M	20	Undergraduate	STEM	Childhood; herbal medicines
P13	F	29	PhD student	Business & Finance	Long-term; herbal medicines
P14	M	26	MSc student	Medicine & Pharmacy	Long-term; malaria pills, multivitamins
P15	M	25	MSc student	Business & Finance	Long-term; weight loss pills
P16	M	22	MSc student	Business & Finance	Short-term; antibiotics, painkillers
P17	F	20	Undergraduate	Business & Finance	Childhood; herbal medicines
P18	F	18	Undergraduate	Medicine & Pharmacy	Short-term; cold and flu medicines
P19	M	24	PhD student	STEM	No experience
P20	M	24	PhD student	STEM	Long-term; herbal medicines
P21	M	23	MSc student	Business & Finance	Childhood; herbal medicines
P22	F	22	MSc student	STEM	Long-term; supplements
P23	F	31	MSc student	STEM	Long-term; fish oil, the Pill
P24	F	34	Undergraduate	Social Sciences	Currently taking; thyroid medications*
P25	M	25	PhD student	STEM	Long-term; supplements
P26	F	24	MSc student	STEM	Long-term; supplements
P27	F	22	MSc student	Business & Finance	Childhood; multivitamins, supplements
P28	F	20	Undergraduate	Social Sciences	Currently taking; the Pill*
P29	M	19	Undergraduate	STEM	Long-term; vitamin C, hay fever pills
P30	F	26	MSc student	Social Sciences	Long-term; malaria pills, the Pill
P31	M	19	Undergraduate	STEM	No experience
P32	M	24	PhD student	STEM	Short-term; cold and flu medicines
P33	F	28	MSc student	Humanities	Long-term; supplements, the Pill
P34	F	21	Undergraduate	Social Sciences	Currently taking; the Pill
P35	M	19	Undergraduate	Business & Finance	Long-term; vitamin C
P36	M	21	Undergraduate	Medicine & Pharmacy	Short-term; antibiotics
P38	F	20	Undergraduate	STEM	Currently taking; herbal medicines*
P39	F	24	PhD student	Social Sciences	Long-term; the Pill

The recruitment form included questions about medications, the 4-item Self-Report Behavioural Automaticity Index (SRBAI; Gardner et al., 2012) and the Prospective and Retrospective Memory Questionnaire (PRMQ; Crawford et al., 2003; Smith et al., 2000). The prospective memory questionnaire was used to assess participants' memory. SRBAI scores were calculated for participants who reported already taking some daily medications and were used to establish the strength of their existing medication habits. The Self-Report Habit Index questionnaire (SRHI; Verplanken & Orbell, 2003) was used in the second interview to guide the discussion and to establish whether daily vitamin C intake has become a habit. Participants were asked to indicate on a 5-point Likert scale whether they agree or disagree with statements about vitamin C tablets (see Appendix G) and to explain their responses. As SRBAI is a subset of SRHI, automaticity scores were also calculated at the end of the study based on the responses to the SRHI questionnaire.

Procedure

The study started in November 2015. Participants were invited to attend two semi-structured interviews. The first interview explored everyday remembering, including remembering healthy behaviours and strategies to prevent forgetfulness, as well as participants' experiences with remembering medications, causes and frequency of forgetting, and plans for remembering vitamin C tablets during the study (see Appendix G for the interview guide). At the end of the interview participants received a box of vitamin C tablets and were instructed to take one every day until the next interview. They were asked not to take any unusual steps to support their memory, e.g. not to use reminders if they normally do not use them. A date of the follow-up interview was also agreed. Two weeks after the first interview participants were asked to send a photo showing where they kept the vitamins.

The second interview took place about 21 days later (median=21; the date varied from 17 to 33 days, depending on person's availability) and focused on remembering vitamin C tablets during the study period. The interview explored remembering strategies, ease of remembering, and reasons for forgetting (see Appendix G for the interview guide). Photos provided by participants were used as interview prompts. Participants were also asked to fill in a habit strength questionnaire that assessed their vitamin-taking habit and to explain their responses. Each participant who attended the second interview received a £15 Amazon voucher.

Pilot

Three UCL PhD students (two women and a man, aged 24-28 years old) participated in the pilot study. They were asked to fill in the recruitment form and were interviewed. Next, they received a box of vitamin C tablets and were invited for a follow-up interview a week later. Interview questions and procedures were updated based on their feedback.

Analysis

Both interviews were recorded (audio only) and later transcribed. Initial notes were taken during the transcription and the first reading. Thematic analysis (Braun & Clarke, 2006) was used to analyse the transcripts, following both top-down and bottom-up approaches. Results of previous studies and relevant literature informed the coding frame that was used in the top-down analysis. Upon the second reading, parts of the transcripts related to general remembering strategies and forgetfulness (first interview) and remembering vitamin C (second interview) were coded on a sentence level, and general impressions and thoughts were noted. Pre-defined code categories included: everyday remembering strategies, reasons for forgetting, information related to current medications, information related to past medications, strategies for remembering vitamins during the study, and information about forgetting them. At the same time, a bottom-up approach helped to identify new trends and issues, including the role of visual cues, problems with automatic behaviour, and the differences between initial plans for remembering vitamins and the actual strategies that were used. After the coding was finished, similar codes were merged or grouped together under the same label, and additional codes were defined. Throughout the process, NVivo for Mac (version 10.2) was used to code, annotate, and analyse the data.

6.2.2 Findings

Thirty-eight participants completed the study; P37 did not attend the follow-up study and had to be excluded from the analysis. Overall, participants were adherent and remembered well: nine participants reported not missing a single tablet and 19 reported missing 1-3 times; only three participants reported missing over 10 tablets. Whilst forgetting rates were mainly based on self-reports, 10 participants brought their vitamin C boxes and counted them during the interview; two counted them at home and emailed the exact number. One person was intentionally non-adherent, as she did not want to take vitamins with her when she went away for a weekend. In

addition, 19 participants reported difficulties with remembering whether they had taken a tablet already; five reported overdosing accidentally at least once, and two could not remember whether they overdosed or not. Two participants reported regularly taking more than one tablet because they liked the taste (vitamins were orange flavoured).

Participants' adherence varied from 100% to 35%, with the majority of participants (N=34, or 89%) reporting adherence over 71% (equivalent of remembering every weekday). PRMQ scores showed that most participants had an average memory, i.e. their scores fell within two standard deviations from the median scores of the PRMQ control group from Crawford et al. (2003). Only four participants' scores fell outside that range, indicating that their memory was below the average. However, during the study there were no differences in rates of forgetting or remembering strategies between them and the rest of the participants (see Table 6.3).

The SRHI scores collected during the final interview indicated that two participants (5%) developed a strong habit (SRHI scores of 48 and 49 out of 60) and 21 participants (54%) developed a weak habit (SRHI scores ranging from 36 to 46). SRBAI scores extracted from the SRHI questionnaire indicated that 11 participants (29%) had started to develop automaticity (SRBAI scores of 14-16 out of 28), but the behaviour did not become fully automatic.

Remembering strategies

In line with the studies from previous chapters, participants reported relying on contextual cues: routine events, locations, and objects. Figure 6.1 shows some of the cues they used. Information about participants' reported remembering strategies and incidents of forgetting can be found in Table 6.3 on the next page. The most adherent participants reported following specific remembering strategies and relying on several cues (see Table 6.2), mainly keeping vitamin boxes

Table 6.2: Effectiveness of different combinations of cues (N=38). SRHI scores range from 5 to 60, SRBAI scores range from 4 to 28.

		SRHI		SRBAI		Adherence	
Cue type	N	Mean	SD	Mean	SD	Mean	SD
Routine only	1	34	-	8	-	80%	-
Location only	11	36	8.1	12	2.6	87%	13.6%
Routine + location	11	37	8.5	12	3.0	90%	12.1%
Location + object	3	37	1.0	10	2.9	75%	35.2%
Routine + location + object	12	36	6.2	12	3.6	92%	8.3%

Table 6.3: Remembering strategies and issues with remembering vitamin C tablets. Participants marked with an asterisk in the "Missed tablets" column had below average memory compared to the control group from Crawford et al. (2003).

#	Remembering strategy & cues	Missed tablets	Reasons for forgetting	Forgot if taken
P1	Desk, with toiletries; morning routine	3-4	Didn't take immediately	Yes
P2	Desk; morning or afternoon	1	Sleepy in the morning	-
P3	Many changes to find the right strategy	1	No contact with vitamins	Yes
P4	With wallet, keys, helmet; after coffee	0	-	-
P5	On a make-up table; morning routine	1	Unplanned stay over	-
P6	Desk; whenever remembered	Over 10	Rushing, often not in the room	No
P7	Next to tea cup; with evening meals	1-2	Returning late, tired	Yes
P8	Desk, with keys; morning	2	Left them at home when travelling	-
P9	Desk; before leaving in the morning	1-2	Rushing	-
P10	In a bag, with the Pill; reminder	0	-	-
P11	By the bed, with keys & wallet	0	-	Yes
P12	First on a cupboard, later inside	Over 10	Busy, not at home	No
P13	In a bag; times varied	2-3	Busy; beliefs	-
P14	By the bed; when getting dressed	2-3	Different morning routine	Yes
P15	Desk; in the morning	0	-	-
P16	Bathroom; after brushing teeth	0	-	Yes
P17	Desk; after breakfast	0	-	No
P18	Tested different strategy each week	4-5	Different weekend routine, rushing	Yes
P19	Bathroom; after brushing teeth	7	Left them at home when travelling	-
P20	Kitchen, next to oven; with breakfast	1-3	Didn't eat breakfast	Yes
P21	Desk, next to laptop	1-2	Worked late, tired	Yes
P22	First in a bag, then on her desk	2	New task, vit. hidden in a bag	Yes
P23	Tea cupboard; with morning tea	5-6	Didn't have time to drink tea	Yes
P24	Pocket; when needed a break	5	Changed jacket, forgot to move vit.	-
P25	Office desk's drawer; at 11am	1	Not sure when it happened	-
P26	Shelf by the bed; morning	0	-	Yes
P27	Backpack; with laptop charger	1	Busy, didn't need laptop charger	No
P28	Drawer, with the Pill; morning	1-2*	Wasn't in the room, visitors	Yes
P29	Kitchen, medicine drawer; breakfast	0*	-	Yes
P30	In a backpack; whenever remembered	1	Changed bags, forgot to move vit.	No
P31	After dinner, before brushing teeth	0	-	Yes
P32	Office desk; whenever remembered	1	Left them in the office	Yes
P33	Bag; on a bus to work	1*	End of study, day off	No
P34	With the Pill, after alarm clock	1	No alarm clock on the weekend	No
P35	Next to bed; whenever remembered	Over 10*	Tired	-
P36	Next to phone; before leaving	2	Unplanned stay over, rushing	Yes
P38	After breakfast; parents prepared	About 5	Didn't eat breakfast with parents	Yes
P39	Office desk; after coming to work	4	Left in the office, rushing	Yes

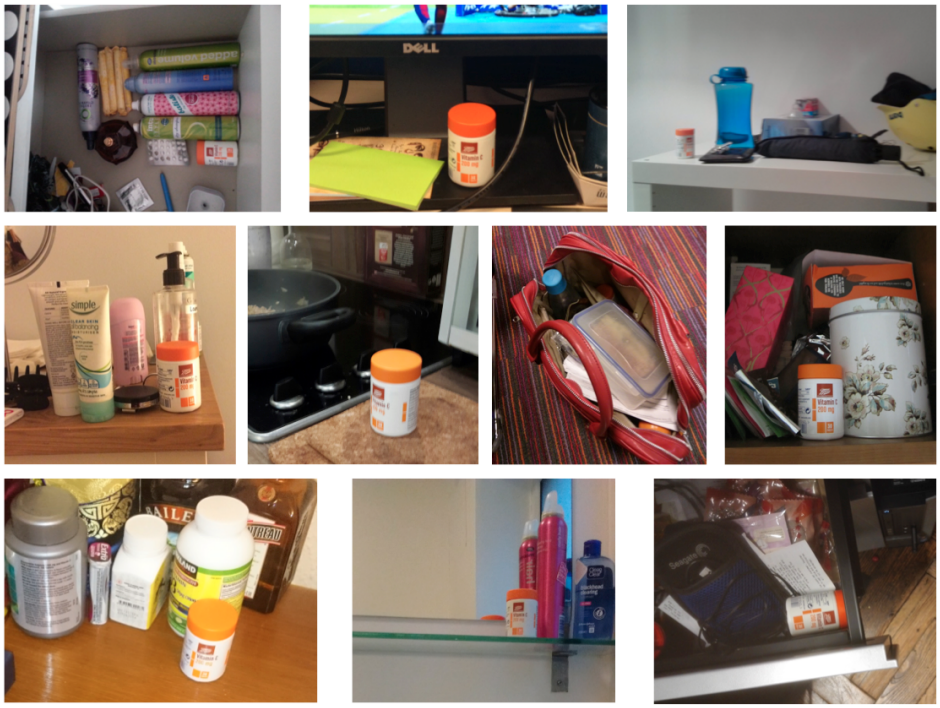


Figure 6.1: Locations and objects that helped participants remember vitamin C tablets. Top row from the left: P28, P32, P4. Middle row from the left: P1, P20, P33, P23. Bottom row from the left: P38, P16, P25.

in places related to their routine events. The most effective were combinations of multiple types of cues. For example, P4 kept vitamins with his keys and wallet, and would take one after his morning coffee when getting ready to leave the house (Figure 6.1, top right); and P16 kept vitamins in the bathroom and took one every morning after brushing his teeth (Figure 6.1, bottom middle).

Even though 17 participants (45%) studied STEM subjects and often used technology to remember everyday tasks, only two participants reported using technology to support their regimen: P10 had already been using a reminder for the Pill and decided to take vitamins together with it; and P18 decided to ignore study instructions and use a reminder in the final week of the study to test if she would like it (she had never used one for medications before).

Factors influencing the selection of cues

The main goal of the study was to understand how people develop effective remembering strategies. The analysis uncovered four themes that explain the selection of cues: Visibility, Effortlessness, Experience and Beliefs. They are described below.

Visibility. One of the main factors influencing the selection of cues was visibility. Participants wanted to see the vitamins and some believed that this would be sufficient to help them remember to take the tablets on a regular basis. They did not associate vitamins with any routine events or objects. Instead, they kept them somewhere where they could see them throughout the day:

> *"When I see it, I take it – that's the plan."* – P15

> *"I think I made a decision to take one by my eye, but not by my mind."* – P32

Other participants tended to keep their vitamins with specific objects they use every day and in places linked to specific routine events, e.g. with keys and wallet, by the toothbrush or in the tea cupboard, which made their strategy more reliable.

> "[It's] *in the main part of my bedroom. So I see it every day and it's lucky that the* [vitamin box] *is bright orange, so it's easy to see.* [...] *I put it next to my keys, the kind of things I have to take every day, so it's very easy to see it and to take it."* – P4

However, while relying on visual cues made remembering easier by making the behaviour automatic, that automaticity was not always desirable:

> *"As I saw it, I would take it automatically. I didn't think about it, because I was thinking about something. And then yeah, sometimes I would be looking at it and thinking 'I will take it' and then almost there, but I would remember that actually I took it today."* – P21

Effortlessness. Visibility was often a part of a wider strategy that aimed to make taking vitamins as easy as possible. Effortlessness was a result of a combination of routine actions and a strategic location, which meant that participants did not have to change their existing behaviour, they only had to add one extra step.

> *"I think* [taking vitamins] *was actually not so bad, I found it alright, especially if I left* [the box] *somewhere where I could do something."* – P36

> *"It's next to my toothbrush* [...] *I brush my teeth and then I put my toothbrush away and then I take my tablet. And because it was like right next to it, and I'm focusing on the toothbrush, and that's where it is, then it would be... I'd remember it more, because it's like the next step kind of thing. So I tried to incorporate it into my daily routine with the toothbrush. That went quite well."* – P18

Routine actions used as cues were mostly effective, although sometimes they were context-dependent. Some participants were aware of it from the start, but the possibility of missing

a few tablets did not bother them. For example, P23 decided to keep vitamins in a tea cupboard even though she was aware that she might miss them on days when she does not drink tea:

> *"If I have to take something every day, I always put it in the coffee and tea cupboard.* [...] *That's the best place in which I remember. I mean, there's always one or two mornings when I don't take coffee or tea, but... so I will forget *laughs*"* – P23

Aiming to reduce effort also meant that participants selected or considered selecting cues that would provide additional safeguards that would make taking missed doses easy as well.

> *"A good thing for me would be also if I recognise that I forgot to take it with breakfast, I can still have the rest of the day to take it. So if I miss them, I can take them in the afternoon or in the evening."* – P26

> *"So I'd probably keep it in my bag and then at least if I've forgotten during the day, I've got them with me."* – P11

During the first interview, 37 participants discussed their plan for remembering vitamins; however, only 27 actually followed it, including only two participants who used the same cues throughout the whole study (P34 kept vitamins with the Pill and P38 with ginseng tablets). Others either started with a completely new strategy or changed and tweaked their strategy as the initial plan did not work (ineffective strategies are described later on page 149). For some, the change happened naturally, others tried multiple options, while for some participants finding the right cues was a long process of trial and error. Nevertheless, sooner or later they all found a satisfactory strategy.

> *"It was on my desk* [on the first] *day. But then* [...] *when I went to brush my teeth I took it* [to the bathroom]*, and then it remained there."* – P16

> *"First couple of days* [...] *I was just thinking of how and where I should put it so* [that] *it's easy for me. So on the first day I put it on the counter in my kitchen and then I decided that I'm going to have breakfast at work* [...] *I'm going to place it there, I will bring it to the office. And after that it was pretty straightforward."* – P39

> *"The first place I had it was in the kitchen.* [...] *If I didn't have breakfast, I wouldn't have it, I wouldn't go there and I would forget about it in the morning.* [...] *Then I put it next to my work desk.* [...] *And then, eventually, I moved it to my bed* [...] *Because sometimes I'm thinking, 'did I take it? or did I not take it?' And so I* [...] *made a choice* [that] *I will just wake up and take it straight away. So that's why it finally got on top of my drawer, but that took me 2 weeks, maybe a bit less, to move it, to place it actually there."* – P3

Experience. Previous experience influenced remembering strategies of some of the participants. Quite often these strategies were proven and tested—that is how they remembered things in general or how they used to remember medications in the past.

> *"So it would be either breakfast or dinner, because I'm used to taking medications around these times."* – P1

> *"I was ill a couple of months ago and I had a cold, and I took some tablets. I kept them on my desk and on my bedside table, so I remembered to take them every 4 hours. So that's the way I tend to remember medicine."* – P18

> *"If I have to take something every day, I always put it in the coffee and tea cupboard."* – P23

People who already had been taking medications regularly decided to add vitamin C tablets to their existing regimen, as it was the easiest way to remember them: with remembering strategy already in place, it did not require any extra effort.

> *"I made it easier because they were both* [the Pill and vitamin C] *at the same time, so I can take two pills and I'm good. For the first few days I had to definitely remind myself to take* [vitamins]*, but closer to the end I was like 'okay, do I have two? right.'"* – P10

> *"It was actually easier than I thought it would be. I remembered actually most of the time* [...] *And I think it helped that I remember my other pills, I had two things together."* – P28

> *"I think that taking the Pill is a part of my routine anyway, it wasn't that weird to add another one."* – P34

However, past experience did not guarantee that the selected strategy would be effective. For example, P35 used to take vitamin C tablets, but almost never remembered to take them, even though they were in a visible spot on his desk. Despite this strategy not being effective in the past, this is exactly how he tried to remember vitamins during the study, possibly because he believed that this time it would be easier as his motivation was different (*"I think if you give me* [the vitamins]*, I will feel that I would be like kind of obliged. Because I committed myself to that. So I think the motivation is actually to fulfil what I committed myself to, not my health."*). However, he reported forgetting over 10 tablets. Such beliefs, including beliefs about remembering in general and vitamins in particular, can also influence the selection of cues.

Beliefs. Some participants believed that vitamins had to be taken at a specific time of day (in the morning, with meals, before sleep, etc.) and this belief dictated how they would remember them, as the strategy had to match the time.

> *"They say that the vitamin is the best before breakfast. So I'll probably have it then."* – P15

> *"I think vitamin C is a morning thing, because you associate it with orange juice and that sort of thing* [...] *something about the colour makes it about the morning."* – P1

> *"Someone said that it is not good to take* [vitamins] *after the caffeine* [...] *and also at night our body is sleeping more, so it is great because nothing else is going inside, so taking the tablet at night* [is] *more useful."* – P13

Beliefs about medications sometimes also determined the location of vitamins:

> *"I normally put* [pills] *beside my bed* [...] *I guess that's a routine for people on medicine. I think they always put it there."* – P11

> *"I don't think it's a lucky thing to keep medicine in a visible place."* – P32

Weak strategies

The analysis also uncovered factors that reduce the effectiveness of remembering strategies. Reliance on a single cue was one of them. It did not make much difference whether the single cue in use was a location, an object or a routine—if it was the only cue, it was too vulnerable and the lack of contact with it often resulted in forgetting.

> *"The days when I actually forgot were the days when I had no contact with this thing."* – P3

> *"I think I forgot to take one* [tablet]*, because I think that day I was so busy I didn't use my charger."* – P27

> *"I've changed my jacket, so the* [vitamin] *box got stuck in the other jacket, so I forgot once or twice."* – P24

Similarly, relying on vaguely defined cues was often ineffective. All participants who reported missing more than seven tablets (a third of all they were supposed to take) had no structured remembering strategy and their approach could be summarised as "I'll take it when I see it". This lack of structure not only made remembering more difficult, but also sometimes caused uncertainty whether the tablet had already been taken that day.

> *"I would walk around my room and it would catch my eye and I would be like 'did I take it or not?'"* – P1

> *"I think a couple of days I probably took one and later was like 'did I take it once a day?', so I guess some days I took two instead of missing out."* – P14

On the other hand, all participants who reported not missing a single tablet had developed strategies made of multiple cues. They often reported that taking vitamins had become part of their routine and clearly defined cues helped them remember the vitamins when their environment changed. For example, six participants went away during the study and three remembered to take the vitamin box. Before the trip, they had kept the vitamins together with other things they would need to pack (make-up, toothbrush, creams) and therefore had no difficulties packing them with everything else.

> *"When I was doing my make-up I would see it or whatever and then I would take it.* [...] *I went home* [...] *during Reading Week* [...] *And I brought that with me, but I think that was because I was packing, obviously I brought a suitcase and stuff. And I brought everything with me"* – P5

Of the three participants who left the vitamins at home, two had kept them with items that did not need to be packed (keys, wallet), and one did not have an established routine for taking the tablets and in addition packed at the last moment.

While combinations of multiple cues were the most effective, they had to be unique, otherwise encountering the same combination at a later point during the day caused doubts. Similarly, getting *too* used to taking the vitamins sometimes caused difficulties with remembering whether the tablet had been taken.

> *"Sometimes, if I did it automatically, I would forget if I have taken it in the morning."* – P23

6.2.3 Conclusions

The aim of the study presented above was to validate with rich qualitative data the findings of the retrospective analysis of the most effective strategies reported in earlier studies, and to explore how people select cues for a new medication regimen and what factors influence the formation of their remembering strategies. Four themes emerged that explain the selection of cues: Visibility, Effortlessness, Experience and Beliefs; the first two being the most important. In addition, two factors that reduce the effectiveness of remembering strategies were identified: reliance on a single cue and loosely defined strategies, which confirmed the earlier findings suggesting that combinations of clearly defined cues are the most effective.

In general, participants did not give much thought to how they were going to remember the vitamins: they mostly focused on visibility and kept the vitamin box in a visible and accessible

place. Since most of the time this strategy worked, they did not always see the need to clearly define their cues. However, this lack of structure made their remembering strategy vulnerable to changes in their daily life. And indeed, the implementation intention research shows that forming general goals is less effective at ensuring the task gets done than forming more specific if-then plans (Oettingen et al., 2000; Prestwich & Kellar, 2014), which is also true for remembering vitamin supplements (Sheeran & Orbell, 1999).

While participants were not directly asked to form implementation intentions, they were asked about their plans. Very few had a specific plan in mind, and in most cases it was abandoned or modified during the study. In addition, if the strategy was based on a single cue (regardless of whether it was linked to a location, an object, or a routine), it introduced dependency: if the cue was not encountered, the participant missed the tablet, which sometimes prompted changes to the strategy and the search for better cues. In this regard, contextual cues were no better than apps that teach people to rely on them (Renfree et al., 2016). All this suggests that people are not good at selecting the right cues and that they cannot always predict what remembering strategies would be best for them, which echoes some of the results from Chapter 5 and previous research showing that people tend to select suboptimal habit cues (Gardner et al., 2014). It also explains why some participants from the healthy habits study were changing their triggers to action: discovering the right strategy requires trial and error. This has implications for apps that facilitate the formation of medication habits. As cues people plan to use or choose initially are seldom the ones that help them remember in the long term, there needs to be space for experimentation. The apps should not only support this process, but actively encourage it.

The study also showed that there was a difference between mindless automatic behaviour and making the vitamins a part of a routine. When participants took the vitamins as another step in a longer, unique sequence (e.g. taking it as the next step in their morning routine, right after putting make-up on), automaticity was not an issue; however, when the routine or a cue was not unique (e.g. taking it with tea as a part of a morning routine, but then drinking tea again in the afternoon), the doubts whether the tablet was taken would appear. This highlights the vulnerability of automatic behaviour (Bargh, 1994) and the difference between habits and implementation intentions: the latter do not stem from the automatic behaviour but from the conscious recognition of the cue (Sheeran et al., 2005). The above suggests then that clearly defined, unique strategies in the format of implementation intentions could help to take the vitamins every day and reduce chances of forgetting if a dose has already been taken.

6.3 Discussion

This chapter presented two studies conducted to understand the characteristics of reliable remembering strategies. The first study analysed effective strategies reported by participants in medication surveys from Chapter 3 and habit formation studies from Chapter 5, while the second study ("vitamin C study") explored how people form remembering strategies for a new medication regimen and what factors influence the selection of cues.

Prospective memory research shows that event-based tasks are easier to remember than time-based tasks (Guynn et al., 1998); results reported in this chapter show that combining event-based tasks with additional cues can support memory even better. Reliance on multiple cues and contextual memory aids has been previously reported in studies investigating how older adults fit medications into their everyday life (e.g. O'Quin et al., 2014; Palen & Aaløkke, 2006; Tordoff et al., 2010), which suggests that these behaviours are universal. The role of multiple cues has been considered in the habit literature (e.g. Gardner et al., 2014; Lally et al., 2011; Tappe & Glanz, 2013), although their impact on medication habits has not been studied. My results suggest that reliance on multiple cues can not only support the formation of medication habits, but also provide safeguards against the limitations of automatic behaviour.

The results of the retrospective analysis of effective strategies showed that the most common remembering strategies included combinations of interconnected cues (routine events, objects and locations), and that participants often reported the use of visual cues and keeping medications at hand as additional safeguards against forgetting. The vitamin C study confirmed the results of the first study and showed that clearly defined multi-cue strategies were the most effective. It also showed that instead of selecting optimal strategies, participants often assumed that as long as they could see the box of vitamins, they would be able to remember to take them every day. However, while for the majority of participants visibility of vitamins was the most important factor, it was not the most effective.

Both studies showed that participants relied on visual cues, either in conjunction with other cues (retrospective analysis) or as primary cues (Vitamin C study). However, while cues that stand out from the environment are effective (McDaniel & Einstein, 1993) and thus could serve as reliable visual reminders, they should not be visible all the time as they lose their salience (Vortac et al., 1995). And indeed, participants who encountered the same cues throughout the day were often unable to determine whether they have taken the vitamin C tablet already. Moreover,

when one has to regularly repeat a habitual task, it can be easy to confuse thinking about the task with the memory of completing it (Einstein et al., 1998). Participants reported this type of error and it could be attributed to the regular exposure to the vitamin C box that served as a visual cue. This also highlights participants' inability to define specific cues that would help them to take vitamins every day and to remember whether a tablet had already been taken.

Previous research confirms that selecting the right cues might be an issue. For example, in a study on healthy eating habits, Gardner et al. (2014) discovered that their participants frequently specified suboptimal cues (e.g. used time of day as the main trigger to action, did not name specific cues) and never named multiple cues in their strategies. The authors did not explore the reasons for selecting these cues, although post-hoc discussions with participants revealed their lack of understanding of which cues would be good in this context. This is similar to the behaviour reported by the interviewees: they also lacked this understanding, although they did not admit it directly. It was evident though, as despite having specific plans for how they would remember the vitamins, almost all of them had to change their strategy to ensure vitamins would fit into their daily routine. Since people are generally bad at selecting cues (Gardner et al., 2014) and may not recognise the cues that prompt their behaviour (Orbell & Verplanken, 2010), it is also possible that they may not fully understand their routines. This suggests that some degree of trial and error experimentation is a necessary step in the formation of good remembering strategies as it helps to develop a better understanding of which cues work and how they fit into one's everyday life.

The results also showed that just as not all cues are good at supporting both prospective remembering and habit formation (see Chapter 5), prospective memory cues that are good for one prospective memory task (e.g. remembering to take medications on time) are not necessarily good for another (e.g. packing the medications before travelling). However, the results suggest that good remembering strategies could prevent different types of forgetting if they involve a combination of daily routines and multiple cues. The effectiveness of this approach was apparent in the retrospective analysis of effective strategies, where participants not only relied on daily routines, but also used contextual cues and visual reminders, and kept spare packets of tablets at hand. The vitamin C study also showed that cues supporting everyday remembering sometimes helped participants to remember about vitamins when preparing for travel. This suggests that remembering strategies could prevent different types of forgetting, but all relevant circumstances should be acknowledged from the start, which further highlights the need for trial and error.

The vitamin C study also highlighted both the usefulness and the danger of automatic behaviour. While dangers of mindless automatic behaviour are acknowledged in the habit literature (Bargh, 1994; Einstein et al., 1998), the research in this area focuses on supporting the development of automaticity and its positive sides, which was also explored in studies reported in Chapter 5. Forgetting whether the task has been completed did not emerge as an issue in other studies exploring the development of healthy habits (e.g. Aarts et al., 1997; Gardner et al., 2014; Judah et al., 2013; Lally et al., 2011), possibly because of the nature of tasks being studied. Healthy behaviours such as physical exercises or flossing are more complex than taking a tablet and they require more effort, thus it is difficult to complete them without thinking or to forget whether they have been done. This difference is evident in studies reported in previous chapters: while forgetting whether the task (reporting lunch, drinking a glass of water, meditating) has been done was not an issue in habit formation studies from Chapter 5, automaticity-related forgetfulness affected half of participants who were taking vitamin C tablets. Therefore, when supporting remembering strategies, rather than focusing on automaticity and habit development, a better approach might be to focus on implementation intentions as they can also support memory. Supporting prospective remembering from the start and linking it to its cues through implementation intentions can help to ensure that the behaviour is regularly repeated and with time may become automatic.

Moreover, it was argued in earlier chapters that implementation intentions can support habit formation and the development of automaticity by linking the task with its cue, but that connection does not need to be automatic. Unlike habits, implementation intentions can be formed—or recognised—on the spot (Gollwitzer, 1999; Sheeran et al., 2005), as they do not stem from mindless repetition (Oettingen et al., 2000). Therefore, when a relevant cue is encountered, people can decide to respond to it in a more conscious way. There is a difference between habitually executed and habitually instigated behaviour (Gardner, Phillips, & Judah, 2016), and thus implementation intentions can serve as either cues to action or cues to intention, i.e. cues that prompt automatic behaviour (e.g. taking medications right after eating breakfast) or cues that automatically remind about an intended task (e.g. finishing breakfast and remembering that there is another step that should be taken). In the context of medication-taking, the latter would be more desirable, as it prevents mindless behaviour that might lead to overdosing if a person forgets whether the pill has already been taken.

These considerations have implications for the design of adherence apps that aim to support prospective memory and facilitate the development of robust remembering strategies. First and foremost, they should use implementation intentions to ensure that relevant cues are recognised and the behaviour is not acted on mindlessly, which would reduce the likelihood of forgetting whether the medication was taken. Second, they should facilitate the use of multiple interconnected cues (routine events, locations, objects), to ensure that memory is supported even if some of the cues are not available. And lastly, the apps should support the process of trial and error that takes place while a person searches for the best strategy. By providing features that offer this support, adherence apps could help users form routine-based remembering strategies that help them to remember a new regimen from the start and to maintain a long-term repetition by facilitating the formation of medication habits without introducing the risks of mindless automatic behaviour.

The next chapter brings together findings from this and the previous chapters, and discusses their implications in more detail. It presents the wider contribution of my work and demonstrates how identified characteristics of good remembering strategies can be implemented in practice.

Chapter 7

General discussion

This chapter:

- ❖ Summarises research findings reported in previous chapters.
- ❖ Outlines implications for design and demonstrates how proposed design guidelines can be implemented in practice.
- ❖ Highlights the contribution to knowledge.
- ❖ Discusses limitations and future work.

Non-adherence to medications is a serious issue that reduces the effectiveness of medical treatments and increases healthcare costs (Hughes et al., 2001; WHO, 2003). For example, approximately one million unwanted pregnancies each year are caused by irregular use or discontinuation of oral contraception regimens (Black et al., 2010; Rosenberg & Waugh, 1999; Smith & Oakley, 2005). While many people are intentionally non-adherent, others simply forget—and forgetting alone accounts for 30% of cases of unintentional non-adherence (Unni & Farris, 2011). However, adherence interventions aiming to address the issue are largely ineffective (Haynes et al., 2008; Horne et al., 2005) and tend to focus on intentional behaviour and improving motivation (Haynes et al., 2008). The interventions that do focus on forgetting prioritise timed reminders (Haynes et al., 2008; Vervloet et al., 2012), even though the effectiveness and salience of alerts decrease with time (Tobias, 2009), which makes them less reliable in the context of long-term medication regimens. Overall, existing approaches tend to ignore the fact that such regimens are habitual in nature (Vrijens et al., 2014) and rely on prospective remembering (Park & Kidder, 1996; Zogg

et al., 2012)—both of which can be effectively supported by daily routine events and contextual cues (Johnson, 2002; Lally & Gardner, 2011; Neal et al., 2012; Park & Kidder, 1996).

As smartphones are an increasingly popular and effective platform for delivering health interventions (Fjeldsoe et al., 2009; Klasnja & Pratt, 2012; Vervloet et al., 2012), in this thesis I have investigated how smartphone apps could support adherence to long-term medication regimens. The results reported in previous chapters show that by taking advantage of cues people already use it is possible to support long-term medication regimens and reduce unintentional non-adherence caused by forgetting. My work is grounded in prospective memory and habit formation research, as both sets of literature highlight the positive role of routine events and contextual cues in maintaining long-term behaviours (Judah et al., 2013; Lally & Gardner, 2011; Maylor, 1990; McDaniel & Einstein, 2007), including medication regimens (Park & Kidder, 1996; Sheeran & Orbell, 1999). However, while existing research suggests that designing an app that helps users make use of daily routines and contextual cues would be an effective solution, I show that the reality is more complicated.

This chapter brings together findings from the studies described in the previous chapters. In the next section I summarise my key findings. As they have implications for the design of adherence technologies, as well as wider behaviour change interventions, I then propose design requirements for apps that support the formation of routine-based remembering strategies and the development of medication habits. The requirements are illustrated by two working apps that demonstrate how the proposed habit support can be implemented. Next, I describe the theoretical contribution of my work that highlights the need to account for prospective remembering in future habit formation theories. The chapter ends with an overview of future work directions.

7.1 Research findings summary

The aim of this thesis was to investigate how smartphone apps could support the creation of reliable routine-based remembering strategies that lead to the formation of medication habits. The results show that, regardless of the regimen or population (see Chapters 3 and 6), people tend to rely on combinations of contextual cues (routine events, locations, objects) to help them remember their medications. Clearly defined strategies consisting of interconnected cues that incorporate additional safeguards (visual cues, backup reminders) are the most effective (see Chapter 6). As these findings are supported by existing adherence studies conducted with older

adults (e.g. Insel & Cole, 2005; O'Quin et al., 2014; Palen & Aaløkke, 2006; Tordoff et al., 2010), it means that the strategies and cues that people use to manage their medications are universal. They can inform the design of adherence technologies in general—regardless of the target population or regimen.

Moreover, findings show that people tend not to use technology as their primary cue, but often supplement their existing strategies with reminders (see Chapter 3 and 6). This seems to be a reasonable strategy: while reminders can effectively support prospective remembering in the short term, they are not appropriate for supporting habitual tasks and can hinder the development of automaticity (see Chapter 5). Reported low app usage levels can be partly explained by the effectiveness of strategies described above, and partly by the limitations of existing apps (see Chapter 4). Instead of supporting the formation of medication routines, medication reminder apps provide simple and inflexible timed notifications that often cannot be postponed. Similarly, habit formation apps do not help users to form habits, but instead facilitate regular repetition through self-tracking, reminders and positive reinforcement—even though self-tracking and reminders do not support habit formation and positive reinforcement is not needed when the behaviour is already reinforced by the right contextual cues (see Chapter 5).

However, contextual cues do not always support prospective memory and habit formation equally well (see Chapter 5). While they can facilitate the development of new habits, the process is too slow to guide the new behaviour and prevent forgetting while the automaticity develops. Moreover, people tend to select suboptimal cues that interfere with the process of habit formation, which increases chances of forgetting (see Chapter 5 and 6). For example, contrary to the expected usefulness of location as a reliable cue (Neal et al., 2012; Verplanken et al., 2008; Wood et al., 2005), responding to routine actions that take place in the same location (but at different times) can be less effective than responding to a routine action in different contexts, e.g. during holidays. In addition, people tend to rely on visual cues (e.g. keeping medications in a prominent spot), but when not linked with a specific routine, reliance on these cues increases chances of forgetting whether the task has already been completed, especially when they are frequently encountered throughout the day. As people do not know what constitutes good cues, finding them requires trial and error, which may have a negative effect on adherence and habit development while the search for the most appropriate cues is in progress.

Overall, my work shows that if apps—and adherence technologies in general—are to effectively support long-term regimens, they need to assist users with selecting event-based cues that link

their medications with a trigger event, and with forming clearly-defined remembering strategies that make use of other contextual cues such as physical objects or meaningful locations. They also should not use timed reminders as the primary cue, but as a tool to reinforce other cues.

Drawing from the findings described in previous chapters and summarised above, in the next section I present a set of design recommendations for adherence apps that facilitate the selection of optimal cues that support prospective remembering and help to embed medication-taking into a daily routine. To provide more concrete guidance to HCI researchers and app developers, the requirements are illustrated by two working example apps—one of which was evaluated through a short situated study—that demonstrate how each requirement can be implemented in practice.

7.2 Implications for design

The findings summarised above, including the characteristics of good remembering strategies and habit-hindering capabilities of timed reminders, can be translated into design requirements that will inform the design of future adherence technologies.

Good implications for design should be both abstract and actionable (Sas, Whittaker, Dow, Forlizzi, & Zimmerman, 2014): some level of abstraction allows them to be generalised to different contexts, while concrete design examples show how they can be applied in practice. Therefore, this section outlines general design requirements for adherence apps that help users select contextual cues that support prospective remembering and facilitate the formation of medication habits (see Table 7.1). As the requirements describe what the apps should do—without explain-

Table 7.1: Design requirements for adherence apps that facilitate the formation of reliable routine-based remembering strategies.

Requirements	Supporting findings
R1. Help users define a good remembering strategy.	Clearly defined multi-cue routines are the most effective.
R2. Provide examples of good remembering strategies.	People do not always know what constitutes a good strategy.
R3. Provide suggestions for strategy improvements and support changes.	Finding the right cues takes time and is a result of trial and error.
R4. Remind about cues and remembering strategies.	Reminders can effectively support prospective memory in the short term.
R5. Disable cue reminders when the behaviour becomes a part of a routine.	Relying on reminders in the long term can hinder habit development.
R6. Help users check whether the medication has already been taken.	It is easy to forget whether a task done automatically has been completed.

ing how—they can be adapted to other types of adherence technologies. To demonstrate their "technological actionability" (Sas et al., 2014), two real-world apps are described next to illustrate how each requirement can be translated into specific features. Their description is followed by a summary of a short evaluation study conducted with one of the apps.

7.2.1 Design requirements for adherence apps that facilitate the formation of reliable routine-based remembering strategies

R1. Help users define a good remembering strategy.

Regardless of the type of medication regimen, people tend to rely on routines and other contextual cues, and clearly defined multi-cue routines are the most effective. The app should help users link their medications with an existing routine task they already do and encourage them to consider additional cues.

R2. Provide examples of good remembering strategies.

People do not always know what constitutes a good strategy. The app should provide a list of routine events that can be effectively used as triggers (meals, getting up, etc.) or help users define their own routines. It could also provide general information about the characteristics of good strategies, emphasising that they need to be clearly defined, made of multiple cues, and ideally presented as implementation intentions.

R3. Provide suggestions for strategy improvements and support changes.

Finding the right strategy takes time and involves some degree of trial and error. Technology should support this process to help users find the right strategy as soon as possible by initially monitoring their performance and suggesting changes to the strategy if they keep forgetting. Users should also be able to modify the strategies recorded in the app when they identify better cues. The app should treat each change in the routine as a starting point of a new regimen and reinforce the new remembering strategy to ensure it fits into user's daily routine.

R4. Remind about cues and remembering strategies.

As reminders can effectively support prospective remembering in the short-term, they could be used to reinforce the cues selected by the user at the beginning of a new regimen. Rather than reminding users to take their dose at a specific time (e.g. "take your Pill"), they could remind

in advance about the whole strategy to help support the formation of associations between the medications and their cues (e.g. "remember to take your Pill with breakfast").

R5. Disable cue reminders when the behaviour becomes a part of a routine.
Relying on timed alerts in the long term can hinder habit development, as there are no incentives to develop other strategies. When starting a new regimen, cue notifications should be available only when the behaviour is still new. They should stop when users learn their cues and the behaviour becomes a part of their daily routine.

R6. Allow users to check whether the medication has been taken.
It is easy to forget whether a task done automatically has been completed, so the app should allow users to check whether a dose has been taken or not. Cue notifications (see R4) could serve as an additional visual cue for situations when the routine changes: as long as the notification is visible and has not been dismissed, users will know they still have not taken their medication.

The design requirements outlined above can be translated into specific app features. The next section presents two real-world apps demonstrating that some aspects of routine support can be provided using existing smartphone capabilities. App descriptions include references to specific requirements to show how each of them was implemented.

7.2.2 Implementation examples

This section presents two apps designed to support the formation of medication habits while helping users to remember about their medications from the beginning of a new regimen. The first app was developed by me to illustrate the requirements as closely as possible. The second app was developed by students and was commissioned to show that the requirements leave space for creative interpretation while still providing actionable research-based guidance.

Habit Cookbook

I developed Habit Cookbook (see Figure 7.1) to illustrate how an app can help users select the best routine-based remembering strategy and how pre- and post-task notifications can be used to reinforce the cues. The app guides users through a step-by-step process, helping them define

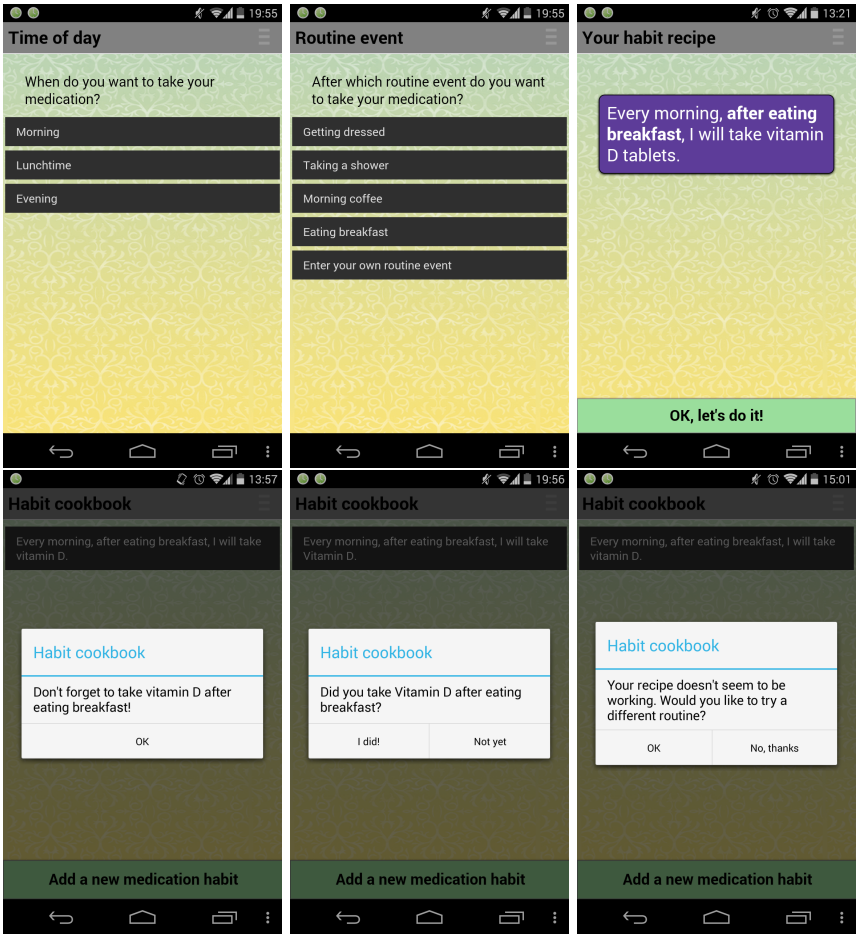


Figure 7.1: Habit Cookbook helps users define a 'recipe for a habit' (an implementation intention) and uses pre- and post-task notifications to reinforce it.

a "habit recipe" (an implementation intention that emphasises the routine event) that will aid their memory and help to develop a habit.

When the app is opened for the first time, users are asked to specify the time they usually wake up, eat lunch, and go to sleep: these values are later used to calculate when cue notifications should be sent (more on that below). After the initial setup, users can add a new "medication habit". They are first asked to select the time of day for their medication (Figure 7.1, top left), as it helps them reflect on their day and find the most suitable cue (R1).

Next, the app shows suggestions of routine events that people usually do at this time of day (R2); these routines are informed by research and also serve as examples of good cues. Users can select a routine from the list or add their own (Figure 7.1, top middle). On the next screen, the app shows the summary of their strategy (a "recipe" for their habit) in a form of an implementation intention (Figure 7.1, top right), which is later reinforced through pre- and post-task notifications.

Pre-task notifications are sent before the selected routine action. The notification time is based on the initial setup: for morning routines, notifications arrive 30 minutes before the usual wake-up time; for lunch routines, 30 minutes before the usual lunch time; and for evening routines, an hour before the time the user usually goes to sleep. Pre-notifications are silent and appear on the notification bar, where they are displayed until the user notices them. The "recipe" is visible in the notification bar and clicking on it shows a pop-up window that repeats the implementation intention (R4; Figure 7.1, bottom left). Users are expected to follow their usual sequence of actions and take their medication after their cue event. About an hour later (or, for evening habits, at the specified sleep time) they receive a post-task notification that repeats the "recipe" (R4) and also stays in the notification bar until users are ready to report that they have taken their tablet (R6). The app tracks users' responses (Figure 7.1, bottom middle). If "Not yet" is pressed frequently (three or more times in the past seven days), the app will suggest a change in the routine (R3; Figure 7.1, bottom right). If users are consistently pressing "I did!" for a month, the pre-task notifications will stop (R5). The goal is to teach users to associate their medications with the selected cue without making them dependent on notifications.

Student app

The second app (also called Habit Cookbook, although here I refer to it as Student app to avoid confusion) was developed by Wahidur Rahman, Alessandro Fael Garcia and Alec Howells. As part of the Apps Design module during their MSc course in Computer Science at UCL, their task was to develop an app that supports medication habits. They based the app primarily on the published version of findings from Chapters 4 and 5 (see [C.1] and [C.2]), but were also familiar with the requirements summarised in Table 7.1. The source code of the app and a working version are available online (Rahman, 2016; UCLIC, 2016).

The Student app helps users identify the right cue first, before any medications are added. When it is opened for the first time, users are asked to add a routine action they do every day (R1). To do so, they must specify a time range that describes when this action usually takes place (Figure 7.2, far left); the start time is used to estimate when pre-task notifications should be sent and the end time is used for post-task notifications. The routine setup screen provides an example routine name that also serves as an example of a good cue (R2).

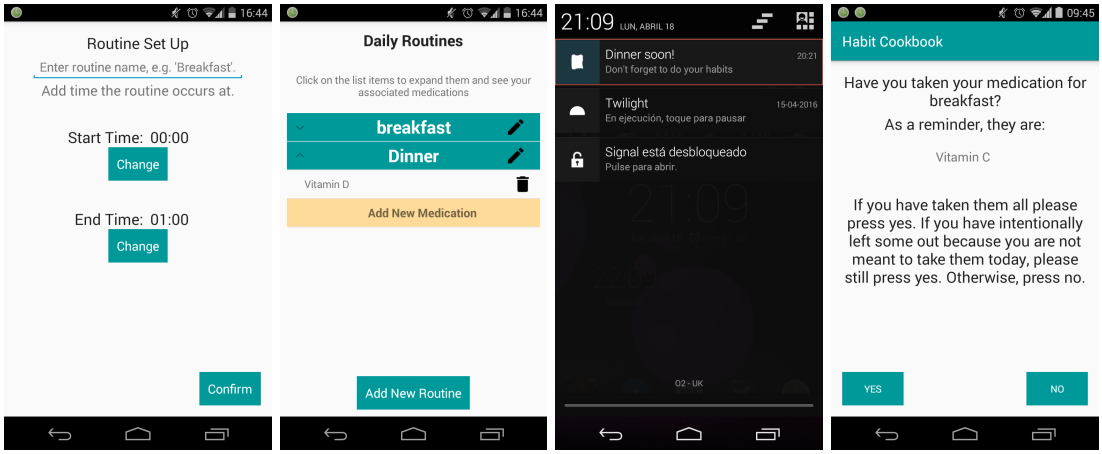


Figure 7.2: The app designed by Rahman, Garcia and Howells helps users link medications to a daily routine and reinforces the cue through notifications.

Once the routine is defined, users can associate medications with it (R1; Figure 7.2, middle left). Multiple medications can be added to a single routine if needed. While the app also provides pre- and post-task notifications (R4), pre-task notifications only remind about the cue (Figure 7.2, middle right; the notification is highlighted with a red square), which encourages the user to remember what medication they have associated with it.

After the routine task is over, the app sends a post-task notification (e.g. "Dinner finished! Click here") that is displayed in the notification bar until the user is ready to click it (R6, implicit). It also does not mention the medication and only reminds about the cue (R5). Users need to click on it to clarify whether they have taken their medication or not (Figure 7.2, far right). Their answers are recorded and if the medications are taken consistently, pre-task notifications become less frequent: they start to arrive every other day, then every three days, then once a week—until they completely stop after a couple of months (R5).

Both apps presented above illustrate how each design requirement outlined earlier can be translated into a specific feature and implemented in practice. They show that it is possible to move away from standard timed reminders and instead assist the users as they develop medication routines. The example apps also demonstrate that the requirements, even though grounded in theory, leave space for creativity and different approaches to implementation, which makes them more actionable and relevant to designers and app developers.

7.2.3 Evaluation study

The Student app was evaluated by Pornpong Soponsakulrat as part of his MSc project (Soponsakulrat, 2016), which I supervised. The aim was to investigate the benefits and limitations of plan reminders provided by the app to support the development of exercise habits. One of the studies conducted by Soponsakulrat was a 3-week situated study with interviews. Ten participants (aged 23-36 years old, average=25 years; seven of them were men) were asked to use the app for three weeks to help them exercise daily. At the end of the study they were interviewed about their experience and had to complete the SRBAI questionnaire (Gardner et al., 2012) to assess the automaticity of their exercise routine.

At the beginning of the study, participants were asked to select a type of exercise, add it to the app, and specify a cue. They were able to choose between a 3-minute stretching routine (that included neck rotations, neck stretches, sideway bends and calf stretches; NHS Choices, 2014), 15 push-ups, and 10 lunges. Six participants selected stretching and four did push-ups daily throughout the study. For their cues, seven participants selected "after waking up" as their cue, two selected "before taking shower", and one person did their stretches "before leaving home".

The results showed that all participants reported high levels of automaticity (average SRBAI score of 19.3; higher than observed in my habit formation studies for regular reminders, see Chapter 5). The interviews confirmed that participants automatically thought about their exercise ("I was thinking of my push-ups task almost every time I took shower" – P2) and with time needed to be reminded about the cue less and less ("They helped me to remember my workouts, but now I think I remember my stretching without them." – P8). However, even though they did remember about the exercise, they often made a decision *not* to do it; laziness and lack of motivation were the main problem. This should not come as a surprise though, as the types of exercise selected for the study were difficult and required effort, which added an extra barrier (Michie, van Stralen, & West, 2011). The app was designed to help users associate their task with its cues, with the assumption that the user would already be motivated to repeat the behaviour. In that sense, the results of this early evaluation are promising, as the users did remember both the task and its cue. This suggests that the app might be even more effective when the task is simple and requires less effort—such as taking medications.

7.3 Theoretical contribution

The primary contribution of this thesis is a better understanding of the role of contextual cues and reminders in supporting long-term habitual behaviours such as medication-taking. By demonstrating that not all cues support both memory and habit formation equally well, I highlight the need to account for prospective remembering in future habit formation theories.

Despite the theory suggesting otherwise, contextual cues that support habit formation are not effective at supporting medication-taking, as the automaticity of behaviour develops too slowly to reliably prevent forgetfulness. At the same time, standard timed reminders can hinder the development of automaticity while helping users to maintain high adherence. This means that reminders are the most effective type of cue if the task requires short-term repetition and there is no need to maintain a long-term habit. However, if the goal is long-term adherence, contextual cues should be used to help people maintain high adherence from the start while facilitating the development of automaticity. Therefore, only specific event-based cues that form a part of a well-defined remembering strategy can guarantee that a behaviour will be regularly repeated from the beginning and become a part of a daily routine.

This need for defined remembering strategies and multiple cues is contrary to the notion that, given enough consistent repetition, anything can become a habit cue (Ji & Wood, 2007; Neal et al., 2012; Pimm et al., 2015; Tappe & Glanz, 2013; Verplanken, 2005; Verplanken et al., 2008; Wood & Neal, 2009; Wood et al., 2005). The potential benefits of combinations of cues have been considered in the habit literature (e.g. Gardner et al., 2014; Lally et al., 2011; Tappe & Glanz, 2013), although no one has investigated whether they are more effective than single cues or whether they could support a new behaviour from the start. This omission is striking, as what happens at the beginning determines whether the habit will develop or not.

When considering starting a new behaviour, intentions, motivation and self-efficacy are recognised as the factors that help to take the first step and cross the intention-action gap (Bandura & Adams, 1977; Prochaska & Velicer, 1997; Ryan & Deci, 2000). However, just like people may fail to act on their intentions (Orbell & Sheeran, 1998), they can also simply forget. And yet, prospective memory is not accounted for in habit formation theories. Even though habit researchers acknowledge that having better prospective memory can help to repeat habitual behaviours (Judah et al., 2013), the role of prospective memory cues has not been investigated to date. In the context of behaviour change and adherence interventions, where the goal is to de-

velop a new behaviour, forgetting to complete the task should not be ignored. While occasional forgetting does not hinder habit development (Lally et al., 2010), consistent lack of repetition in the first weeks of the new behaviour can have negative consequences (Armitage, 2005)—and it is during the first weeks that habit cues are the least effective.

The importance of prospective remembering in the process of habit formation has implications for the design of interventions and technologies that aim to help people start and maintain a new behaviour, including new medication regimens. However, existing adherence interventions do not support prospective memory cues or the formation of remembering strategies that lead to habit formation. Instead, they predominantly rely on reminders as the main tool for facilitating regular medication-taking (Haynes et al., 2008; Vervloet et al., 2012), even though reminders are largely ineffective in supporting habitual tasks: not only does their salience decrease with time (Tobias, 2009), but they can also actively hinder habit development. To address this disparity, I have presented a set of design recommendations for adherence apps that help users facilitate the selection of the best cues that support prospective memory by making medication-taking a part of a daily routine. As the example apps show, my findings can be applied in practice and this new approach to supporting adherence can be effective.

7.4 Limitations and future work

Limitations of my studies have been discussed in their corresponding chapters, although two points need to be addressed as they concern all studies. First, given the nature of the research question and the interest in people's everyday behaviour, a large part of the data was based on self-reports. While people may not always be honest or accurate when talking about adherence (Myers & Midence, 1998; Wagner & Rabkin, 2000), patients perceive forgetfulness as more socially acceptable than admitting intentional non-adherence (Atkins & Fallowfield, 2006; Unni & Farris, 2011) and when they do admit it, their reports are often accurate (Cramer, 1991). This suggests that when describing remembering strategies—without elaborating whether they work or not—participant's accounts should be reliable. Moreover, self-reported survey data (Chapter 3) and remembering strategies reported in Chapter 6 are supported by existing literature, while habit formation studies (Chapter 5) included objective measures to complement self-reported information. Overall, remembering strategies and cues reported by participants were consistent and thus were deemed reliable in this context.

Second, the majority of my participants were women. This was inherent to the focus of the first survey from Chapter 3, as oral contraception was selected as an example of a habitual regimen. The gender imbalance of antibiotics and older adults surveys could be explained by the higher percentage of women as primary carers (Family Caregiver Alliance, 2003) and their longer average lifespans compared to men (Office for National Statistics, 2015). The participants in the habit formation studies (Chapter 5) were also primarily women, possibly because women tend to be more interested in behaviours explored in the studies (food tracking, healthy habits; Wardle et al., 2004). An equal number of men and women participated in the vitamin C study (Chapter 6); just like in the studies with the majority of female participants, there were no gender differences in participants' performance or in the remembering strategies they developed. Nevertheless, the design requirements presented earlier in this chapter (see page 160) are based on the premise that people need help with making medications part of their daily routine, which makes them relevant to users of all genders. However, given that men tend to consult healthcare services less frequently than women (Banks, 2001; Wang, Hunt, Nazareth, Freemantle, & Petersen, 2013) and thus are less likely to have established medication management strategies, future work could investigate this issue in more detail.

My work opens up new avenues for future research. The design requirements were inspired by current research on plan reminders (Prestwich et al., 2009, 2010). However, in these studies participants received plan reminders until the end of the study, which may not be optimal in the context of supporting the development of medication routines. This is also true for wider adherence research: reminders are not expected to stop and users have to respond to them for as long as they are using the technology. Since reminders can inhibit habit formation (see Chapter 5), I proposed that they should be available only at the beginning and stop with time. Future work should explore the benefits and limitations of phasing out reminders, as this has not been investigated yet. More work is needed to understand what is the best way to disable notifications: should they stop at a specific point or should they become less frequent with time until they finally disappear? Both approaches were implemented in the example apps, but a thorough investigation is needed to find the optimal solution.

Another possibility for supporting memory after a habit develops are context-aware reminders. Rather than stopping completely after a period of phasing out, notifications could switch into a context-aware mode and appear only when the environment changes. For example, the post-task notifications could reappear if a person spends a whole day in a new location. If the location

changed for a longer period (e.g. when a person moves house), they could start phasing out again. Habits can reactivate when old cues are encountered again (Gardner et al., 2012) and notifications reacting to context changes could support the reactivation process. However, more work is needed to understand how this could be implemented in practice.

Despite several similarities between the example apps, their pre-task notifications differ slightly: in my version of the Habit Cookbook notifications used the format of implementation intentions ("after doing X, I will do Y"), while the Student app reminded only about the cue. Prospective memory research shows that reminding about the task and its cue is more effective than reminding just about a cue (Guynn et al., 1998); however, it is so in the context of episodic prospective memory. As the adherence apps aim to help people repeat the behaviour every day (habitual prospective memory) in response to the same cue, reminding just about the cue might work in this context, especially since there is evidence that "content-free" cues that simply remind that something needs to be done—without specifying what or when exactly—can be effective (Fish et al., 2007). Future research could compare both approaches to assess their effectiveness in supporting medication habits, as well as more complex healthy behaviours. Overall, future work should investigate the best ways for implementing the requirements in a clear and usable way.

While the proposed design requirements were intended for smartphone apps, they could be used to inform the design of wearable technologies or smart home devices. Other channels that reach a wider population could also be investigated. For example, since leaflets can be an effective behaviour change tool (e.g. Lally et al., 2008), future work could investigate whether providing patients with a leaflet summarising "good remembering strategies" (based on the characteristics identified in Chapter 6 or adapted from design requirements) when they start a new medication regimen would help them fit medications into their everyday life and improve their adherence.

The requirements could also be adapted to support other types of regimens and treatments. Implications for design arising from the results of app reviews (Chapter 4) and the first habit formation study (Chapter 5) published in [C.1] and [C.2] have already influenced the design of a few technologies aimed at different populations and treatments: diabetes (Kalkattawi & Nakajima, 2015), older adults with chronic conditions (Rodríguez et al., 2015), and children with ADHD (Sonne, Müller, Marshall, Obel, & Grønbæk, 2016). As the evaluation study described earlier shows, they are also applicable to other types of healthy behaviours that rely on routine behaviour and regular repetition, such as regular exercise. Therefore, further studies could explore in more detail what approaches would be best for different behaviours.

Chapter 8

Conclusions

Vitamins in one's pocket, in a tea cabinet, on a desk—people tend to keep their medications in the most convenient places and take them at the most convenient times: when getting ready, with breakfast, at work. Daily routines, meaningful spots, and visual cues are frequently—and often effectively—used as memory aids and cues to action. Existing literature suggests that event-based tasks are easier to remember than time-based tasks, but my research shows that simply relying on a routine event is not enough. A good remembering strategy has to be unique and made of multiple cues that support prospective remembering and habit formation—only then can it effectively support memory from the start of a new regimen and be resilient to changes in the environment while facilitating the formation of medication habits. This has implications for the design of adherence technologies and the set of requirements presented earlier shows that a new approach that takes into account people's everyday behaviour is possible.

My work contributes to the HCI, medication adherence and habit literature. By demonstrating that not all cues support both memory and habit formation equally well at the same time, it highlights the need to account for prospective remembering in future habit formation theories. My results reported in earlier chapters expand our understanding of how people form daily routines, how they remember simple tasks, and what types of cues are the most effective at supporting both prospective remembering and the development of automaticity; this understanding can help us design better technologies that support people's everyday lives. The findings not only apply to medication-taking routines, but could also be extended to other types of health-related behaviours that require repetition and rely on prospective memory in their initial stages.

Supporting routine-based remembering strategies could also enhance wider behaviour change interventions and this type of support could not only be delivered by smartphone apps, but also adapted to other types of digital interventions.

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Appendix A

Oral contraception survey

Introduction

Thank you for your interest in my survey. I am a PhD student at UCL Interaction Centre and my research focuses on understanding how people remember their medication and in what circumstances they forget. If you are a woman who currently takes contraceptive pills, please take this short (approx. 6 minutes) survey. Questions explore pill taking routines, the use of technology and memory aids, and general remembering of everyday situations.

Participation in this survey is voluntary and you should participate only if you want to. You are free to close the survey at any time. If you decide to complete the survey, you can enter the £25 Amazon voucher raffle by leaving your email address at the end. Your email will be kept separately from your survey responses.

This research is conducted by Katarzyna Stawarz (katarzyna.stawarz.10@ucl.ac.uk) and supervised by Dr. Anna L. Cox (anna.cox@ucl.ac.uk). It has been approved by UCL Ethics Committee, project ID: Staff/1213/005. All data will be collected and stored in accordance with the Data Protection Act 1998.

Contraceptive pills and the daily routine

1. How long have you been taking contraceptive pills?
   (a) Less than a year
   (b) 1-2 years
   (c) 3-5 years
   (d) 6-10 years
   (e) More than 10 years
2. What type of a contraceptive pill do you take?

   (a) Every day for 21 days and then 7 days break; all pills are the same
   (b) Every day for 21 days and then 7 days break; different amounts of hormones, so pills need to be taken in the right order
   (c) Every day for 28 days, no breaks; all pills are the same
   (d) Every day for 28 days, no breaks; different amounts of hormones, so pills need to be taken in the right order
   (e) I don't know / I don't remember
   (f) Other

3. Ideally, contraceptive pills should be taken at the same time every day. However, different types of pills allow you to be late a few hours without reducing the effectiveness of the pills. How late can you be with your pills without having to worry about using additional protection?
   (a) Up to 3 hours
   (b) Up to 12 hours
   (c) I don't know
   (d) Other

4. When do you take your pills?
   (a) In the morning when I wake up
   (b) In the morning at a set time
   (c) With breakfast
   (d) In the evening at a set time
   (e) With dinner
   (f) Before going to sleep
   (g) Other

5. Where do you keep your contraceptive pills?
   (a) By my bed
   (b) In my handbag
   (c) In the bathroom
   (d) In the kitchen
   (e) Other

6. How many times in the last week did you completely forget to take your pill?
   (a) None
   (b) Once
   (c) Twice
   (d) 3-4 times
   (e) 5 times or more

7. How many times in the last month (including last week) did you completely forget to take your pill?
   (a) None

(b) Once

(c) Twice

(d) 3-4 times

(e) 5 times or more

8. Generally speaking, how often do you completely forget to take your pill?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

9. How many times in the last week were you late taking your pill?

(a) None

(b) Once

(c) Twice

(d) 3-4 times

(e) 5 times or more

10. How many times in the last month (including last week) were you late taking your pill?

(a) None

(b) Once

(c) Twice

(d) 3-4 times

(e) 5 times or more

11. Generally speaking, how often are you late taking your pill?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

12. When you forget to take your pill on time, what's usually the cause? *Select all that apply*

(a) Simply forgot

(b) Was busy / distracted

(c) Missed reminder (e.g. on the phone)

(d) Change in my daily routine

(e) Traveling

(f) Time zone differences

(g) Other

13. How useful do you find the days of the week printed on the packaging?

   (a) Very useful
   (b) Useful
   (c) Neutral
   (d) Useless / I don't pay attention
   (e) My pills don't have days printed on the packaging

14. Most people's daily routines differ between weekdays and weekends, which may have ain impact on remembering about contraceptive pills. Please select the sentence that best describes your situation:
   (a) It's more difficult to remember about my pill on weekdays
   (b) It's more difficult to remember about my pill over the weekends
   (c) There is no difference between weekdays and weekends
15. What do you use to help you remember to take your pills on time? *Select all that apply*
   (a) I just try to remember
   (b) Smartphone app – dedicated medicine reminder
   (c) Smartphone app – generic reminder app
   (d) Smartphone's alarm clock
   (e) A pill organiser
   (f) It's a part of my daily routine
   (g) Other
16. *(If uses an app)* What is the name of the app?
17. *(If uses an app)* To what extent do you agree with this statement: "I wouldn't be able to remember my pill without this app"?
   (a) Strongly agree
   (b) Agree
   (c) Neither agree or disagree
   (d) Disagree
   (e) Strongly disagree
18. Is there anything else you would like to add about remembering your pill?

General memory questions

1. How often do you decide to do something in a few minutes' time and then forget to do it?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never

2. How often do you fail to recognise a place you have visited before?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
3. How often do you fail to do something you were supposed to do a few minutes later even though it's there in front of you, like take a pill or turn off the kettle?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
4. How often do you forget something that you were told a few minutes before?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
5. How often do you forget appointments if you are not prompted by someone else or by a reminder such as a calendar or diary?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
6. How often do you fail to recognise a character in a radio or television show from scene to scene?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
7. How often do you forget to buy something you planned to buy, like a birthday card, even when you see the shop?
   (a) Very often
   (b) Quite often
   (c) Sometimes

(d) Rarely

(e) Never

8. How often do you fail to recall things that have happened to you in the last few days?

   (a) Very often

   (b) Quite often

   (c) Sometimes

   (d) Rarely

   (e) Never

9. How often do you repeat the same story to the same person on different occasions?

   (a) Very often

   (b) Quite often

   (c) Sometimes

   (d) Rarely

   (e) Never

10. How often do you intend to take something with you, before leaving a room or going out, but minutes later leave it behind, even though it's there in front of you?

    (a) Very often

    (b) Quite often

    (c) Sometimes

    (d) Rarely

    (e) Never

11. How often do you mislay something that you have just put down, like a magazine or glasses?

    (a) Very often

    (b) Quite often

    (c) Sometimes

    (d) Rarely

    (e) Never

12. How often do you fail to mention or give something to a visitor that you were asked to pass on?

    (a) Very often

    (b) Quite often

    (c) Sometimes

    (d) Rarely

    (e) Never

13. How often do you look at something without realising you have seen it moments before?

    (a) Very often

    (b) Quite often

    (c) Sometimes

(d) Rarely

(e) Never

14. Try to contact a friend or relative and – when it turns out they are out – forget to try again later?

(a) Very often

(b) Quite often

(c) Sometimes

(d) Rarely

(e) Never

15. How often do you forget what you watched on television the previous day?

(a) Very often

(b) Quite often

(c) Sometimes

(d) Rarely

(e) Never

16. How often do you forget to tell someone something you had meant to mention a few minutes ago?

(a) Very often

(b) Quite often

(c) Sometimes

(d) Rarely

(e) Never

Demographics

1. What is your age?

(a) Under 18 years old

(b) 18-25 years old

(c) 26-35 years old

(d) 36-40 years old

(e) Over 40 years old

2. What is your marital status?

(a) Single

(b) Seeing someone

(c) Cohabiting

(d) Civil partnership / Married

(e) Other / Prefer not to say

3. How many children do you have?

   (a) 0
   (b) 1
   (c) 2
   (d) 3
   (e) More than 3

4. What best describes the highest level of education you have achieved?
   (a) None / Primary education
   (b) Secondary education (GSCEs/O-Levels equivalent)
   (c) College education (A/AS Levels or equivalent)
   (d) University degree (BSc/BA)
   (e) Postgraduate degree (e.g. MSc, MA, PG Cert, PhD)
   (f) Other
5. What best describes your occupation?
   (a) Student
   (b) Part-time worker
   (c) Full-time worker
   (d) Self-employed
   (e) Unemployed
6. On a scale from 1 ("completely relaxing and stress-free") to 9 ("hectic and stressful"), how busy would you say your life is?

Finishing questions

1. We may have a few follow-up questions based on your responses. In case there is anything we would like to clarify with you, would you be willing to answer a few questions via email?
   (a) Yes
   (b) No
2. Would you like to be included in the £25 Amazon voucher raffle?
   (a) Yes
   (b) No

Appendix B

Children's antibiotics survey

Introduction

Thank you for your interest in my survey. I am a PhD student at UCL Interaction Centre and my research focuses on understanding how people remember their medication and in what circumstances they forget. If you are a parent or a carer whose child took antibiotics at home either recently or within the past couple of years, please take this short (approx. 6 minutes) survey. Questions explore pill taking routines, the use of technology and memory aids, and general remembering of everyday situations.

Participation in this survey is voluntary and you should participate only if you want to. You are free to close the survey at any time. If you decide to complete the survey, you can enter the £25 Amazon voucher raffle by leaving your email address at the end. Your email will be kept separately from your survey responses.

This research is conducted by Katarzyna Stawarz (katarzyna.stawarz.10@ucl.ac.uk) and supervised by Dr. Anna L. Cox (anna.cox@ucl.ac.uk). It has been approved by UCL Ethics Committee, project ID: Staff/1213/005. All data will be collected and stored in accordance with the Data Protection Act 1998.

Antibiotics and the daily routine

1. How many children do you have?
   (a) 1
   (b) 2
   (c) 3
   (d) More than 3
2. When was the last time your child was on antibiotics?
   (a) Within the last 4 weeks

   (b) 1-3 months ago

   (c) 4-6 months ago

   (d) Over 6 months ago

3. How old was your child then?

   (a) Under a year old

   (b) 1-3 years old

   (c) 4-6 years old

   (d) 7-10 years old

   (e) 11-15 years old

   (f) Over 15 years old

4. Last time your child was on antibiotics, how many doses per day were required?

   (a) 2 doses per day / A dose every 12 hours

   (b) 3 doses per day / A dose every 8 hours

   (c) 4 doses per day / A dose every 6 hours

   (d) Other

5. Who is responsible for giving the antibiotics to your child? *Select all that apply.*

   (a) Me

   (b) My partner

   (c) Other family members

   (d) Nursery worker / Teacher

   (e) Nanny / Babysitter

   (f) Other

6. Was your child in any way involved in remembering about the antibiotics?

   (a) No

   (b) Asked when was the next time to take the medication

   (c) Reminded me when it was time to take the medication

   (d) Reminded me when I forgot about the medication

   (e) Other

7. Last time your child was on antibiotics, where did you keep your medication?

   (a) In the kitchen (hidden from sight, e.g. in the fridge)

   (b) In the kitchen (visible)

   (c) In the bathroom (hidden from sight, e.g. in the cabinet)

   (d) In the bathroom (visible)

   (e) In my child's room

   (f) Other

8. It is quite common to forget about antibiotics and give them later than planned. When this happens to you, what is often the cause? *Select all that apply.*

(a) My child always gets antibiotics on time

(b) Distractions / Busy with other things

(c) Missed reminders

(d) Change in our daily routine, e.g. away on holiday

(e) Other

9. Last time your child was on antibiotics, how many times did you forget to give the medication on time?

(a) None

(b) 1-2 times

(c) 3-4 times

(d) 5 or more times

10. Generally speaking, when your child is on antibiotics, how often do you forget give the medicine on time?

(a) Very often

(b) Quite often

(c) Sometimes

(d) Rarely

(e) Never

11. Most people's daily routines differ between weekdays and weekends, which may have an impact on remembering about antibiotics. Please select the sentence that best describes your situation:

(a) It's more difficult to remember about antibiotics on weekdays

(b) It's more difficult to remember about antibiotics over the weekends

(c) There's no difference between weekdays and weekends

12. Please finish the sentence: *Fitting an antibiotics regime in my daily routine is...*

(a) Very Difficult

(b) Difficult

(c) Easy

(d) Very Easy

13. Could you explain why fitting antibiotics into your daily routine is difficult/easy?

14. What do you use to help you remember about your child's antibiotics? *Select all that apply.*

(a) I just try to remember

(b) Smartphone app – dedicated medicine reminder app

(c) Smartphone app – generic reminder app

(d) Smartphone's alarm clock

(e) A written schedule in a visible place, e.g. on a fridge

(f) A pill organiser

(g) It's a part of my daily routine

(h) Other

15. *if uses an app* What is the name of the app?

16. *if uses an app* To what extent do you agree with this statement: "I wouldn't be able to remember my child's antibiotics without this app"?
    (a) Strongly agree
    (b) Agree
    (c) Neither agree or disagree
    (d) Disagree
    (e) Strongly disagree
17. Is there anything else you would like to add about remembering to give antibiotics to your child or situations that make you forget?

General memory questions

1. How often do you decide to do something in a few minutes' time and then forget to do it?
    (a) Very often
    (b) Quite often
    (c) Sometimes
    (d) Rarely
    (e) Never
2. How often do you fail to recognise a place you have visited before?
    (a) Very often
    (b) Quite often
    (c) Sometimes
    (d) Rarely
    (e) Never
3. How often do you fail to do something you were supposed to do a few minutes later even though it's there in front of you, like take a pill or turn off the kettle?
    (a) Very often
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5. How often do you forget appointments if you are not prompted by someone else or by a reminder such as a calendar or diary?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
6. How often do you fail to recognise a character in a radio or television show from scene to scene?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
7. How often do you forget to buy something you planned to buy, like a birthday card, even when you see the shop?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
8. How often do you fail to recall things that have happened to you in the last few days?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
9. How often do you repeat the same story to the same person on different occasions?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
10. How often do you intend to take something with you, before leaving a room or going out, but minutes later leave it behind, even though it's there in front of you?
   (a) Very often
   (b) Quite often
   (c) Sometimes

(d) Rarely

(e) Never

11. How often do you mislay something that you have just put down, like a magazine or glasses?

(a) Very often

(b) Quite often

(c) Sometimes

(d) Rarely

(e) Never

12. How often do you fail to mention or give something to a visitor that you were asked to pass on?

(a) Very often

(b) Quite often

(c) Sometimes

(d) Rarely

(e) Never

13. How often do you look at something without realising you have seen it moments before?

(a) Very often

(b) Quite often

(c) Sometimes

(d) Rarely

(e) Never

14. Try to contact a friend or relative and – when it turns out they are out – forget to try again later?

(a) Very often

(b) Quite often

(c) Sometimes

(d) Rarely

(e) Never

15. How often do you forget what you watched on television the previous day?

(a) Very often

(b) Quite often

(c) Sometimes

(d) Rarely

(e) Never

16. How often do you forget to tell someone something you had meant to mention a few minutes ago?

(a) Very often

(b) Quite often

(c) Sometimes

(d) Rarely

(e) Never

Demographics

1. What is your gender?
   (a) Female
   (b) Male
   (c) Other / Prefer not to say
2. What is your age?
   (a) Under 18 years old
   (b) 18-25 years old
   (c) 26-35 years old
   (d) 36-45 years old
   (e) 46-55 years old
   (f) 55 years or more
3. What best describes the highest level of education you have achieved?
   (a) None / Primary education
   (b) Secondary education (GSCEs/O-Levels equivalent)
   (c) College education (A/AS Levels or equivalent)
   (d) University degree (BSc/BA)
   (e) Postgraduate degree (e.g. MSc, MA, PG Cert, PhD)
   (f) Other
4. What best describes your occupation?
   (a) Student
   (b) Part-time worker
   (c) Full-time worker
   (d) Self-employed
   (e) Unemployed
5. On a scale from 1 ("completely relaxing and stress-free") to 9 ("hectic and stressful"), how busy would you say your life is?

Finishing questions

1. We may have a few follow-up questions based on your responses. In case there is anything we would like to clarify with you, would you be willing to answer a few questions via email?
   (a) Yes
   (b) No
2. Would you like to be included in the £25 Amazon voucher raffle?
   (a) Yes
   (b) No

Appendix C

Older adults survey (English translation)

General information

1. Age
2. Gender
   (a) Male
   (b) Female
3. Do you work?
   (a) Yes
   (b) No
4. Are you retired?
   (a) Yes
   (b) No
5. Where do you live?
   (a) Alone
   (b) With a spouse
   (c) With children
   (d) With a spouse and children
   (e) In a care home
6. What medical conditions do you have? *Select all that apply*
   (a) Cancer
   (b) Hypertension
   (c) High cholesterol
   (d) Arthritis

(e) Asthma

(f) Diabetes

(g) Other

General questions about medications

1. How many times per day do you take medications?
   (a) 1
   (b) 2
   (c) 3
   (d) 4
   (e) Other
2. When do you take your medications? *Select all that apply*
   (a) In the morning, after waking up
   (b) In the morning, at a specific hour
   (c) During breakfast
   (d) After breakfast
   (e) Before lunch
   (f) During lunch
   (g) After lunch
   (h) In the evening, at a specific hour
   (i) During supper
   (j) Before going to sleep
   (k) Other
3. Why do you take your medications at these times? *Select all that apply*
   (a) It is easier to remember
   (b) Doctor told me to take them at this time
   (c) Other
4. Where do you keep your medications? *Select all that apply*
   (a) By my bed
   (b) In the kitchen cabinet
   (c) On the kitchen table
   (d) In the bathroom cabinet
   (e) On the sink in the bathroom
   (f) In my bag or wallet
   (g) Other

5. Why do you keep your medications there?
6. How many times in the past week did you forget to take your medications?
   (a) Never
   (b) Once
   (c) Twice
   (d) 3-4 times
   (e) 5 or more times
7. How many times in the past month (including the past week) did you forget to take your medications?
   (a) Never
   (b) Once
   (c) Twice
   (d) 3-4 times
   (e) 5 or more times
8. Generally speaking, how often do you forget your medications?
   (a) Never
   (b) Seldom
   (c) Sometimes
   (d) Often
   (e) Very often
9. When you forget your medication, what is usually the cause?
   (a) I simply forget
   (b) I'm busy or distracted
   (c) Reminder does not work or I miss it (e.g. my phone)
   (d) There's a change in my daily routine
   (e) I'm travelling
   (f) Other
10. Most people's daily routines differ between weekdays and weekends, which may have an impact on remembering about antibiotics. Please select the sentence that best describes your situation:
    (a) It's more difficult to remember about antibiotics on weekdays
    (b) It's more difficult to remember about antibiotics over the weekends
    (c) There's no difference between weekdays and weekends
11. What do you use to help you remember your medications?

General memory questions

1. How often do you decide to do something in a few minutes' time and then forget to do it?

   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never

2. How often do you fail to recognise a place you have visited before?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never

3. How often do you fail to do something you were supposed to do a few minutes later even though it's there in front of you, like take a pill or turn off the kettle?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never

4. How often do you forget something that you were told a few minutes before?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never

5. How often do you forget appointments if you are not prompted by someone else or by a reminder such as a calendar or diary?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never

6. How often do you fail to recognise a character in a radio or television show from scene to scene?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never

7. How often do you forget to buy something you planned to buy, like a birthday card, even when you see the shop?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
8. How often do you fail to recall things that have happened to you in the last few days?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
9. How often do you repeat the same story to the same person on different occasions?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
10. How often do you intend to take something with you, before leaving a room or going out, but minutes later leave it behind, even though it's there in front of you?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
11. How often do you mislay something that you have just put down, like a magazine or glasses?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely
   (e) Never
12. How often do you fail to mention or give something to a visitor that you were asked to pass on?
   (a) Very often
   (b) Quite often
   (c) Sometimes
   (d) Rarely

(e) Never

13. How often do you look at something without realising you have seen it moments before?

    (a) Very often

    (b) Quite often

    (c) Sometimes

    (d) Rarely

    (e) Never

14. Try to contact a friend or relative and – when it turns out they are out – forget to try again later?

    (a) Very often

    (b) Quite often

    (c) Sometimes

    (d) Rarely

    (e) Never

15. How often do you forget what you watched on television the previous day?

    (a) Very often

    (b) Quite often

    (c) Sometimes

    (d) Rarely

    (e) Never

16. How often do you forget to tell someone something you had meant to mention a few minutes ago?

    (a) Very often

    (b) Quite often

    (c) Sometimes

    (d) Rarely

    (e) Never

Appendix D

App reviews

List of apps included in user reviews analysis

#	Simple medication reminders	Advanced medication reminders	Personal medication management apps	Family medication management apps
1	PillReminder	MediSafe Medication Reminder	Medication Reminder	Med Helper – Prescription App
2	Birth Control	Med Minder – Free	eMedsMate	Med Helper Pro
3	Get Pills	Any Time Pill Reminder	Your Medicine 1-2-3 free	Rx Care Minder
4	Pillbox Alert	Pills On The Go – Free	OnTime Rx Full	RX Pal Family Pill Minder Free
5	Pill Reminder	Dosecast – Medication Reminder	Rx Medicine Reminder	Visual Pill Reminders
6	RememberMe – pill alarm clock	Med Reminder – Pill Reminder	Medi Droid	My PillBox (Pill reminder)
7	Medicine Reminder Lite	Pill Reminder	Prescription Manager Free	My Meds
8	Medicine Reminder Free	Lady Pill Reminder	Med On Time Lite	Pill App
9	Pill Reminder	RxTime Pill Reminder	Your Medicine 1-2-3 pro	Zibdy Health
10	Exynos Medication Reminder	MyOC	Medi Alert	RX Pal Family Pill Reminder

NB. Google Play store allows apps to have the same name.

Table D.1: List of apps included in the analysis of user reviews.

List of categories identified during apps reviews analysis

Category	Theme	Review's content codes
Better usability and user experience	Ease of use / user experience	Barcode scanner, dosage info, calendar view, medication library, scanning, 24 hour clock, medication info
	Look & feel	Nicer UI, customisable looks, nicer graphics, better icon
Data management options	Data management	Backup regimen information and medication history, save to an SD card, sync with other devices, export data, password protection
Medication management and tracking options	Health management	User's health information, doctor's and pharmacy details, insurance number, multiple users support, drug interactions, overdosing protection
	Medication management	Refill reminders, inventory tracking
	Medication logging	Medication history, ability to add ad-hoc medication, charts, missed doses statistics, manually add medication
More customisation	Customisation	Customisable alerts, flexible scheduling, user notes, distinguishable medication types, medication photos
Flexible and customisable reminders	Reminders	Flexible reminders, snooze, ability to contact others, SMS alerts, print schedule, medication free periods, groups of reminders

Table D.2: Categories and themes identified during the analysis of reviews including feature requests.

Category	Theme	Review's content codes
Good reminders	Reminders	Reliable, alternative types of reminders (e.g. SMS, email), notifications for other people, good sounds, smart grouping of multiple reminders
Good medication management	Flexible tool	Multiple medication support, ad-hoc medication tracking, medication photos, retroactive logging, snooze, time zone support, user notes, overdosing protection
	Medication history	Medication log, missed doses & adherence stats, medication taking instructions, printing & sharing regimen information
	Inventory tracking	Refill reminders, prescription tracking
Good level of customisation	Customisation	Flexible reminder scheduling, customisable reminders
Positive experience	Good usability and user experience	Simple, reliable, works well, useful, indispensable, helpful, easy to use & set up, good design, good customer support
Good health management support	Health management	Medication info, drugs database, pharmacy and doctor's details, patient information

Table D.3: Categories and themes identified during the analysis of reviews including positive functionality comments.

Category	Theme	Review's content codes
Problems with reminders	General issues	Not reliable, confusing to set up, no snooze
	Sound issues	No sound or sound too loud, lack of control
Lack of customisation	Lack of customisation	No way to customise alerts (type, frequency, etc.), cannot edit medication history or regimen entries
Limited functionality	Limited functionality	Limited number of medication supported, reminder scheduling is not flexible enough, problems with time zones and daylight saving time, too basic, missing features (e.g. no medication log)
Negative user experience	App doesn't work	Update has broken the app, the app doesn't work on some devices, app crashes or freezes
	Bugs	Existing features don't work (e.g. not able to mark medication as taken), loses data (e.g. dismissing a reminder deletes it completely)
	Bad user experience and usability issues	Annoying ads, slow, confusing, difficult to use, not reliable, drains battery

Table D.4: Categories and themes identified during the analysis of reviews including negative functionality comments.

Appendix E

Habit formation study materials

Recruitment questionnaire

Lunch patterns study

Would you like to eat more vegetables? Or perhaps you are thinking of losing weight? Research shows that one of the best ways towards changing behaviour is understanding what exactly needs to change – and it can be done simply by paying attention to what you eat. Even though having a varied diet can make it easier to stay healthy, we all develop eating patterns and eat the same things regularly, even when they are not good for us.

Are you aware of your eating patterns? Have you noticed any trends in your behaviour? Some people tend to have fish & chips for lunch on Fridays and eat roasts on Sundays. Others eat pizza on Thursdays and bring homemade vegetable curry on Tuesdays. Would you like to find out if there are any patterns in your eating behaviour?

We are recruiting participants for a study exploring people's lunch eating patterns. The study starts on the 18th of November and lasts 4 weeks. All you need to do is send us a daily text message describing briefly what you had for lunch.

All participants who complete the study will receive £5 Amazon vouchers in recognition of their text messaging costs and also will be entered into a raffle to win one of five £25 Amazon gift vouchers. In addition, we will provide a summary of all lunches to help you better understand your eating habits.

Requirements

- In order to participate in the study, you must fulfil the following requirements:
- Own and use a mobile phone (it doesn't have to be a smartphone)
- Live in the UK
- Eat lunch every day
- Don't have any trips abroad planned until the 15th of December

- Be aged 18 or over

The study The study lasts 4 weeks. All participants will be required to send a text message to the researchers every day, briefly describing when they had lunch that day and what they ate – this should take no more than 1-2 minutes each day. At the end of each week, participants will receive a summary of their weekly meals. After 4 weeks, all participants will be asked to complete an online questionnaire and those who submit their responses and officially complete the whole study will be entered into the raffle and will receive their vouchers.

If you match the study requirements and wish to participate, please tick the box below and go the next page where you will be able to provide your details and answer a few questions.

This research is conducted by Katarzyna Stawarz (kstawarz@cs.ucl.ac.uk) and supervised by Dr. Anna L. Cox (anna.cox@ucl.ac.uk). It has been approved by UCL Ethics Committee, project ID: Staff/1213/005. All data will be collected and stored in accordance with the Data Protection Act 1998.

- I agree to participate in the study and I understand that I am free to withdraw from the study at any point.

Please provide your details and answer all questions below.

1. Name
2. E-mail address. *Will be used only for communication during the study*
3. Mobile phone number. *Will be used to combine your text messages with the final questionnaire*
4. Age
5. Gender
   (a) Female
   (b) Male
   (c) Other / Prefer not to say
6. What best describes your occupation?
   (a) Student
   (b) Part-time worker
   (c) Full-time worker
   (d) Self-employed
   (e) Unemployed
7. Do you live in the UK?
   (a) Yes
   (b) No
8. Do you have a mobile phone with a UK number?
   (a) Yes
   (b) No
9. Do you eat lunch every day?
   (a) Yes

(b) No

10. The study will start on the 18th of November and will run until the 15th of December. Do you have any trips abroad planned for this period?
    (a) Yes
    (b) No
11. What time do you usually eat lunch on weekdays? *E.g. 12:00, 1pm, 12-14, 12-3pm*
12. What time do you usually eat lunch on weekends? *E.g. 12:00, 1pm, 12-14, 12-3pm*

All participants who fully participate in the study will be entered into a raffle with a chance to win one of five £25 Amazon vouchers. They will also receive a complimentary £5 voucher in recognition of text messaging costs and a summary of their lunch reports.

Full participation means sending text messages during all 4 weeks and completing the final questionnaire.

I understand that if I drop out from the study and stop sending text messages OR will not send at least a few text messages each week OR will not complete the final questionnaire I WILL NOT be entitled to any of the rewards, i.e. I will not receive the voucher and I will not be entered into the raffle.

Study instructions

Basic instructions – Control and N&PR group

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 4 weeks is simple: text me what time you had lunch each day and what you ate. I will send another email on Monday morning to remind you about the study.

Your lunch reports should be simple and should include the time of your lunch. Below are a few examples. Please stick to this format (time - lunch description):

12:30 - pea soup with bread

1pm - fish & chips

1.15pm - vegetarian curry with rice

12:15 - beef burger with fries

12.45 - tuna sandwich, crisps, banana

13:30 - biscuits and a chocolate bar

Make sure you include the time you had lunch and provide a brief description of what you ate. Remember: we're looking at general patterns, so the food description doesn't have to be detailed.

This is the number we have for you: +44XXXXXXXXXX -– it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, please let me know as soon as possible.

Please save this number: +44XXXXXXXXXX. This is a special number for this study, so please only use it for sending in your lunch reports. It is a local mobile number, so don't worry – your normal text prices apply.

Use this number to send your lunch reports only! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting a few lunches is fine (we all forget!) as long as it doesn't happen too often. Even if you're very late remembering to text me (e.g. in the evening, the next morning), send it anyway. If for some reason you end up not eating lunch at all, text me as well – "no lunch" or "nothing" will do.

If you end up eating multiple meals near lunchtime (e.g. you were hungry and started snacking early), please report the thing you consider to be your lunch. Similarly, weekend meals can be a bit ambiguous so report only the one you eat around your usual weekend lunch time (even if it's a really late breakfast or a very early dinner!).

At the end of each week we will send you a summary of your weekly lunches.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Trigger event instructions – Trigger and T&PR group

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 4 weeks is simple: every day, right after lunch, text me what time you started to eat and what you ate. I will send another email on Monday morning to remind you about the study.

Your lunch reports should be simple and should include the time of your lunch. Below are a few examples. Please stick to this format (time - lunch description):

12:30 - pea soup with bread

1pm - fish & chips

1.15pm - vegetarian curry with rice

12:15 - beef burger with fries

12.45 - tuna sandwich, crisps, banana

13:30 - biscuits and a chocolate bar

Make sure you include the time you had lunch, provide a brief description of what you ate, and that you send the text right after you finished eating. Think of your last bite as a sign it's time to send your lunch report. So: first lunch, then a text message :-) Remember: we're looking at general patterns, so the food description doesn't have to be detailed.

This is the number we have for you: +44XXXXXXXXXX – it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, please let me know as soon as possible.

Please save this number: +44XXXXXXXXXX. This is a special number for this study, so please only use it for sending in your lunch reports. It is a local mobile number, so don't worry – your normal text prices apply.

Use this number to send your lunch reports only! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting a few lunches is fine (we all forget!) as long as it doesn't happen too often. Even if you're very late remembering to text me (e.g. in the evening, the next morning), send it anyway. If for some reason you end up not eating lunch at all, text me as well – "no lunch" or "nothing" will do.

If you end up eating multiple meals near lunchtime (e.g. you were hungry and started snacking early), please report the thing you consider to be your lunch. Similarly, weekend meals can be a bit ambiguous so report only the one you eat around your usual weekend lunch time (even if it's a really late breakfast or a very early dinner!).

Remember: first lunch, then – right after the last mouthful – send me the text. Think of your lunch as a sign it's time to text me.

At the end of each week we will send you a summary of your weekly lunches.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Reminder instructions – Reminder and R&PR group

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 4 weeks is simple: every day in the afternoon you will receive a text message reminder to which you will have to respond straight away and let me know what time you had lunch that day and what you ate. I will send you another email on Monday morning to remind you about the study.

Your lunch reports should be simple and should include the time of your lunch. Below are a few examples. Please stick to this format (time - lunch description):

12:30 - pea soup with bread

1pm - fish & chips

1.15pm - vegetarian curry with rice

12:15 - beef burger with fries

12.45 - tuna sandwich, crisps, banana

13:30 - biscuits and a chocolate bar

Make sure you include the time you had lunch and provide a brief description of what you ate, and that you respond as soon as you get the reminder. Remember: we're looking at general patterns, so the food description doesn't have to be detailed.

This is the number we have for you: +44XXXXXXXXXX – it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, please let me know as soon as possible.

Please save this number: +44XXXXXXXXXX. This is a special number for this study, so please only use it for sending in your lunch reports. It is a local mobile number, so don't worry – your normal text prices apply.

Use this number to send your lunch reports only! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting a few lunches is fine (we all forget!) as long as it doesn't happen too often. Even if you're very late remembering to text me (e.g. in the evening, the next morning), send it anyway. If for some reason you end up not eating lunch at all, text me as well – "no lunch" or "nothing" will do.

If you end up eating multiple meals near lunchtime (e.g. you were hungry and started snacking early), please report the thing you consider to be your lunch. Similarly, weekend meals can be a bit ambiguous so report only the one you eat around your usual weekend lunch time (even if it's a really late breakfast or a very early dinner!).

At the end of each week we will send you a summary of your weekly lunches.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Final questionnaire

Thank you for your participation so far! This questionnaire is the last step in the study. Please answer all questions.

1. Please enter your phone number so we can combine your text messages with your answers
2. Please confirm your email address
3. How did you remember to send the lunch report each day?
4. How easy or difficult did you find remembering to send lunch reports every day?
   (a) Very easy
   (b) Somewhat easy
   (c) Somewhat difficult
   (d) Very difficult
5. Please explain why
6. Was there a situation when you made a conscious decision NOT to send a lunch report at all?
   (a) No
   (b) Yes
7. If yes, please explain why and often it happened

   For questions below, please indicate to what extent you agree or disagree with each statement.

   Over the past 4 weeks. . .
8. Sending lunch reports was something I did frequently.
   (a) Strongly Agree
   (b) Agree
   (c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

9. Sending lunch reports was something I did automatically.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

10. I did not have to consciously remember to send lunch reports.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

11. I would have felt weird if I did not send a lunch report every day.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

12. Sending lunch reports was something I did without thinking.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

13. Sending lunch reports did not require any effort.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

14. Sending lunch reports was a part of my daily routine.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

15. Sending lunch reports was something I would start doing before realising I was doing it.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

16. I would have found it hard not to send lunch reports every day.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

17. I didn't need to think about sending lunch reports every day.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

18. Sending daily lunch reports felt like something that's typically "me".

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

19. It felt like I have been sending lunch reports for a long time.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

20. Do you have any other comments?

Debrief email

Hi [participant's name],

Thank you very much for your participation, it was incredibly useful! Here is your £5 Amazon voucher, it's valid until 2023:

XXXX-XXXX-XXXX-XXXX

You can find your monthly lunch summary here:

http://usabilitypanda.com/lunchreports/XXXXXX.pdf

Hopefully it will help you identify your eating patterns.

The first step in understanding our eating habits is identifying own patterns, both good and bad, and learning to pay attention to what we actually eat. Please read this for more information on healthy diet and compare it with your own lunch data: http://www.nutrition.org.uk/healthyliving/healthyeating/a-healthy-varied-diet

Apart from helping you to identify your own eating patterns, we were interested in understanding how people form new habits. In this case, the new habit was texting us every day to report lunch – hence the questions about texting in the final questionnaire. However, studying how people develop new routines is difficult because if we

tell them that is what we are doing, it may (and most likely will) influence their behaviour, so we had to keep quiet about that.

Now the study is complete we are able to tell you everything we were interested in. We had 6 groups of participants and systematically manipulated:

- how much detail we gave them in the instructions about when to send us a text,
- whether they received a reminder text from us, and
- what kind of response (if any) we gave them after they sent the message.

If you're interested in knowing more about the method we're testing watch this TED talk: https://www.youtube.com/watch?v=AdKUJxjn-R8 and if you want to test it yourself and try to develop a new habit (whatever it might be), follow this link: http://tinyhabits.com/

We are looking forward to analysing the data and finding out how our instructions to participants influenced how well they developed the routine of texting us each day, how often they forgot, and how many still texted us after the study finished.

Once again thank you for your help!

PS. Raffle winners will receive a separate email.

Example lunch summary participants received at the end of the study

See next page

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1	rice noodles with vegetables, and sliced vegetables topped with Vietnamese salad dressing + nestle walnut whip	sandwich with cheese and smoked salmon, medium sized mocha, booked carrot sticks + mini brownie	boiled carrot sticks with roasted Aubergine spread + matcha and soy latte	2 baked corn fritters and a pear + salmon and cheese sandwich with half a slice of carrot cake	a conference pear, a box of dried fruits, a Granny Smith apple + a small bowl of fried rice	2 conference pears + fried rice with salmon, persimmon	cappuccino + Phad Thai + white chocolate macaroon
Week 2	boiled carrot sticks Turkey and cheese sandwich	roasted vegetable, mushroom, avacado and hummus sandwich + 2 starburst fruit chews	fruit and nut flapjack + cappuccino	1 falafel + a slice of dark cherry and ricotta cheesecake + 4 baby peaches and a slice of banana bread	cappuccino + hummus, roast veg and avacado sandwich + half a chocolate bar	apple cinnamon latte	Black soybean milk + chocolate and walnut ben's cookie
Week 3	venti skinny caramel macchiato, wine gums, graze whole meal shortbread with summer berry compote	grain breakfast biscuits + time out chocolate bar	pitta bread with red pepper hummus and salad + mocha	Bonnie wee oat bakes with onion marmalade, glutinous rice balls with peanut filling, banana, and a half slice of peach an apple crumble	toblerone chocolate bar, green apple, roasted vegetable and cream cheese sandwich	Roasted vegetable with cheese and hummus crepe	graze poppy seed pretzels with chocolate sauce, graze lightly sweetened popcorn
Week 4	steak fajita + apple and 2 chocolates	mcvities porridge oats biscuits + tall caramel macchiato + green apple	matcha soy latte + muller corner Greek style yoghurt with cherry compote	1 falafel and a cube of laughing cow cheese	Seafood pasta with muiller apple rice pudding and 2 laughing cow cheeses	No data	No data

Table E.1: Example lunch summary participants received at the end of the study.

Appendix F

Habit formation follow-up materials

Recruitment questionnaire

Healthy habits study

Would you like to develop a new healthy habit? Perhaps you'd like to drink more water or start meditating? We can help you with that! We are recruiting participants for a study exploring how people develop these types of healthy habits.

During the study we will give you a chance to develop one of two healthy habits: drinking more water or meditating. Both these activities are associated with improved overall wellbeing and can be quite easily fitted into your daily schedule. To change a behaviour, it's always good to start small, so all we ask of you is to have a glass of water or focus on your breathing for a few seconds every day.

The study will run for 12 weeks. All you need to do is choose whether you would prefer to have a glass of water or pay attention to your breathing for a few seconds, and then repeat this every day, making sure to send us a text to report you did it. All participants who complete the study will be entered into a raffle to win one of three £50 or one of three £25 Amazon vouchers. And, of course, you will have a chance to develop a new healthy habit!

Requirements

In order to participate in the study, you must fulfil the following requirements:

- Use a mobile phone with a UK number (it doesn't have to be a smartphone)
- Use one of the mainstream mobile operators (Vodaphone, O2, giffgaff, EE, Three, T-Mobile, Orange, Virgin Media)
- Be aged 18 or over
- Be willing to send at least 4 text messages per week for 12 weeks

If you would like to participate, but have holidays planned or are thinking of going away between now and August – don't worry! As long as you're able to text us every day (or at least 4 times per week), you can join the study.

The study

The study starts in May and will run for 12 weeks. Participants will be required to do their selected task (drinking water or meditating) every day and send us a text right after they finish, stating at what time they did it. We will send you detailed instructions before the study starts, including what kind of information should be included in your SMS reports. It shouldn't take more than 1-2 minutes every day. At the end of the study, all participants will be asked to complete an online questionnaire and those who submit their responses, and therefore complete the whole study, will be entered into the raffle.

Raffle

The raffle will take place at the end of the study. All active participants who will complete the study and fill in the final questionnaire, will have a chance to win one of six Amazon vouchers worth £50 or £25 each. Active participants will have their name added to the raffle list every 4 weeks, so they will have a higher chance to win in the end.

How do I sign up?

If you meet study requirements and wish to participate, please tick the box below and go to the next page where you will be able to provide your details and answer a few questions. Once we have enough participants, we will send you detailed study instructions.

This research is conducted by Katarzyna Stawarz (kstawarz@cs.ucl.ac.uk) and supervised by Dr. Anna L. Cox (anna.cox@ucl.ac.uk) and Prof. Ann Blandford (a.blandford@ucl.ac.uk). It has been approved by UCL Ethics Committee, project ID: Staff/1213/005. All data will be collected and stored in accordance with the Data Protection Act 1998.

- I agree to participate in the study and I understand that I am free to withdraw from the study at any point.

Please provide your details and answer all questions below.

1. Which habit would you like to develop?
   (a) Drinking more water
   (b) Meditating
2. Name
3. E-mail address. *Will be used only for communication during the study.*
4. Mobile phone number. *Will be used to combine your text messages with the final questionnaire.*
5. Age
6. Gender
   (a) Female
   (b) Male
   (c) Other / Prefer not to say
7. What best describes your occupation?
   (a) Student
   (b) Part-time worker

(c) Full-time worker

(d) Self-employed

(e) Unemployed

(f) Retired

8. Do you live in the UK?

   (a) Yes

   (b) No

9. Do you have a mobile phone with a UK number?

   (a) Yes

   (b) No

10. Who is your mobile operator? *If your operator is not on the list, you won't be able to participate in the study. Sorry.*

    (a) EE

    (b) giffgaff

    (c) O2

    (d) Orange

    (e) T-Mobile

    (f) Three

    (g) Virgin Media

    (h) Vodafone

11. Are you planning to be on holidays between now and the end of July?

    (a) Yes

    (b) Possibly

    (c) No

12. If you do have holidays planned or are thinking of going away, please let us know when it might happen. *It's just for information only, so if you don't know yet if you're going on holiday, that's fine. You can still participate in the study as long as you keep sending us daily text messages.*

All participants who fully participate in the study will be entered into a raffle with a chance to win one of three £50 Amazon vouchers or one of three £25 Amazon vouchers.

Full participation means sending at least 4 text messages each week for 12 weeks and completing the final questionnaire.

I understand that if I

- drop out from the study and stop sending text messages OR
- will not send at least a four text messages each week OR
- will not complete the final questionnaire

I WILL NOT be entitled to any of the rewards, i.e. I will not be entered into the raffle.

- I understand.

Study instructions

Basic instructions – Control and N&PR group

Meditating

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 12 weeks is simple: close your eyes and focus on your breath once every day and text me when you do it. Just be aware of your breath and how your belly expands with each inhalation. Doing it just for a few seconds is fine – it's best to start a new habit small. Remember: tiny steps! Don't force yourself too much and try to do just the bare minimum. More often than not, once you start, you will meditate for longer anyway!

Your reports should be simple: just text me the time you focused on your breath. Here are some examples:

10:00

9:23 – done!

18:34 – did my short meditation

Just time alone is fine. Please stick to this format: XX:XX and if you want to add any comments, please put them after a dash (XX:XX – your message).

This is the number we have for you: +XXXXXXXXXXXX – it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, let me know as soon as possible.

Save this number: +XXXXXXXXXXXX. This is a special number for this study, so please only use it for sending in your reports.

Use this number to SEND YOUR MEDITATION REPORTS ONLY! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting to send a few reports is fine (we all forget!) as long as it doesn't happen too often. Even if you're very late remembering to text me (e.g. the next morning), send it anyway. If you decide to focus on your breath and meditate more than once per day, please report only the first time you do it.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Drinking water

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 12 weeks is simple: drink a glass of water once every day and text me when you do it. Your glass doesn't have to be full and you don't have to drink everything – it's best to start a new habit small. Remember: tiny steps! Don't force yourself too much and try to do just the bare minimum. More often than not, once you start, you will drink more anyway!

Your reports should be simple: just text me the time you drank a glass of water. Here are some examples:

10:00

9:23 – done!

18:34 – had my glass of water

Just time alone is fine. Please stick to this format: XX:XX and if you want to add any comments, please put them after a dash (XX:XX – your message).

This is the number we have for you: +XXXXXXXXXXXX – it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, let me know as soon as possible.

Save this number: +XXXXXXXXXXXX. This is a special number for this study, so please only use it for sending in your reports.

Use this number to SEND YOUR WATER-DRINKING REPORTS ONLY! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting to send a few reports is fine (we all forget!) as long as it doesn't happen too often. Even if you're very late remembering to text me (e.g. the next morning), send it anyway. If you decide to drink more than one glass per day, please report only the first time you do it.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Reminder instructions – Reminder and R&PR group

Meditating

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 12 weeks is simple: every day you will receive a text message (at 8am, 2pm or 9pm – please let me know what time is best for you) reminding you to close your eyes and focus on your breath – do it and then text me back to let me know you've done it. Just be aware of your breath and how your belly expands with each inhalation. Doing it just for a few seconds is fine – it's best to start a new habit small. Remember: tiny steps! Don't force yourself too much and try to do just the bare minimum. More often than not, once you start, you will meditate for longer anyway!

Your reports should be simple: just text me the time you focused on your breath. Here are some examples:

10:00

9:23 – done!

18:34 – did my short meditation

Just time alone is fine. Please stick to this format: XX:XX and if you want to add any comments, please put them after a dash (XX:XX – your message).

This is the number we have for you: +XXXXXXXXXXXX – it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, let me know as soon as possible.

Save this number: +XXXXXXXXXXXX. This is a special number for this study, so please only use it for sending in your reports. Your reminders will be coming from this number.

Use this number to SEND YOUR MEDITATION REPORTS ONLY! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting to send a few reports is fine (we all forget!) as long as it doesn't happen too often. Even if you're very late remembering to text me (e.g. in the evening, the next morning), send it anyway. If you decide to focus on your breath and meditate more than once per day, please report only the first time you do it.

Please let me know at what time you want to receive the reminder: 8am, 2pm or 9pm. You can always choose a different reminder time later if it's not working for you.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Drinking water

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 12 weeks is simple: every day you will receive a text message (at 8am, 2pm or 9pm – please let me know what time is best for you) reminding you to drink a glass of water – do it and then text me back to let me know you've done it. Your glass doesn't have to be full and you don't have to drink everything – it's best to start a new habit small. Remember: tiny steps! Don't force yourself too much and try to do just the bare minimum. More often than not, once you start, you will drink more anyway!

Your reports should be simple: just text me the time you drank a glass of water. Here are some examples:

10:00

9:23 – done!

18:34 – had my glass of water

Just time alone is fine. Please stick to this format: XX:XX and if you want to add any comments, please put them after a dash (XX:XX – your message).

This is the number we have for you: +XXXXXXXXXXXX – it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, let me know as soon as possible.

Save this number: +XXXXXXXXXXXX. This is a special number for this study, so please only use it for sending in your reports. Your reminders will be coming from this number.

Use this number to SEND YOUR WATER-DRINKING REPORTS ONLY! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting to send a few reports is fine (we all forget!) as long as it doesn't happen too often. Even if you're very late remembering to text me (e.g. in the evening, the next morning), send it anyway. If you decide to drink more than one glass per day, please report only the first time you do it.

Please let me know at what time you want to receive the reminder: 8am, 2pm or 9pm. You can always choose a different reminder time later if it's not working for you.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Trigger event instructions – Trigger and T&PR group

Meditating

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 12 weeks is simple: close your eyes and focus on your breath once every day and text me when you do it. Just be aware of your breath and how your belly expands with each inhalation. Doing it just for a few seconds is fine – it's best to start a new habit small. Remember: tiny steps! Don't force yourself too much and try to do just the bare minimum. More often than not, once you start, you will meditate for longer anyway!

Pick a routine event, something you do every day, e.g. waking up, eating breakfast, taking medication, coming home. Then, close your eyes and focus on your breath every day right after you do that routine thing – this will help you remember and will support the formation of a new habit. Try to use the same event every day and make sure you meditate right after that event. If you decide that the event doesn't work for you for some reason, you can pick another one, but generally try to stick with the same one.

Your SMS reports should be simple: text me the time you focused on your breath and after what routine event. Here are some examples:

10:00 – after breakfast

9:23 – after taking my medication

18:34 – same as yesterday

21:33 – the same event

12:30 – same

Please stick to this format: XX:XX – your message. If you end up using the same event every day, then you can just text me the time and I will assume it was after the same routine event as before.

If you forget to meditate after your chosen routine event, don't worry: do it as soon as you remember, report the time and let me know it was not after the routine event, e.g.

17:45 – just remembered

22:50 – not after the routine event

This is the number we have for you: +XXXXXXXXXXXX – it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, let me know as soon as possible.

Save this number: +XXXXXXXXXXXX. This is a special number for this study, so please only use it for sending in your reports.

Use this number to SEND YOUR MEDITATION REPORTS ONLY! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting to send a few reports is fine (we all forget!) as long as it doesn't happen too often. Even if you're very late remembering to text me (e.g. in the evening, the next morning), send it anyway. If you decide to focus on your breath and meditate more than once per day, please report only the first time you do it.

Remember: attaching a new task to an existing routine helps to turn it into a new habit. So do your regular routine thing of choice first and then meditate right after you finish it. And then text me to let me know you did it.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Drinking water

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 12 weeks is simple: drink a glass of water once every day and text me when you do it. Your glass doesn't have to be full and you don't have to drink everything – it's best to start a new habit small. Remember: tiny steps! Don't force yourself too much and try to do just the bare minimum. More often than not, once you start, you will drink more anyway!

Pick a routine event, something you do every day, e.g. waking up, eating breakfast, taking medication, coming home. Then, drink a glass of water every day right after you do that routine thing – this will help you remember and will support the formation of a new habit. Try to use the same event every day and make sure you drink water right after that event. If you decide that the event doesn't work for you for some reason, you can pick another one, but generally try to stick with the same one.

Your SMS reports should be simple: text me the time you drank a glass of water and after what routine event. Here are some examples:

10:00 – after breakfast

9:23 – after taking my medication

18:34 – same as yesterday

21:33 – the same event

12:30 – same

Please stick to this format: XX:XX – your message. If you end up using the same event every day, then you can just text me the time and I will assume it was after the same routine event as before.

If you forget to drink a glass of water after your chosen routine event, don't worry: do it as soon as you remember, report the time and let me know it was not after the routine event, e.g.

17:45 – just remembered

22:50 – not after the routine event

This is the number we have for you: +XXXXXXXXXXXX – it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, let me know as soon as possible.

Save this number: +XXXXXXXXXXXX. This is a special number for this study, so please only use it for sending in your reports.

Use this number to SEND YOUR WATER-DRINKING REPORTS ONLY! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting to send a few reports is fine (we all forget!) as long as it doesn't happen too often. Even if you're very late remembering to text me (e.g. in the evening, the next morning), send it anyway. If you decide to drink more than one glass per day, please report only the first time you do it.

Remember: attaching a new task to an existing routine helps to turn it into a new habit. So do your regular routine thing of choice first and then drink a glass of water right after you finish it. And then text me to let me know you did it.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Stable context instructions – SC and SC&PR group

Meditating

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 12 weeks is simple: close your eyes and focus on your breath once every day and text me when you do it. Just be aware of your breath and how your belly expands with each inhalation. Doing it just for a few seconds is fine – it's best to start a new habit small. Remember: tiny steps! Don't force yourself too much and try to do just the bare minimum. More often than not, once you start, you will meditate for longer anyway!

Pick a routine event, something you do every day in the same place, e.g. waking up, eating breakfast, taking medication, coming home. Then, every day close your eyes and focus on your breath right after you do that routine thing – this will help you remember and will support the formation of a new habit. Try to use the same

event every day and be in the same place every day, and make sure you meditate right after that event. If you decide that the event or location doesn't work for you for some reason, you can pick another one, but generally try to stick with the same one.

Your SMS reports should be simple: text me the time you focused on your breath, after what routine event and where you were. Here are some examples:

10:00 – after breakfast, kitchen

9:23 – after taking my medication, my bedroom

18:34 – same event, but in my parents' house

21:33 – the same event and location

12:30 – same, same

Please stick to this format: XX:XX – your message. If you end up using the same event and location every time, then you can just text me the time and I will assume it was after the same routine event and it was done in the same place as before.

If you forget to meditate after your chosen routine event, don't worry: do it as soon as you remember, report the time and location, and let me know it was not after the routine event, e.g.

17:45 – just remembered; kitchen

22:50 – not after the routine event; bathroom

This is the number we have for you: +XXXXXXXXXXXX -– it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, let me know as soon as possible.

Save this number: +XXXXXXXXXXXX. This is a special number for this study, so please only use it for sending in your reports.

Use this number to SEND YOUR MEDITATION REPORTS ONLY! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting to send a few reports is fine (we all forget!) as long as it doesn't happen too often. Even if you're very late remembering to text me (e.g. in the evening, the next morning), send it anyway. If you decide to meditate more than once per day, please report only the first time you do it.

If you're travelling or visiting friends or family, don't worry and just try to use a similar location. If that's impossible (e.g. you decided to meditate in the kitchen after morning coffee and you're in a hotel and there's no kitchen), just report where you did it instead.

Attaching a new task to an existing routine and doing it in the same location every day helps to turn it into a new habit. Remember: do your regular routine thing of choice first and then close your eyes and focus on your breath right after you finish it. And then text me to let me know you did it.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Drinking water

Hi [participant's name],

Thanks a lot for agreeing to participate in the study!

Starting on Monday, your task for the next 12 weeks is simple: drink a glass of water once every day and text me when you do it. Your glass doesn't have to be full and you don't have to drink everything – it's best to start a new habit small. Remember: tiny steps! Don't force yourself too much and try to do just the bare minimum. More often than not, once you start, you will drink more anyway!

Pick a routine event, something you do every day in the same place, e.g. waking up, eating breakfast, taking medication, coming home. Then, every day drink a glass of water right after you do that routine thing – this will help you remember and will support the formation of a new habit. Try to use the same event every day and be in the same place every day, and make sure you drink water right after that event. If you decide that the event or location doesn't work for you for some reason, you can pick another one, but generally try to stick with the same one.

Your SMS reports should be simple: text me the time you drank a glass of water, after what routine event and where you were. Here are some examples:

10:00 – after breakfast, kitchen

9:23 – after taking my medication, my bedroom

18:34 – same event, but in my parents' house

21:33 – the same event and location

12:30 – same, same

Please stick to this format: XX:XX – your message. If you end up using the same event and location every time, then you can just text me the time and I will assume it was after the same routine event and it was done in the same place as before.

If you forget to drink a glass of water after your chosen routine event, don't worry: do it as soon as you remember, report the time and location, and let me know it was not after the routine event, e.g.

17:45 – just remembered; kitchen

22:50 – not after the routine event; bathroom

This is the number we have for you: +XXXXXXXXXXXX – it will be used to combine your responses with the final questionnaire. Please check if it's the correct one and if not, let me know as soon as possible.

Save this number: +XXXXXXXXXXXX. This is a special number for this study, so please only use it for sending in your reports.

Use this number to SEND YOUR WATER-DRINKING REPORTS ONLY! If you have any questions or want to clarify something, e.g. if you want to let me know that you forgot to send your text for the previous day, email me instead. Forgetting to send a few reports is fine (we all forget!) as long as it doesn't happen too often. Even

if you're very late remembering to text me (e.g. in the evening, the next morning), send it anyway. If you decide to drink more than one glass per day, please report only the first time you do it.

If you're travelling or visiting friends or family, don't worry and just try to use a similar location. If that's impossible (e.g. you decided to drink water in the kitchen after morning coffee and you're in a hotel and there's no kitchen), just report where you did it instead.

Attaching a new task to an existing routine and doing it in the same location every day helps to turn it into a new habit. Remember: do your regular routine thing of choice first and then drink a glass of water right after you finish it. And then text me to let me know you did it.

If you have any questions, don't hesitate to email me. Hope you enjoy the study!

Examples of weekly emails

Week 2

Hi [participant's name],

Here's your summary of Week 2, based on the messages I've received from you:

- Monday: Done
- Tuesday: Done
- Wednesday: -
- Thursday: Done
- Friday: -
- Saturday: -
- Sunday: Done

Nice! With time it should get easier to remember :-)

Week 7

Hi [participant's name],

We've just finished week 7! Getting closer to the end of the study. Here's your summary for last week based on the messages I've received from you:

- Monday: Done
- Tuesday: Done
- Wednesday: Done
- Thursday: Done

- Friday: Done
- Saturday: Done
- Sunday: Done

Excellent! :-)

Week 10

Hi [participant's name],

We're getting closer to the end of the study! Here's your summary for week 10:

- Monday: -
- Tuesday: -
- Wednesday: Done
- Thursday: -
- Friday: -
- Saturday: Done
- Sunday: -

Week 6 questionnaire

Meditation

1. Please enter your phone number so we can combine your answers with your text messages.

   Thinking of the past 6 weeks, please indicate to what extent you agree or disagree with each statement.

2. Meditating briefly is something I do automatically.
   (a) Strongly Agree
   (b) Agree
   (c) Somewhat Agree
   (d) Neither Agree nor Disagree
   (e) Somewhat Disagree
   (f) Disagree
   (g) Strongly Disagree
3. Meditating briefly is something I do without having to consciously remember.
   (a) Strongly Agree
   (b) Agree
   (c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

4. Meditating briefly is something I do without thinking.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

5. Meditating briefly is something I start doing before I realise I'm doing it.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

6. In the past 6 weeks I have enjoyed meditating very much.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

7. Meditating has been fun to do.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

8. I would describe meditating as very interesting.

(a) Strongly Disagree

(b) Disagree

(c) Neither Agree nor Disagree

(d) Agree

(e) Strongly Agree

Drinking water

1. Please enter your phone number so we can combine your answers with your text messages.

   Thinking of the past 6 weeks, please indicate to what extent you agree or disagree with each statement.

2. Drinking a glass of water is something I do automatically.

   (a) Strongly Agree

   (b) Agree

   (c) Somewhat Agree

   (d) Neither Agree nor Disagree

   (e) Somewhat Disagree

   (f) Disagree

   (g) Strongly Disagree

3. Drinking a glass of water is something I do without having to consciously remember.

   (a) Strongly Agree

   (b) Agree

   (c) Somewhat Agree

   (d) Neither Agree nor Disagree

   (e) Somewhat Disagree

   (f) Disagree

   (g) Strongly Disagree

4. Drinking a glass of water is something I do without thinking.

   (a) Strongly Agree

   (b) Agree

   (c) Somewhat Agree

   (d) Neither Agree nor Disagree

   (e) Somewhat Disagree

   (f) Disagree

   (g) Strongly Disagree

5. Drinking a glass of water is something I start doing before I realise I'm doing it.

   (a) Strongly Agree

   (b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

6. In the past 6 weeks I have enjoyed drinking a glass of water every day very much.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

7. Drinking a glass of water has been fun to do.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

8. I would describe drinking a glass of water every day as very interesting.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

End-of-study survey

Meditation

Thank you for your participation so far! This questionnaire is the last step in the study. Please answer all questions.

1. Please enter your phone number so we can combine your answers with your text messages.
2. Did you continue to meditate last week?
   (a) Yes
   (b) No
3. *(If Q2 = yes)* On what days did you do it?
   (a) Monday
   (b) Tuesday
   (c) Wednesday
   (d) Thursday
   (e) Friday
   (f) Saturday
   (g) Sunday
4. Throughout the study, how easy or difficult did you find remembering to focus on your breath every day?
   (a) Very easy
   (b) Somewhat easy
   (c) Somewhat difficult
   (d) Very difficult
5. Please explain why
6. Was there a situation when you made a conscious decision NOT to practice meditation on a given day?
   (a) Yes
   (b) No
7. *(If Q6 = yes)* Please explain why and how often it happened
8. Did you receive daily SMS reminders?
   (a) Yes
   (b) No
9. *(If Q8 = yes)* How would you describe SMS reminders?
   (a) Very Useful
   (b) Useful
   (c) Neutral
   (d) Useless
   (e) Very Useless
10. *(If Q8 = yes)* Please explain why
11. Did you go on holiday during the study?
    (a) Yes
    (b) No
12. *(If Q11 = yes)* How long were you away?

13. *(If Q11 = yes)* While you were away, how easy or difficult was it for you to focus on your breath every day?
    (a) Very Easy
    (b) Easy
    (c) Neutral
    (d) Difficult
    (e) Very Difficult
14. *(If Q11 = yes)* Please explain why
15. Did you receive confirmation messages after texting us?
    (a) Yes
    (b) No
16. *(If Q15 = yes)* How would you describe them?
    (a) Very Useful
    (b) Useful
    (c) Neutral
    (d) Useless
    (e) Very Useless
17. *(If Q15 = yes)* Please explain why

    Thinking of the past 13 weeks, please indicate to what extent you agree or disagree with each statement.

18. Focusing on my breath for a few seconds is something I do automatically.
    (a) Strongly Agree
    (b) Agree
    (c) Somewhat Agree
    (d) Neither Agree nor Disagree
    (e) Somewhat Disagree
    (f) Disagree
    (g) Strongly Disagree
19. Focusing on my breath for a few seconds is something I do without having to consciously remember.
    (a) Strongly Agree
    (b) Agree
    (c) Somewhat Agree
    (d) Neither Agree nor Disagree
    (e) Somewhat Disagree
    (f) Disagree
    (g) Strongly Disagree
20. Focusing on my breath for a few seconds is something I do without thinking.
    (a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

21. Focusing on my breath for a few seconds is something I start doing before I realise I'm doing it.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

22. Focusing on my breath for a few seconds is a part of my daily routine.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

23. In the past 13 weeks I have enjoyed meditating very much.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

24. Meditating has been fun to do.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

   (g) Strongly Disagree

25. I would describe meditating as very interesting.
   (a) Strongly Agree
   (b) Agree
   (c) Somewhat Agree
   (d) Neither Agree nor Disagree
   (e) Somewhat Disagree
   (f) Disagree
   (g) Strongly Disagree
26. Have you expanded your meditation practice from focusing on your breath for a few seconds to doing it regularly for longer?
   (a) Yes
   (b) No
27. Would you say you have developed a habit?
   (a) Yes
   (b) No
28. Are you planning to continue meditating briefly every day?
   (a) Yes
   (b) No
29. Can we email you in a few weeks to check whether you are still meditating regularly?
   (a) Yes
   (b) No
30. Would you like to receive a summary of the results of the study?
   (a) Yes
   (b) No
31. *(If Q30 = yes)* What email address should we use?
   (a) The one you used in the study
   (b) Different one:
32. Do you have any other comments about the study or your experience with learning to focus on your breath and meditate daily?

Drinking water

Thank you for your participation so far! This questionnaire is the last step in the study. Please answer all questions.

1. Please enter your phone number so we can combine your answers with your text messages.

2. Did you continue drinking water last week?
   (a) Yes
   (b) No
3. *(If Q2 = yes)* On what days did you do it?
   (a) Monday
   (b) Tuesday
   (c) Wednesday
   (d) Thursday
   (e) Friday
   (f) Saturday
   (g) Sunday
4. Throughout the study, how easy or difficult did you find remembering to drink a glass of water every day?
   (a) Very easy
   (b) Somewhat easy
   (c) Somewhat difficult
   (d) Very difficult
5. Please explain why
6. Was there a situation when you made a conscious decision NOT to drink a glass of water on a given day?
   (a) Yes
   (b) No
7. *(If Q6 = yes)* Please explain why and how often it happened
8. Did you receive daily SMS reminders?
   (a) Yes
   (b) No
9. *(If Q8 = yes)* How would you describe SMS reminders?
   (a) Very Useful
   (b) Useful
   (c) Neutral
   (d) Useless
   (e) Very Useless
10. *(If Q8 = yes)* Please explain why
11. Did you go on holiday during the study?
    (a) Yes
    (b) No
12. *(If Q11 = yes)* How long were you away?
13. *(If Q11 = yes)* While you were away, how easy or difficult was it for you to drink a glass of water every day?

(a) Very Easy

(b) Easy

(c) Neutral

(d) Difficult

(e) Very Difficult

14. *(If Q11 = yes)* Please explain why

15. Did you receive confirmation messages after texting us?

(a) Yes

(b) No

16. *(If Q15 = yes)* How would you describe them?

(a) Very Useful

(b) Useful

(c) Neutral

(d) Useless

(e) Very Useless

17. *(If Q15 = yes)* Please explain why

Thinking of the past 13 weeks, please indicate to what extent you agree or disagree with each statement.

18. Drinking a glass of water is something I do automatically.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

19. Drinking a glass of water is something I do without having to consciously remember.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

20. Drinking a glass of water is something I do without thinking.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

21. Drinking a glass of water is something I start doing before I realise I'm doing it.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

22. Drinking a glass of water is a part of my daily routine.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

23. In the past 13 weeks I have enjoyed drinking a glass of water very much.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

24. Drinking a glass of water has been fun to do.

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

25. I would describe drinking a glass of water as very interesting.

   (a) Strongly Agree
   (b) Agree
   (c) Somewhat Agree
   (d) Neither Agree nor Disagree
   (e) Somewhat Disagree
   (f) Disagree
   (g) Strongly Disagree

26. Have you expanded your water-drinking routine from one glass per day to higher volumes?
   (a) Yes
   (b) No
27. Would you say you have developed a habit?
   (a) Yes
   (b) No
28. Are you planning to continue drinking water daily?
   (a) Yes
   (b) No
29. Can we email you in a few weeks to check whether you are still drinking water regularly?
   (a) Yes
   (b) No
30. Would you like to receive a summary of the results of the study?
   (a) Yes
   (b) No
31. *(If Q30 = yes)* What email address should we use?
   (a) The one you used in the study
   (b) Different one:
32. Do you have any other comments about the study or your experience with learning to focus on your breath and meditate daily?

Debrief email

Thank you very much for your participation! Hope you enjoyed it and that you managed to develop your new healthy habit.

We had 8 groups of participants and were testing different ways to develop new habits, so some of you might have been more successful than others. We systematically manipulated:

- how much detail we gave you in the instructions about when/where to do your task,
- whether you would receive a reminder text from us, and

- what kind of response (if any) we sent after receiving your SMS.

To develop a new habit, you need to be motivated to start a new task, but with time the importance of motivation decreases as the task becomes a routine. If this task is repeated regularly in the presence of the same cues, ideally in the same environment, it will sooner or later become a habit. We wanted to learn more about those cues and how specific they should be.

If you have any questions about the study or habit formation in general, feel free to email me.

Once again thank you for your help!

Follow-up survey

Thank you for agreeing to answer our few questions. It won't take more than 2 minutes of your time.

1. Before we start, please enter the phone number you used for the study, so we can use it to combine your answers with the data gathered over the summer. We will not use the number for anything else.
2. What task did you choose to do every day during the Healthy Habits study last summer?
   (a) Meditating briefly
   (b) Drinking a glass of water
   (c) I don't remember
3. Are you still doing it?
   (a) Yes
   (b) No, I've stopped recently
   (c) No, I stopped weeks ago
   (d) No, I stopped right after the study ended
4. If you have stopped doing it, could you explain why?
5. If you are still doing it, could you explain how you remember to do it every day?

And that's it! Please submit your answers

Appendix G

Situated study materials

Recruitment questionnaire

Struggling with the cold? Not eating enough fruit and vegetables? Would you like to start supporting your diet with vitamin C supplements?

We are recruiting participants who would like to take vitamin C supplements to help us understand how people remember daily medications.

Vitamin C provides several health benefits: it protects the cells and supports the maintenance of connective tissue, and taking vitamin C supplements is associated with quicker recovery from colds or milder symptoms. However, it cannot be stored in the body and we need to renew its supplies every day. Healthy and varied diet rich in fruit and vegetables provides enough vitamin C, but when we're busy we often neglect our diets – that's where supplements can help.

The study will take place this term. At the beginning you will be interviewed, given a **free box of vitamin C tablets** and asked to take one per day for a month. After 3 weeks, we will interview you about your experience. At the end of the study you will receive a **£15 Amazon voucher**.

Requirements

In order to participate, you must fulfil the following requirements:

- Be aged 18 or over
- Be a UCL student
- Be able to attend two interviews at UCL campus
- Do not take any vitamin supplements at present

If you would like to participate, but are planning to be away for a few days between and the end of term – don't worry! As long as you can take vitamins with you and come back for the final interview, you can join the study.

Please keep in mind that too much vitamin C can cause stomach pain, nausea and diarrhoea. If your diet is already rich in vitamin C (i.e. you reach the 5-a-day goal every day), you **should not** participate in the study!

The study

The study starts with an initial interview. We will discuss briefly what helps you remember healthy behaviours (e.g. regular exercises, drinking water) or existing medications (e.g. oral contraception or any other tablets that you need to take regularly). The interview will take place at the main UCL campus and will last about 30 minutes, and at the end you will receive your vitamins. About 3 weeks later we will interview you again to understand how you remembered your vitamins, what worked, what didn't, etc. The date of the second interview will be agreed at the end of the first one. It will also last about 30 minutes and take place at UCL, although it might be possible to conduct it over Skype in certain circumstances.

Rewards

After the first interview you will receive a **free box of chewable vitamin C tablets** (suitable for vegetarians) to supplement your diet. After the second interview you will receive a **£15 Amazon voucher**.

How do I sign up?

If you wish to participate, please read and select the boxes below, and go to the next page where you will be able to provide your details and answer a few questions. We will get back to you in the next few days to let you know if you qualify for the study.

Please read the statements below and click/select them to confirm that you understood:

- I agree to participate in the study and I understand that I am free to withdraw from the study at any point.
- I confirm that I do not take any vitamin supplements at the moment and that I do not eat 5 portions of fruit or vegetables every day.
- I confirm that I am aware that too much vitamin C can cause stomach pain, nausea and diarrhoea.

This study is a part of PhD research. It is conducted by Katarzyna Stawarz (k.stawarz@cs.ucl.ac.uk) and supervised by Dr. Anna L. Cox (anna.cox@ucl.ac.uk) and Prof. Ann Blandford (a.blandford@ucl.ac.uk). It has been approved by UCL Ethics Committee, project ID: 7459/001. All data will be collected and stored in accordance with the Data Protection Act 1998.

1. Name:
2. Email address: *We will need it to get in touch with you and arrange the interviews*

3. Age:
4. Gender:
   (a) Female
   (b) Male
   (c) Other

   Please answer the following questions to help us assess whether you qualify for the study.
5. Are you able to attend an interview at UCL in the next couple of weeks?
   (a) Yes
   (b) No
6. Are you able to attend an interview at UCL during the first weeks of December (before the end of term)?
   (a) Yes
   (b) No
7. Are you taking any pills/tablets at the moment? Select all that apply
   (a) None
   (b) Oral contraception
   (c) Chronic condition medications
   (d) Vitamin supplements
   (e) Other

   [The following 5 questions are only visible if the respondent is currently taking medications]

   Please answer the following questions about your current medications.

   If you take more than one type of regular medications, please respond thinking about the ones you've been taking the longest.
8. How often do you take your pills/tablets?
   (a) Daily
   (b) Weekly
   (c) Other

   Please indicate whether you agree or disagree with the following statements:
9. I take my pills/tablets automatically
   (a) Strongly Agree
   (b) Agree
   (c) Somewhat Agree
   (d) Neither Agree nor Disagree
   (e) Somewhat Disagree
   (f) Disagree
   (g) Strongly Disagree
10. I take my pills/tablets without having to consciously remember
    (a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

11. I take my pills/tablets without thinking

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

12. I start taking my pills/tablets before I realise I'm doing it

(a) Strongly Agree

(b) Agree

(c) Somewhat Agree

(d) Neither Agree nor Disagree

(e) Somewhat Disagree

(f) Disagree

(g) Strongly Disagree

Questions on this page present a set of typical everyday situations that can happen to anyone. Please indicate how often, if at all, each of them happens to you.

13. How often do you decide to do something in a few minutes' time and then forget to do it?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

14. How often do you fail to recognise a place you have visited before?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

15. How often do you fail to do something you were supposed to do a few minutes later even though it's there in front of you, like take a pill or turn off the kettle?
    (a) Never
    (b) Rarely
    (c) Sometimes
    (d) Quite often
    (e) Very often
16. How often do you forget something that you were told a few minutes before?
    (a) Never
    (b) Rarely
    (c) Sometimes
    (d) Quite often
    (e) Very often
17. How often do you forget appointments if you are not prompted by someone else or by a reminder such a calendar or your phone?
    (a) Never
    (b) Rarely
    (c) Sometimes
    (d) Quite often
    (e) Very often
18. How often do you fail to recognise a character in a radio or television show from scene to scene?
    (a) Never
    (b) Rarely
    (c) Sometimes
    (d) Quite often
    (e) Very often
19. How often do you forget to buy something you planned to buy, like a birthday card, even when you see the shop?
    (a) Never
    (b) Rarely
    (c) Sometimes
    (d) Quite often
    (e) Very often
20. How often do you fail to recall things that have happened to you in the last few days?
    (a) Never
    (b) Rarely
    (c) Sometimes

(d) Quite often

(e) Very often

21. How often do you repeat the same story to the same person on different occasions?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

22. How often do you intend to take something with you before leaving a room or going out, but minutes later leave it behind, even though it's there in front of you?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

23. How often do you mislay something that you have just put down, like a magazine or glasses?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

24. How often do you fail to mention or give something to a visitor that you were asked to pass on?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

25. How often do you look at something without realising you have seen it moments before?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

26. How often do you try to contact a friend or relative and – when it turns out they are out – forget to try again later?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

27. How often do you forget what you watched on television the previous day?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

28. How often do you forget to tell someone something you had meant to mention a few minutes ago?

(a) Never

(b) Rarely

(c) Sometimes

(d) Quite often

(e) Very often

Semi-structured interview guide

Initial interview

- What do you study? Do you have a fixed schedule? (i.e. wakes up at the same time very day?) How do you remember everyday tasks?
- What healthy behaviours do you engage in on a regular basis? e.g. exercises, walking, drinking water, eating fruit and veg, flossing)
  - How often? How do you remember?
  - Do you forget? If so/if not, why?
- Do you take any medications? (or used to take in the past)
  - How often?
  - Where do you keep them?
  - What helps you remember?
- Do you ever forget your medications? If so/if not, why?
- When starting a new regular task, how do you decide what is going to help you remember?
- How do you think you're going to remember the vitamins?
- Why would you like to take the vitamins?

Post-study interview

- How was it? How did you remember?
  - Where did you keep the vitamins? Did you keep them there from the start?
  - What time did you take it? Did you try other times?
  - What helped you remember?
  - Were there any issues?
  - Talk about the photo
- Was there a difference in how you remembered it during the first week and now?
- Was there a difference between weekdays and weekends?
- How many times did you forget? Why?
- Did you take more than one? Why?
- What do you think might have helped you to remember better?
- SRHI questionnaire – explain your answers
- Are you planning to continue taking them?
- Has anything changed in the past 3 weeks in terms of healthy behaviours?
- What was your motivation to participate in the study?

Habit strength questionnaire

Based on Self-Report Habit Index questionnaire (Verplanken & Orbell, 2003).

1. Taking vitamin C was something I did frequently
2. It was something I did automatically
3. It was something I did without having to consciously remember
4. I felt weird if I did not take my daily vitamin C tablet
5. I did it without thinking
6. Not taking vitamin C every day would require effort
7. Taking vitamin C belongs to my daily routine
8. It was something I would start doing before I realised I was doing it
9. I would find it hard not to take vitamin C every day
10. I had no need to think about taking vitamin C tablets
11. I'd say that taking it daily was something that's typically "me"
12. It feels like I have been doing it for a long time