Ulysses in Cyberspace: Examining the Effectiveness of Design Patterns for Digital Self-Control

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To my parents, and to *Farfars Hus*

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Abstract

Instant access to information, entertainment, and connection enabled by smartphones and computers provides innumerable benefits, but also unprecedented opportunity for distraction. However, while technology companies have devoted enormous resources to keeping users 'hooked' on digital systems, little is known about how designers can best support people in regaining control over their digital device use. This thesis argues that the emerging research into design patterns for digital self-control, which attempts to address this challenge, will benefit from (i) drawing on established psychological research on self-control, and (ii) using the existing landscape of apps and browser extensions for digital self-control on online stores as a resource for understanding potential design patterns and implementations.

To substantiate these arguments, the thesis proceeds in four steps: First, we adapt a well-established dual systems framework to the context of digital device use, to help explain the psychological mechanisms that underlie self-control struggles. Second, we investigate digital self-control tools (n = 367) on the Chrome Web, Google Play, and Apple App stores, by analysing their design features, user numbers, ratings, and reviews. Third, we present a controlled study of interventions for Facebook, drawn from popular tools on the Chrome Web store. Fourth, distilling findings from the previous steps, we present a workshop format intended as a research tool for long-term investigation of user struggles and solution strategies, to better understand and respond to the pervasive challenge of digital self-control. Throughout the thesis, we adopt open science practices and make our materials, data, and analyses publicly available.

The thesis concludes by arguing that future research should focus on design patterns that enable users to sculpt their digital environments such that the amount of — and motivational pull from — the information they are exposed to remain within a range that allows them to exert effective self-control without being overwhelmed by distractions.

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List of Abbreviations

DBCI . . . . . Digital Behaviour Change Intervention.

DSCT . . . . . Digital Self-Control Tool.

EVC . . . . . Expected Value of Control.

HARKing . . Hypothesising After the Results are Known.

HCI . . . . . Human-Computer Interaction.

ICT . . . . . Information Communication Technology.

NHST . . . . . Null-Hypothesis Significance Testing.

PFU . . . . . Problematic Facebook Use.

ReDD . . . . . Reducing Digital Distraction (branding name of new workshop and intervention format).

UI . . . . . User Interface.

. . . she said we were to keep clear of the Sirens, who sit and sing most beautifully in a field of flowers; but she said I might hear them myself so long as no one else did. Therefore, take me and bind me to the crosspiece half way up the mast; bind me as I stand upright, with a bond so fast that I cannot possibly break away, and lash the rope's ends to the mast itself. If I beg and pray you to set me free, then bind me more tightly still.

— Homer's *The Odyssey*, Book XII

1 Introduction

The problem of digital self-control

In the ancient Greek epic poem *The Odyssey*, the hero Ulysses and his men must sail close by the Sirens, whose enchanting singing fatally distracts anyone who hears it. To overcome this self-control challenge, Ulysses stops his men's ears with wax, commands them to tie him to the mast, and also to ignore him if, upon hearing the Sirens' song, he asks to be untied. As they sail past, and the Sirens call out his name, Ulysses is overpowered by a desire to get close to them and signals to his men that they should untie him. His men, however, follow his earlier command and refuse to untie him, thereby holding him accountable to his past goal. Not until they are safely out of hearing range of the Sirens' voices do the men take the wax out of their ears and unbind Ulysses.

This story is sometimes referenced by self-control researchers to illustrate one possible strategy — 'pre-commitment' (Elster 1984; Willigenburg and Delaere 2005) — by which people help themselves act in accordance with their longer-term goals in the face of temptation. Today, the advent of smartphones, lightweight laptops, and smartwatches has meant that most people keep a 'Siren song' from unwanted distractions permanently within reach. Thus, whereas the instant access to information, entertainment, and connection provided by such devices brings

numerous benefits, many people also find that it makes it difficult for them to focus on their current task without being distracted by notifications, habitual check-ins, or endless opportunities for procrastination (Dabbish et al. 2011; Marotta and Acquisti 2017; Stothart et al. 2015; Thomas et al. 2016). A viral blog post summarised this as "I can't handle infinity in my pocket" (Knapp 2013). The challenge is exacerbated by tech companies whose business models depend on getting people to use digital services frequently and extensively (cf. the 'attention economy', Davenport and Beck (2001), Wu (2016); and 'surveillance capitalism', Zuboff (2015)). This incentivises software designers to make users 'hooked' on their products and craft a Siren song that is as enchanting as possible (cf. Eyal 2014).

Catering to users struggling to control their use of digital devices, a niche has emerged for apps and browser extensions that provide a wide range of self-control interventions ('digital self-control tools'), such as blocking access to distractions—and sometimes going to lengths to make blocking impossible to override, akin to Ulysses requesting to be tied to the mast—or more subtle approaches such as visualising time spent or rewarding intended use (Lyngs, Lukoff, Slovak, Binns, et al. 2019). Following growing public concerns over addictive design patterns (e.g., Foer 2016; Harris 2016; Tiku 2018), Apple, Google, and Facebook recently begun to implement similar 'digital wellbeing' features into their products (Apple 2018; Google 2018; Ranadive and Ginsberg 2018).

Meanwhile, a growing body of work in Human-Computer Interaction (HCI) is building an evidence base on what design patterns are actually effective in supporting users in exerting self-control over digital device use. Yet, this research is in its early stages. The existing studies provide initial indicators of how design patterns ranging from visualisations of device use (Whittaker et al. 2016) to goal-setting with social support (Ko, Chung, et al. 2015) can be helpful, but we still lack high-quality evidence on basic questions: In what contexts are different design patterns more useful? To what extent does their effectiveness depend on individual differences? What does the overall design space look like for design patterns for digital self-control? Moreover, basic conceptual questions, such as how to define

'success' for these patterns, and which theoretical frameworks are most suited to guide research efforts, remain open. The work presented in this DPhil thesis aims to move research forward on these questions.

Research question, approach, and scope

Based on the existing literature, which is laid out in greater detail in Chapter 2, the thesis aims to answer the following research question:

> How can existing digital self-control tools help us identify effective design patterns for supporting self-control over digital device use?

To answer this question, the thesis sets the following objectives:

- Explore how established self-regulation research can help us organise and evaluate existing design patterns, and provide a deeper understanding of the self-control struggles they seek to address (Chapter 3)
- Understand, at scale, how current digital self-control tools in online stores have explored the design space and how users have responded in store ratings and reviews (Chapters 3 and 4)
- Explore how digital self-control tools in online stores can be used to identify specific, promising interventions, and inform targeted studies (Chapter 5)
- Explore how the landscape of existing tools can help us elicit personal needs for digital self-control interventions in specific populations (Chapter 6)

In addressing these objectives, we narrow the scope of our investigations in the following ways (cf. Chapter 7):

- we focus on design patterns for digital self-control on *smartphones* and *laptops*,
- we focus on *individual users'* ability to exercise self-control (as opposed to, e.g., how system design impacts communities at a group level, cf. Hekler et al. (2013)),

- we exclude design patterns for regulating use in relation to families, children and young teenagers, as well as distracted driving, because design motivations in these cases include wider normative questions over, e.g., promotion of 'healthy' child development, or policy or legal concerns over traffic safety, and
- we focus on design patterns motivated by self-control struggles experienced by average users, as opposed to more clinical cases of severe 'addictive' use, where the underlying main causes are likely to be unfulfilled psychological needs in the user's life more broadly rather than digital devices' design affordances per se (Przybylski and Weinstein 2019).

Finally, in terms of research approach, we address our objectives through a combination of quantitative and qualitative methods, in addition to reviewing existing literature:

- we review cognitive neuroscience literature on dual systems approaches to self-regulation and contextualise it to digital self-control (Chapter 3),
- we combine web scraping, feature coding, and thematic analysis to characterise the existing landscape of apps and browser extensions for digital self-control (Chapters 3 and 4),
- we combine usage logging, surveys, and semi-structured interviews in a longitudinal study to evaluate specific, promising interventions identified among existing tools (Chapter 5)
- we collaborate with the University of Oxford Counselling Service on a workshop and intervention format to help understand how current interventions may address digital self-control struggles among students (Chapter 6).

Contributions

The thesis provides a number of contributions to research on digital self-control:

An extension of current applications of dual systems theory in HCI, that is in sync with basic research on self-regulation. The dual systems

framework presented in this thesis incorporates the 'expected value of control', which in the recent cognitive neuroscience literature is considered central in explaining why success at self-control fluctuates over time and with emotional state. This demystifies the concept of self-control and helps clarify how specific design features may work to scaffold successful self-control.

The first systematic analysis of digital self-control tools on the Google Play, Chrome Web, and Apple App stores. While a couple of existing papers have investigated this landscape, the number of tools studied in this thesis is approximately an order of magnitude larger than previous studies, and also provides the first analysis of user numbers and ratings. This contributes a broad characterisation of how the design space have been explored by current tools, as well as an indication of the effectiveness of specific design patterns and implementations.

The first demonstration of how design interventions can support self-control on Facebook. Whereas a large number of studies have investigated 'Problematic Facebook Use', a very small number have used experimental methods, and none have investigated the effectiveness of interventions common in online stores for browser extensions. This thesis demonstrates that two specific interventions, drawn from the Chrome Web store, can potently influence behaviour and reduce unintended use, which suggests potential remedies for problematic use that present a less tall barrier to action than deactivating or deleting one's account.

A new workshop format for in-depth studies of personal digital self-control struggles and appropriate interventions among university students. While numerous studies have highlighted these struggles among students, the present thesis work is the first to focus on this demographic in a workshop that embeds interventions drawn from comprehensive reviews of digital self-control tools. The thesis contributes open materials for the workshop alongside implications for how design patterns may be better aligned with users' goals via focused, within-app interventions, or by supporting the formation of habits and beliefs that help users stay in control with less reliance on external interventions.

An advancement of open and transparent research in the field. Open science practices have been called for in HCI (Haroz 2019), but has seen little adoption in digital self-control research. This thesis represents the first work in the field to make its materials, data, and analysis pipelines openly available, as well as to use a reproducible plain text format (R Markdown, Xie et al. (2018)) for the manuscript source files.[1] Moreover, the thesis work has led to the creation of a number of R packages for reproducible academic writing (e.g., for ACM CHI submissions), all of which are openly available.

Terminology

Throughout this thesis, we will use the terms

- 'digital self-control' to describe users' ability to align their digital device use with their valued, longer-term goals,
- 'design patterns' to refer to specific functions intended to support user self-control (e.g., hiding newsfeeds, providing goal reminders),
- 'intervention' to refer to design patterns when they have been instantiated in a piece of software (i.e. a digital self-control tool or feature) being evaluated, or when considering the way a design pattern changes a user's usual digital environment,
- 'digital self-control tools' (DSCTs) to refer to apps and browser extensions that implement a given design pattern (e.g., a browser extension for hiding Facebook's newsfeed), and
- 'conceptual framework' to refer to theories that provide an account of how fundamental building blocks, or 'constructs', are interrelated in human behaviour at one or two distinct levels (following Hekler et al. (2013), see section 2.3.5).

[1] The materials, data, and source files for the present thesis are available via the Open Science Framework on osf.io/ed3wh.

Thesis outline

The structure of the thesis is as follows:

In Chapter 2, we summarise the background and motivation. We first review work on user self-control struggles and the challenges of defining 'success'. Afterwards, we review findings and theory applied in existing studies of design patterns for digital self-control, before summarising the current research limitations and opportunities that motivate this thesis.

In Chapters 3 and 4, we present a broad view of how existing tools can help us identify effective design patterns. Chapter 3 characterises the design space for digital self-control design patterns, in two ways: 'bottom-up' by analysing features of current digital self-control tools, and 'top-down' by applying a dual systems framework. To this end, we first formulate a dual systems framework of self-regulation, and contextualise it to digital self-control. Afterwards, we conduct a systematic search for apps and browser extensions for digital self-control on the Google Play, Chrome Web, and Apple App stores, categorise their features, and analyse them using the dual systems framework.

In Chapter 4, we extend Chapter 3's feature review by collecting store popularity metrics and user reviews for the same set of digital self-control tools. We then conduct a combined analysis of tool functionality, user numbers, average ratings, and the content of reviews, and interpret the findings using the dual systems framework.

In Chapter 5, we illustrate how the landscape of existing digital self-control tools may be used to identify specific research opportunities and drive focused studies: we conduct the first controlled study of how user interface interventions on Facebook — drawn from popular extensions on the Chrome Web store — affect behaviour and perceived control among university students. We use the dual systems framework as a lens for selecting interventions, interpreting the findings, and predicting the limits and potential of the design patterns implemented by the interventions.

In Chapter 6, we show how the range of existing design patterns can be used in an active workshop to elicit user needs for digital self-control interventions: we

report on four 'Reducing Digital Distraction' (ReDD) workshops conducted with students at the University of Oxford. We use the dual systems framework to analyse the interventions included, and to discuss workshop findings in relation to tools that serve as 'training wheels' for improving self-discipline over time.

In Chapter 7, we discuss contributions of the thesis as a whole, in addition to wider challenges and opportunities regarding methodology and application of theory in digital self-control research. The thesis closes by revisiting what 'success' might look like, before presenting a longer-term vision for the ReDD workshops as a tool for data collection in digital self-control research, as well as for practical impact.

Dissemination

This thesis' research has been disseminated in the following papers, blog posts, and open source contributions:

Published conference papers

- Ulrik Lyngs, Kai Lukoff, Petr Slovak, William Seymour, Helena Webb, Marina Jirotka, Jun Zhao, Max Van Kleek, and Nigel Shadbolt (2020). 'I Just Want to Hack Myself to Not Get Distracted': Evaluating Design Interventions for Self-Control on Facebook. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20). Association for Computing Machinery, New York, NY, USA, 1–15. DOI: `https://doi.org/10.1145/3313831.3376672`
- Ulrik Lyngs, Kai Lukoff, Petr Slovak, Reuben Binns, Adam Slack, Michael Inzlicht, Max Van Kleek, and Nigel Shadbolt (2019). Self-Control in Cyberspace: Applying Dual Systems Theory to a Review of Digital Self-Control Tools. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19). Association for Computing Machinery, New York, NY, USA, Paper 131, 1–18. DOI: `https://doi.org/10.1145/3290605.3300361` (**Honourable Mention award**)

- Ulrik Lyngs, Reuben Binns, Max Van Kleek, and Nigel Shadbolt (2018). "So, Tell Me What Users Want, What They Really, *Really* Want!". In Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems (CHI EA '18). ACM, New York, NY, USA, Paper alt04, 10 pages. DOI: `https://doi.org/10.1145/3170427.3188397`
- Ulrik Lyngs. (2018a). A Cognitive Design Space for Supporting Self-Regulation of ICT Use. In Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems (CHI EA '18). ACM, New York, NY, USA, Paper SRC14, 6 pages. DOI: `https://doi.org/10.1145/3170427.3180296`

Workshop papers / blog posts

- Ulrik Lyngs (2019a). 367 tools of resistance in the battle for online attention. Blog post published on the UX Collective's Medium page.
- Ulrik Lyngs (2019d). Putting Self-Control at the Centre of Digital Wellbeing. CHI'19 workshop paper: Designing for Digital Wellbeing
- Ulrik Lyngs (2017c). Ulysses in Cyberspace. Blog post written for the Oxford Internet Institute's Connected Life Conference.
- Ulrik Lyngs (2017b). Curiosity, ICTs, and Attention Management. CHI'17 workshop paper: Designing for Curiosity: An Interdisciplinary Workshop.

Open source contributions

- Ulrik Lyngs (2019b). chi20-papers-rmarkdown. Template for writing CHI'20 Paper submissions in R Markdown. GitHub repository.
- Ulrik Lyngs (2019c). oxforddown. Template for writing University of Oxford thesis submissions in R Markdown, with output to PDF or gitbook. GitHub repository.
- Ulrik Lyngs (2018c). chi-proc-rmd-template. Template for writing CHI'19 Paper submissions in R Markdown. GitHub repository.
- Ulrik Lyngs (2018b). chi-ea-rmd-template. Template for writing CHI'19 Extended Abstracts submissions in R Markdown. GitHub repository.

2

Background and Motivation

Contents

In this chapter, we summarise the background and motivation of the present thesis:
First, we review evidence on the existence of self-control struggles in relation to digital device use. Next, we consider what criteria of 'success' design patterns might be benchmarked against, summarising HCI research attempting to bridge the gap between what users *actually* do and what they *'really wanted'*, as well as main insights from basic research on the nature of self-control. Afterwards, we zoom in on the existing studies of design patterns for digital self-control, reviewing their approaches, findings, and guiding theory. Laying the ground for the subsequent chapters, we end by highlighting limitations of existing studies and pointing to the thesis chapters that explore corresponding research opportunities.

2.1 Digital device use and self-control challenges

2.1.1 Behavioural addiction

It has long been posited that use of Information Communication Technologies (ICTs) for some subset of users can become associated with severe breakdowns of self-regulation, causing distress or impaired functioning in important life domains (Chakraborty et al. 2010). For more than two decades, the concept of 'addiction' has been applied by some researchers to such instances, originally in the form of 'internet addiction' (Young 1998), and more recently 'cell phone' and 'smartphone addiction' (Chakraborty et al. 2010; Sapacz et al. 2016), as well as 'social media' or 'Facebook addiction' (Andreassen, Billieux, et al. 2016; Marino et al. 2018a,b; Ryan et al. 2014; Sleeper et al. 2015). This research tends to focus on a more restricted subset of self-control difficulties than the present thesis, namely struggles with controlling digital device use that are so severe that they result in real negative life impact, where a clinical term may be appropriate. However, because the concept of 'addiction' has often been applied somewhat loosely — and because narratives of

addiction have had a significant influence on public discourse and users' personal reflections (Lanette and Mazmanian 2018; Orben 2019; Tiku 2018) — this research space provides a useful point of departure.

'Internet addiction' has been defined as 'time-consuming computer usage that causes distress or impairs functioning in important life domains' (Chakraborty et al. 2010), mobile phone addiction as 'repetitive use of mobile phones to engage in behaviour known to be counterproductive to health' (Lopez-Fernandez et al. 2014), and 'Facebook addiction' (also 'Facebook dependence' or simply 'Problematic Facebook Use') as 'problematic behaviour characterised by addictive-like symptoms and/or self-regulation difficulties related to Facebook use leading to negative consequences in personal and social life' (Marino et al. 2018a). Early work on internet addiction found that 'addicts' on average spent 8 times as much time online as 'non-addicts' and reported problems akin to substance abuse, including negative consequences on educational, work, and personal life, inability to break problematic usage patterns, and withdrawal symptoms when unable to access the internet. 'Addicts' also tended to be heavy users of online chat rooms and multiplayer role playing games, suggesting that addictive use was driven by interactivity and need-provision online rather than "The Internet" as such (cf. more recent work describing social networking sites as "addiction prone technologies", Tarafdar et al. (2013); Turel and Serenko (2012); Ryan et al. (2014)). Similarly, research on cell phone addiction has found that users classified as 'addicts' experience withdrawal symptoms in absence of their device — feelings of loss, signs of craving, and functional impairment — and a resulting loss of control in managing other activities (Cheever et al. 2014; Lopez-Fernandez et al. 2014; Roberts et al. 2015).

However, applying the concept of addiction to ICT use has been enveloped in controversy. Initial work on 'internet addiction' modified the American Psychiatric Association's DSM-IV diagnostic criteria for pathological gambling (Young 1998), and came to describe it in terms of four components: i) excessive use (often associated with a loss of sense of time or neglect of basic drives), ii) withdrawal symptoms when one's computer is inaccessible (e.g. anger, tension, or depression), iii) tolerance

(e.g. increased hours of use and increased expense on equipment over time), and iv) negative repercussions (e.g. social isolation, fatigue, lying to one's surroundings about use, poor achievement, etc.) (Beard and Wolf 2001; Chakraborty et al. 2010; Tao et al. 2010). However, the subsequent literature has seen little agreement on how to delineate the boundaries of addictive use, and researchers have often used terms such as 'addiction', 'abuse', and 'problematic use' interchangeably (Gutiérrez et al. 2016). As a result, a wide range of prevalence estimates for addictive use has been given: 'internet addiction' has been suggested to affect anywhere between 0.3 and 38% of populations in developed economies (Chakraborty et al. 2010; Cheng and Li 2014; Weinstein et al. 2014), 'smartphone addiction' similarly between 0 and 38% (Lopez-Fernandez et al. 2014; Pedrero et al. 2012), and 'Problematic Facebook Use' from 3.1% to 47% (Cheng, Burke, et al. 2019; Jafarkarimi et al. 2016; see also Bányai et al. 2017; Khumsri et al. 2015; Wolniczak et al. 2013). Accordingly, some researchers have pushed back against a perceived pathologisation of everyday patterns of ICT use in this literature, and argued that even frequent, extensive use which distract users from daily life should not be considered "addiction" unless it also leads to functional impairment and psychological distress (Billieux et al. 2015; Kardefelt-Winther et al. 2017; Tran et al. 2019).

For the purposes of the present thesis, this literature suggests severe self-control difficulties in relation to digital device use among some smaller subset of users. Moreover, the high prevalence estimates of 'addictive' use in studies that apply less strict inclusion criteria suggests that milder struggles with self-control are widespread.

2.1.2 Common self-control struggles

The current surge of public discussion around self-control struggles and unwanted distraction — and the recent related initiatives by some of the tech giants (Apple 2018; Gonzalez 2018; Google 2018) — have a broader focus, namely daily self-control struggles assumed to be experienced by many, if not most, users (cf. Centers 2018; Wolwerton 2018). Thus, a wealth of articles and opinion pieces have in recent years

appeared on the topic in major news outlets, viral blog posts, and popular science books (e.g., Alter 2017; Eyal 2019; Foer 2016; Harris 2016; Knapp 2013; Popescu 2018; Wu 2016). Empirical research suggests that this does not merely reflect another 'moral panic' over new technology in society (cf. Lanette and Mazmanian 2018; Orben 2019): whereas it is unclear how often habits of digital device use meet clinical definitions of addiction, there is wide support for the claim that a high proportion of people regularly experience difficulties with self-control (Hiniker, Hong, et al. 2016; Ko, Choi, et al. 2016; Ko, Chung, et al. 2015; Lundquist et al. 2014; Tran et al. 2019; Whittaker et al. 2016).

Initial work on intentional 'non-use' looked into why some users quit, or take breaks from Facebook (Baumer and Adams 2013), Twitter (Schoenebeck 2014), or other social networking sites. This work found that a major motivation for disengaging was struggles with distraction and self-control, with, e.g., users reporting deactivating Facebook because they found it 'too interesting', or 'superficial yet addictive' and felt a need to delete or deactivate their accounts to concentrate on work or break out of a perceived addiction (Baumer and Adams 2013).

Most recent research has focused on smartphone use, where a number of studies have found broad frustration among ordinary users with their usage habits, particularly in relation to self-control struggles with high-reward, low-demand experiences such as games and browsing social media (Ames 2013; Lee, Lee, et al. 2014; Lukoff et al. 2018; Shin and Dey 2013; Tran et al. 2019). For example, in a survey by Ko, Chung, et al. (2015) posted in large online communities, a majority of smartphone users felt they were overusing their devices (64%) and wanted to change their usage habits (60%). The patterns respondents wished to change clustered around two themes: *too frequent short usage*, where incoming notifications or urges to, e.g., check the news derailed focus from tasks they wished to complete; and *excessive long usage*, where, e.g., habitually checking devices before bedtime 'sucked them in' (see also Ko, Choi, et al. 2016; Oulasvirta et al. 2012). Most users also reported that their strategies for changing this behaviour most often failed, especially when relying on 'willpower', because good intentions to limit use tended

to be overridden by momentary impulses (Ko, Chung, et al. 2015; cf. Elhai et al. 2016; Hofmann, Vohs, et al. 2012; Lim et al. 2017).

In a survey of American smartphone users recruited on MTurk, 58% said they wanted to spend less time using their phones (Hiniker, Hong, et al. 2016). Elaborating on their responses, many said they wanted to make context-dependent changes to their use, such as use their phones less before bedtime, or restructure time spent so that, e.g., their proportion of time in work-related activities were higher during commutes (Hiniker, Hong, et al. 2016; see also Przybylski and Weinstein 2017).

In a recent study by Tran et al. (2019), which interviewed American participants from three subpopulations (high school students, college students, and post-graduation adults), participants reported filling every moment of downtime with habitual smartphone checking, which they engaged in with minimal awareness. They expressed frustration with their checking habits, particularly in relation to apps that drove them into compulsive use without adding enduring value to their lives, and most had tried regulating their use by deleting such apps after a sense of frustration built up.

Finally, related work on multitasking and media use has found that people often perceive their use of internet services to be in conflict with other important goals (Reinecke, Meier, et al. 2018; Rosen et al. 2013; Xu, Wang, et al. 2016). For example, an experience sampling study of adults in the US questioned participants at random times during the day about whether and how they were currently using media (Reinecke and Hofmann 2016). In 51% of sampled episodes, participants were engaged in media use, with internet use the most common form (55% of instances; the most frequent content was social media, including Facebook and Twitter, video streaming sites, including YouTube, and online news sites). Importantly, participants reported that their use conflicted with other important goals on more than half of all use occurrences (61%) suggesting a high prevalence of self-control struggles with digital media use.

Some recent work on associations between device use and measures of well-being has called for careful examination of when self-reported frustration over, e.g., habitual smartphone use reflect users' own lived experience, and when it reflects internalised narratives of, e.g., distracted addicts neglecting a morally 'superior' external world (Harmon and Mazmanian 2013; Orben 2019). This is an important point, and the study mentioned above by Tran et al. (2019) was specifically conducted as such a deeper examination among a random sample of smartphone users. Tran et al. (2019) found that, in addition to reporting general frustration with aspects of smartphone use they experienced as compulsive, participants also critically reflected on what use was meaningful and what was not, and described steps they had taken to minimise specific usage that did not provide them value. Whereas the influence on participant self-report of larger social narratives in relation to addictive use should be kept in mind, this research evidence suggests that reports of self-control struggles do reflect real aspects of users' lived experience.

2.1.3 Challenges from constant connectivity and the attention economy

It is to be expected that tools which provide instant and permanent access to endless information, entertainment, and social connection come with self-control challenges. Thus, psychologists studying self-control have long known that relying on conscious willpower as self-control strategy in environments where distractions and temptations are readily available is unreliable: in general, people who are better at self-control instead reduce their exposure to temptation in the first place, and/or develop habits that make their intended behaviour more reliant on automatic processes than conscious control (Duckworth, White, et al. 2016; Ent et al. 2015; Galla and Duckworth 2015; Hofmann, Baumeister, et al. 2012). Therefore, we should predict that digital devices, which make a wide range of behaviours constantly available with minimal effort, would come with significant self-control challenges and a corresponding need to translate people's ordinary strategies for managing temptation into the digital realm.

This challenge is compounded by the business models of many tech companies, which incentive design that nudges people into using services frequently and extensively, a dynamic often referred to as the 'attention economy' (Davenport and Beck 2001; Einstein 2016; Wu 2016): in 1971, Herbert Simon noted that when information is overabundant, human attention becomes a scarce resource, which must be allocated efficiently among the information sources that may consume it (Simon 1971). Simon made this point in the context of system design, where he argued that digital systems should filter information to ensure the user is not distracted or overwhelmed by less relevant details. More recently, however, Simon's insight has been applied to analyse how the explosion of readily available information via ICTs has led to a breakneck competition among technology and media companies over capturing and holding users' attention (Harris 2016; Leslie 2016; Wu 2016). This competition has been intensified by the rise of 'free' as a dominant business model: if users do not pay for the product, such as in services provided by Facebook, Google, and a large majority of mobile apps (*Distribution of Free and Paid Android Apps 2019* n.d.), companies usually monetise products through advertising, collection of user data (cf. 'surveillance capitalism', Zuboff (2015)), or in-app purchases. This in turn creates a financial incentive to design in ways that keep users coming back to their digital devices and services and make them spend as much time as possible. (Perhaps unsurprisingly, the American author Nir Eyal's book *Hooked: How to Build Habit-Forming Products* (2014), became an international best-seller.)

The incentives of the attention economy create a potential misalignment between how the end-user wishes to use a digital service (e.g., using Facebook for specific tasks such as event coordination or messaging) and how the product designer wishes the end-user to behave (e.g., spending as much time as possible on Facebook to optimise advertising revenue). Advertising agencies competing for attention is, of course, not a new development (Wu 2016). However, what is new — and why the challenge at this moment in history is particularly important to tackle — is that portable digital devices extend the battle for attention to any time of day and any situation, from the bathroom to the bedroom; can influence users in multi-modal

and interactive formats; and can precisely target audiences using previously collected user data, at scale (Boyd and Crawford 2012; Fogg 2003).

2.1.4 The rise of digital self-control tools

In parallel with the massive investment of resources in keeping users 'hooked' on digital systems, online stores have seen the rise of a counter-movement in the form of a niche for 'digital self-control tools' (DSCTs). Thus, hundreds upon hundreds of apps and browser extensions now cater to people struggling with self-control over device use, and claim to provide means of resistance in the battle over their attention (Lyngs 2019a; Lyngs, Lukoff, Slovak, Binns, et al. 2019). As we will review in Chapter 3, these tools provide a wide range of interventions which may, e.g., block or remove digital distractions, track and visualise device use, remind users of their goals, or provide rewards and punishments for how devices are used. For example, they may restrict the amount of functionality available on devices' home screen (such as the Android app *LessPhone Launcher*, Mohan (2019)) gamify self-control by tying device use to the wellbeing of virtual creatures (such as the smartphone app and browser extension *Forest*, Seekrtech (2018)), or hide or change content on distracting websites (such as the browser extension *Newsfeed Eradicator*, JDev (2019)). Some of these tools now have millions of users (Google Play (2017), cf. Chapter 4).

In 2018, the perceived demand for such tools, as well as public debate and pressure on tech platforms fanned by organisations including the Center for Humane Technology (formerly know as 'Time Well Spent'), led Mark Zuckerberg to announce "making sure that time spent on Facebook is time well spent" as his annual personal challenge (Mark 2018), and his company to announce tools for 'managing your time on Facebook and Instagram' (Ranadive and Ginsberg 2018); and Apple and Google to similarly implement features for visualising and limiting use on their operating systems (Apple 2018, 2019; Google 2018). In 2019, public discussion has continued unabated, with a recent US senate hearing on the perceived threats of 'Persuasive Technology' (*Optimizing for Engagement* 2019), and a call from a UK All-Party Parliamentary Group for a duty of care to be established on social media companies

(All Party Parliamentary Group on Social Media and Young People's Mental Health and Wellbeing 2019). Following the turning of the tide, Nir Eyal published a new book, this time called *indistractable*, focused on tools for managing attention and self-control when digital technologies are designed to hook their users in (Eyal 2019).

2.2 What does success look like?

If people struggle with distraction and self-control in relation to their use of digital devices, what are the criteria of success that design patterns should be benchmarked against? It is important to make our assumptions in this respect explicit, because they set the stage for what design patterns we imagine and how we evaluate effectiveness. Much recent debate, especially in relation to children and adolescents' use of digital technology, has focused on 'screen time' and on how much of it might constitute unhealthy 'overuse' (Dickson et al. 2019; Przybylski and Weinstein 2017). Fittingly, a main focus of both Apple's and Google's new tools is to help people manage the overall amount of time they spend on their devices (Apple's app is aptly named 'Screen Time', *Use Screen Time on Your iPhone, iPad, or iPod Touch* (n.d.)) and find 'the right balance' (Google 2018). One underlying justification for this is the *displacement hypothesis*, according to which users should avoid excessive use of digital devices because it may supplant other important activities such as exercising, reading books, or socialising with peers and family (Neuman 1988; Przybylski and Weinstein 2017). Accordingly, researchers have tried to establish what amount of screen time might be 'optimal' to gain the benefits of digital connection without displacing other meaningful activities (Przybylski, Orben, et al. 2019; Przybylski and Weinstein 2017).

The problem with this approach, however, is that today's smartphones, tablets, and laptops support an incredible range of activities and contents, from social media, TV, and video streaming, to gaming, reading, writing, and shopping. Moreover, some platforms — such as Facebook — have themselves come to integrate a vast range of functionality. Therefore, whereas 'screen time' may be helpful as umbrella term,

the ever-expanding range of digitally mediated activities makes it a poor indicator of whether people's use aligns with what they intended (Cecchinato, Rooksby, et al. 2019; cf. parallel discussions in research exploring relationships between screen time and well-being, Orben, Etchells, et al. 2018; Orben and Przybylski 2019b). For example, one possible pitfall from using screen time to guide interventions is to get people to set simplified usage goals that are easy to enforce and measure (e.g., limit Facebook use to 30 minutes per day) but which fail to capture their actual goal (e.g., decrease time spent scrolling the newsfeed, but *increase* time spent in the Facebook group for their local Taekwondo club, Lukoff (2019); cf. research on targeted non-use Hiniker, Hong, et al. (2016)).

For these reasons, several HCI researchers have argued that developing design patterns for helping people reduce 'screen time' is inadequate, and advocated for more contextual understandings (Hiniker, Radesky, et al. 2019; Lukoff 2019). However, what might that more specifically mean?

2.2.1 User behaviour vs 'true intentions' in HCI

In human-computer interaction research, the question of how to bridge the potential gap between what users *actually* do and what they *'really wanted'* to do has a relatively long history. In the 1960's, Warren Teitelman's 'Do What I Mean' (DWIM) philosophy argued that systems should not just execute whatever potentially erroneous instructions users put into a terminal (Teitelman 1966). Instead, they should try to interpret users' true intentions and correct their errors (the implication being DWIM, Now What I Say (or Do)). In practice, however, Teitelman's error-correction systems were critiqued as merely reflecting what their *designer* would have meant ('do what Teitelman means', Steele and Gabriel (1996)).

The issue has cropped up in more fundamental ways in the domains of decision support and recommender systems, where the gap is not just between what the user typed and what they really intended, but between recorded interaction behaviour and what can be inferred about the user's wants and needs. In recent years, behaviourism has been the dominant paradigm for recommendation, expressed in trends such

as measuring user activity in A/B tests instead of capturing user experiences in surveys and ethnographic analyses, and ignoring people's explicit preferences when it disagrees with their behaviour (Ekstrand and Willemsen (2016); industry case studies include Facebook's introduction of the newsfeed which involved striking contrast between users' sentiment and their behaviour, Fisher (2018)). However, much recent critique of social media platforms has revolved around the problems associated with equating users' true needs and desires with simple behavioural measures of engagement (cf. current debates about whether removing 'like' counts on social media platforms would benefit user well-being Martineau (2019)). Whereas people's behaviour obviously provides some valuable information about their goals — on the basis of which an extensive knowledge base has been generated about how recommendations can effectively lead users to action — relying purely on behaviour may render recommender systems unable to distinguish between addiction and the user deriving value from the system (Ekstrand and Willemsen 2016). Thus, Ekstrand and Willemsen (2016) argued that in order to know whether users are satisfied with their choices both short-term and long-term; to know what keeps them from aligning their actions and desires if they are dissatisfied; and to know whether the recommender system is helping or hindering the user in achieving the goals they have for their life, explicit input from the user is necessary.

Numerous ways to explicitly elicit users' preferences have been explored in the literature, including user ratings and example-critiquing in recommender systems (Pommeranz et al. 2012; Pu and Chen 2009), and pairwise comparison in decision support systems (Aloysius et al. 2006; Chen and Pu 2004). Moreover, pioneering work in this space explored ways to let users inspect and tweak a system's model of them (Cook and Kay 1994; Kay 1995, 1997; Pu and Chen 2009). However, explicit methods have their own challenges. Foremost, the elicitation process itself influences what users say they want. For example, users may prefer different options based on whether they are framed as losses or gains (Pommeranz et al. 2012), or depending on the moment in time in which they are asked. What point in time reflects what the user 'really' wants - the most recent, a weighted average over the

last day / week / year, or something else (Kahneman and Riis 2005; Redelmeier and Kahneman 1996)? Jameson et al. (2014) suggest that decision-support systems should optimise for outcomes that "the chooser is (or would be) satisfied with in retrospect, after having acquired the most relevant knowledge and experience", but add that "Admittedly, this assumption is subject to debate..." (2014, p.35).

Another point of tension is between broad or narrow construals of the user's context. One of the foundational tenets of user-centred design, as articulated by Ritter et al. (2014), is to consider the user context more broadly. That is, to move beyond the immediate, task-related issues pertaining to a specific product, where the user's goals can be more easily approximated, and instead view applications of technology as "the development of permanent support systems and not one-off products that are complete once implemented and deployed" (Ritter et al. 2014, p. 44). In other words, the designer should consider longer-term effects of systems on people's lives, which in turn requires deeper insight in order to align systems with users' more general goals, values, and life situation (cf. Peters et al. 2018). However, this runs the risk of not being actionable, partly because it involves a potentially boundless number of concerns in relation to a product's impact, and partly because it leaves a much bigger role for normative disagreements over values and visions of the 'good life' and the role digital devices 'ought' to play, which are not easily resolved (cf. Orben 2019).

Summing up, Pommeranz et al. (2012) noted that "More research is needed to design preference elicitation interfaces that elicit *correct* preference information from the user" (2012, p. 361), and called for explicit consideration in HCI research of the normative aspects that might be required to determine such 'correctness' (cf. Lyngs, Binns, et al. 2018).

2.2.2 The view from self-control research: Aligning device use with valued, longer term goals in the face of conflicting impulses

Whereas HCI research has run up against the challenge of distinguishing between what people do and what they 'really want' in relation to systems design, fundamental research on self-control within psychology, neuroscience, and behavioural economics have tackled this problem space for decades, with an aim to understand the mechanisms involved (Baumeister, Vohs, et al. 2007; Hagger, Wood, et al. 2010; Inzlicht, Schmeichel, et al. 2014; Kotabe and Hofmann 2015; Shea et al. 2014).

In contrast to notions of 'rational actors' with consistent preferences, this research has highlighted that people frequently experience internal conflict in which short-term desires (e.g., checking one's Instagram feed) conflict with longer term goals that they, upon reflection, deem to be more valuable (e.g., doing well on a school test, Duckworth and Steinberg (2015)). Often, people fail to act in accordance with their stated longer term goals (Consolvo et al. 2009), which behavioural economists have described as 'time-inconsistent preferences' (Ariely and Wertenbroch 2002; Hoch and Loewenstein 1991) and explained through decision biases such as a tendency to value potential rewards less the further away they are in time ('future discounting', Ainslie (2010); Critchfield and Kollins (2001)). For example, even though we may value getting a good night's sleep and know that tomorrow we will appreciate having gone to bed at a reasonable hour, the short-term gratification of, e.g., watching another YouTube video often looms larger in the moment (see Ariely and Wertenbroch 2002).

Hence, this literature has defined 'self-controlled behaviour' as "actions aligned with valued, longer term goals in the face of conflicting impulses to seek immediate gratification" (Duckworth and Steinberg 2015, p.32). Sometimes, self-controlled behaviour involves inhibiting an undesired impulse (e.g., suppressing an urge to check one's phone in a social situation) whereas it at other times involves strengthening a desired action (e.g., spending time on a MOOC course rather than on Facebook, cf. Fujita (2011); Duckworth and Steinberg (2015)).

Research in this space has also investigated the many "tricks" by which people try to out outmanoeuvre their myopic present self, from distracting themselves from temptations in the heat of the moment, to 'pre-committing' to a particular course of action, or simply avoiding exposure to temptation (Ariely and Wertenbroch 2002; Duckworth, White, et al. 2016). Ultimately, all such strategies attempt to decrease the strength of momentarily rewarding, but ultimately less desired, impulses and/or increase the strength of enduringly beneficial, but relatively less immediately gratifying ones (Duckworth, White, et al. 2016).

Self-control has been studied under various names, including *effortful control*, *will power*, *ego-resilience*, and *cognitive control* and the literature on the topic is vast (see Duckworth and Steinberg 2015; Inzlicht, Bartholow, et al. 2015). For our purposes, the main take-away is that across research in this space, the notion of 'success' — what people 'really want' — is defined as being able to act in accordance with one's enduringly valued goals in the face of conflicting urges that may be more potent in the moment (Duckworth and Steinberg 2015). In chapter 3, we expand on one particular approach drawn from this literature, dual systems theory, which we then adapt to the context of self-control struggles in relation to digital device use, and apply throughout the rest of this thesis.

2.3 Studies of design patterns for digital self-control

When I began my DPhil project in the autumn of 2016, research into design patterns for supporting user self-control over digital device use was a relatively new area of exploration. Since then, research interest has rapidly grown. In this section, we review main design approaches, findings, and guiding theory from the studies conducted in this space. We add a brief overview of theory applied in the wider area of digital behaviour change interventions, before highlighting some of the limitations and opportunities given our current state of evidence.

Table 2.1: Existing studies of design patterns for digital self-control.

Citation	Summary	Guiding conceptual framework	Evaluation	Control group?
Lottridge et al. (2012)	Firefox extension which classifies URLs as work or non-work, then makes non-work tabs less prominent and displays time spent	Multitasking, inhibitory brain function (Gazzaley et al. 2008)	experimental	no
Löchtefeld et al. (2013)	*AppDetox*, an Android app which let users voluntarily create rules intended to keep them from certain apps	None	observational	-
Collins et al. (2014)	*RescueTime*, a commercial Windows/Mac application which provides visualisations of how much time is spent in different applications	Cognitive Load theory (Block et al. 2010)	experimental + observational	yes (in study 2)
Lee, Ahn, et al. (2014)	*SAMS*, an Android app for tracking smartphone usage and setting time limits for app use	Relapse prevention model (Witkiewitz and Marlatt 2004), clinical guidelines for internet addiction (Young 1999)	experimental	no
Ko, Chung, et al. (2015)	*NUGU*, a smartphone app which let users set goals for limiting usage, then share goals, contexts, and performance with friends and receive encouragement	Social Cognitive Theory (Bandura 1991)	experimental	no
Foulonneau et al. (2016)	*TILT*, an Android app which displays time spent and frequency of phone use over daily, weekly, and full history intervals, alongside about benefits of less use	Fogg's behaviour model for persuasive design (Fogg 2003)	experimental	no
Andone et al. (2016)	*Menthal*, a smartphone app displaying the 'MScore', a single number summarising overall phone usage, as well as a series of main usage measures	None	none	-
Hiniker, Hong, et al. (2016)	*MyTime*, an Android app showing time spent in apps (and whether a daily limit was hit) plus a daily prompt asking what the user wished to achieve	None	experimental	no
Kim, Jeon, et al. (2016)	*TimeAware*, an ambient Windows and Mac widget which presents time spent in 'distracting' or 'productive' applications	Framing effects (Marteau 1989)	experimental	no
Ko, Choi, et al. (2016)	*Lock n' LoL*, a smartphone app which lets users as a group set their phones in a lock mode in which notifications are muted and usage restricted	None	observational	-
Ruan et al. (2016)	*PreventDark*, an Android app which detects phone use in the dark and notifies the user that they should put it away	None	none	-
Whittaker et al. (2016)	*MeTime*, a computer application providing a floating visualisation of time spent in different applications within the last 30 mins	None	experimental	no
Kim, Jung, Jung, et al. (2017)	*Let's FOCUS*, an Android and iOS app letting users enter a 'virtual room' where notifications and apps are blocked; links to location or time	None	observational	-
Park et al. (2017)	*SCAN*, a Android app which uses built-in sensors to detect opportune moments to deliver notifications so that they are minimally disruptive of social interaction	None	experimental	no
Kim, Cho, et al. (2017)	*PomodoLock*, a PC and Android application plus Chrome extension lets users set a timer for a fixed period during which distracting apps and websites are blocked across multiple devices	Strength model of self-control (Baumeister, Vohs, et al. 2007)	experimental	no
Marotta and Acquisti (2017)	*Freedom*, a commercial Windows/Mac/Android/iOS app which blocks access to distracting parts of the web or the internet altogether	Rational choice, commitment devices (Bryan et al. 2010)	experimental	yes

Table 2.1: (continued)

Citation	Summary	Guiding conceptual framework	Evaluation	Control group?
Kovacs, Wu, et al. (2018)	*HabitLab*, a Chrome extension in which the user sets time limit goals for specific sites, then tries a range of interventions to reach the goal	Numerous, including goal setting theory (Locke and Latham 2002), operant conditioning (Baron et al. 1991), and self-consistency theory (Sherman 1980)	experimental	yes
Mark et al. (2018)	*Freedom*, described above	Attentional resources (Wickens 1980), Big 5 (McCrae and Costa 1999)	experimental	no
Okeke et al. (2018)	Android app nudging users to close Facebook when a usage limit has been hit, using pulsing vibrations that stop when the user leaves the site	Nudge theory (Sunstein and Thaler 2008), operant conditioning (Iwata 1987)	experimental	yes
Borghouts et al. (2018)	A system (browser extension?) for providing people feedback on how long they navigate away from a task for	None	experimental	yes
Kim, Lee, et al. (2018)	A prototype smartphone app which automatically locks a user's phone with a lock screen when the user has been stationery for more than 5 minutes (as this might indicate that the user is a 'focusing context'), and displays how long it has been locked for	None	user study	-
Kovacs, Gregory, et al. (2019)	*HabitLab* browser extension (described above) plus companion HabitLab Android app - similarly to the browser extension, in the app users specific target apps to reduce time spent.	Numerous, including goal setting theory (Locke and Latham 2002), operant conditioning (Baron et al. 1991), and self-consistency theory (Sherman 1980)	experimental	yes
Roffarello and De Russis (2019a)	Review of functionality + user reviews for 42 'digital wellbeing' apps on Google Play; *Socialize*, an Android app providing usage statistics at the phone and app-level, and also can provide reminders or blocking after the phone or specific apps have been used for a certain amount of time.	None	review + experimental	no
Kim, Jung, Ko, et al. (2019)	*GoalKeeper*, an Android app applying varying intensities of restrictive interventions (provide notifications, lock phone for increasing amounts of time, or lock phone for remainder of day) to keep users to their self-defined daily time limit for smartphone use. Also provides usage statistics.	Dual-self theory of impulse control (Fudenberg and Levine 2006), commitment devices (Bryan et al. 2010)	experimental	yes
Tseng et al. (2019)	*UpTime*, a browser extension which senses activity and inactivity during computer work and automatically blocks distracting websites at points of transition; a Slack chatbot informs the user of the blocking and provides control if needed.	None	experimental	yes
Kim, Park, et al. (2019)	*Lockntype*, an Android app requesting users to type in a fixed number of varying lengths (0 digits ("press OK to continue"), 10 digits, 30 digits) whenever a target app is launched	Expectancy-value theory (Rayburn and Palmgreen 1984), Uses and Gratifications theory (Wei and Lu 2014), dual systems-theory (Evans 2003)	experimental	yes

Table 2.1: (continued)

Citation	Summary	Guiding conceptual framework	Evaluation	Control group?
Roffarello and De Russis (2019b)	*Socialize* (different to the identically named app above), an Android app for detecting and changing smartphone usage habits - when a habit is detected (e.g., using Facebook and Chrome between 10-12 AM,), the user can define an alternative behavior to be reminded about next time the habit is enacted.	Habit formation (Lally and Gardner 2013)	experimental	no
van Velthoven et al. (2018)	Presents aim, main features, platform, and price for 21 tools for 'regulating phone use' identified by searching through https://alternativeto.net	None	review	-
Biskjaer et al. (2016)	Present a basic typology and preliminary framework for understanding features in 'Do Not Disturb' tools, on the basis of 10 select examples from the Apple App, Chrome Web, and Google Play stores as well as online technology magazines	None (develops their own typology)	review	-

Table 2.1 summarises studies to date that have developed and/or evaluated design patterns for supporting user self-control of digital device use, along with their guiding self-regulation theory/s. I identified these studies by conducting searches on the ACM Digital Library, Web of Science, and Google Scholar using keywords including *mobile app addiction, internet addiction, smartphone use, non-use, intentional use, intervention, self-regulation, self-control*, and *digital wellbeing*, as well as by reviewing the references of listed studies published in 2018 or 2019. In line with the scoping considerations outlined in Chapter 1, I included studies which developed and/or evaluated new or existing design patterns, while excluding studies aimed at regulation of technology use in relation to children/families or distracted driving.

2.3.1 Tools/design patterns investigated

The existing studies have investigated a wide range of design patterns: Overall, some focus on *visualisations of device use* (e.g., Whittaker et al. (2016)'s *MeTime* displayed a floating window of relative time spent in computer applications over the past 30 minutes); others on *blocking distractions* (e.g., Marotta and Acquisti (2017) studied effects of using the commercial tool *Freedom* to block distracting websites among crowdworkers on Amazon's platform Mechanical Turk); and yet others on

goal setting (e.g., Ko, Chung, et al. (2015)'s *NUGU* let users set goals for limiting smartphone use and share goals, contexts, and performance with friends).

Whereas earlier work mainly focused on one specific implementation of a potential design pattern, more recent investigations have moved towards more informative studies of (i) how varying key implementation parameters influences effectiveness, (ii) how interventions can be made more useful by being sensitive to context, and (iii) how cross-device use can be taken into account.

In relation to varying parameters, recent studies have varied *amount of friction* for accessing distraction instead of simply studying binary blocking: Kim, Jung, Ko, et al. (2019) compared effects of blocking target apps at three levels of intensity, and Kim, Park, et al. (2019) compared effects of requiring the user to type in digit combinations of varying lengths before target apps could be accessed.

In relation to context sensitivity, Park et al. (2017) investigated use of built-in smartphone sensors to detect socially appropriate moments to deliver notifications, and Tseng et al. (2019) studied how distraction blocking in work contexts might be made more useful by being automatically triggered at break-to-work transitions.

In relation to cross-device use, Kim, Cho, et al. (2017) investigated benefits of coordinated distraction blocking on personal computers and smartphones, and Kovacs, Gregory, et al. (2019) evaluated potential 'spillover' effects from one device (or one distraction) to another, when applying interventions to reduce use of target apps or websites on smartphones and computers.

2.3.2 Evaluation approaches

In evaluating the effectiveness of such design patterns, most studies (20/29) have taken an experimental approach and compared user behaviour and perceptions when applying a particular intervention to its absence and/or some alternative intervention. Four studies have been purely observational and studied use and perceptions when, e.g., releasing a tool in online stores or deploying it as part of a student well-being campaign. Four studies have focused on (or included) reviews of available tools in online stores and described their features and/or created typologies of functionality.

Two studies evaluated only whether the technical aspects of a proposed intervention worked as intended, but not how it influenced users' behaviour or perceptions.

2.3.3 Findings

Behavioural effects

A basic outcome measured in most studies is time spent and frequency of use overall and/or in specific functionality such as social media. Overall, the existing studies suggest a strong potential for many of the tested strategies to influence these behavioural outcomes in targeted ways.

For example, Kovacs, Wu, et al. (2018)'s *HabitLab*, a Chrome extension and Android app which rotates between many interventions to discover what most effectively reduces users' time spent (from removing newsfeeds to adding countdown timers), was found in controlled field experiments to reduce time spent on goal sites and apps (by 8% on the Chrome version, and 37% on the Android version in one of their studies). Moreover, Kovacs, Gregory, et al. (2019) found that reduced time on goal sites did not 'spill over' to increase time on other distractions or between devices.

Whereas the *HabitLab* investigations binned effects from a range of interventions, other studies point to effects of specific strategies. Thus, studies of *distraction blocking* suggest that this design patterns can reduce both overall device use and use of specific targeted functionality. For example, Tseng et al. (2019) found that when automatically blocking distracting websites during break-work transitions (users could override blocking via a chatbot), users visited distracting sites in 5.5% of transitions, compared to 14.8% without the system and 17.8% when blocking was self-initiated. Perhaps unsurprisingly, it has also been found that when distraction blocking is more difficult for the user to override, time spent is more effectively reduced, compared to 'weaker' solutions, though users generally prefer solutions that provide them some flexibility (Kim, Jung, Ko, et al. 2019). Adding 'friction' rather than blocking distractions per se has similarly been found to exert a potentially powerful influence on use: Kim, Park, et al. (2019) found that requiring users to type in a specific 30-digit sequence, before being allowed to use a target app,

discouraged use in 48% of cases, compared to 27% for 10 digits and 13% for a pause-only version without number input.

The studies of *visualising device use* have found that this design pattern‘s potential to influence behaviour depends heavily on how visualisations are presented. Thus, one study of the commercial tool *RescueTime* found no impact on behaviour, which researchers attributed mainly to participants not engaging with the tool, as its visualisations needed to be actively accessed via a website (Collins et al. 2014). By contrast, Whittaker et al. (2016) found that their tool *MeTime*, which constantly displayed relative time in computer applications in a floating window, effectively reduced time spent in ’non-critical’ applications as well as overall time online. Kim, Jeon, et al. (2016)‘s evaluation of their similar tool *TimeAware* further found that influence on behaviour depended on how information is displayed — a ’negative’ framing in which the widget highlighted time in ‘distracting’ applications increased users’ time in productive applications relative to total computer use, whereas a ‘positive’ framing which highlighted time spent in ‘productive’ applications had no influence on behaviour.

In terms of *goal setting*, the existing studies also suggest potential, depending on the implementation details. Hiniker et al.’s *MyTime* asked users to set a goal for daily time in target apps (with a “Time’s up!” dialog appearing when the limit is hit) and provided a daily prompt asking the user what they would like to achieve. This tool reduced overall daily phone use by 11% (33 minutes), via a selective reduction of time spent in apps users felt was a ‘waste of their time’, while time in apps reported to be a ‘good use of their time’ was unaffected (Hiniker, Hong, et al. 2016). Meanwhile, Ko, Chung, et al. (2015) found that only the social version of their tool *NUGU*, in which users could share their goal for limiting smartphone use with others, significantly reduced usage; an alternative version, which involved only goal setting without the social accountability element, had no effect on behaviour.

Subjective effects

For the present thesis, the central question is how these design patterns affect users' perception of the extent to which they are able to effectively use their devices in line with their goals. One complication is that the existing studies have conceptualised the problem space in somewhat different ways — from supporting productivity in professional or academic settings to improving social interactions — which means that an accordingly broad range of outcome measures have been used to assess user perceptions (from subjective workload to self-reported smartphone addiction). Nevertheless, combined results suggest that their tested interventions have the potential to positively influence users' perceptions of their own device use in at least three directly relevant aspects: (i) increasing awareness of one's patterns of device use, (ii) increasing perceived ability to focus on an intended task and be in control, (iii) preventing 'chains of distraction'.

In terms of *awareness of use*, different types of interventions have been reported by research participants as having beneficial effects. For example, *MeTime*'s ambient window displaying relative usage in different applications (Whittaker et al. 2016) was reported by users to help them be more aware of how they used their computer and keep their usage goals in mind. Subjective reports have also pointed out that visualisations of use should be actionable for increased awareness to be beneficial. Thus, in Collins et al. (2014)'s evaluation of *RescueTime*, participants reported not knowing what to do with the information obtained. Kim, Jeon, et al. (2016) suggested that their finding that an ambient display of time spent influenced behaviour only when time in 'distracting' — as opposed to in 'productive' — applications were highlighted, could be explained by only the former being actionable to users.

Other types of interventions have also been reported to benefit awareness of use, especially in relation to raising awareness of use typically engaged in without conscious intent. For example, Okeke et al. (2018) made smartphones emit intermittent vibrations when a daily limit on Facebook use was hit, which was reported by participants to make them more aware of how they used the

app. Similarly, a preliminary study by Kim, Lee, et al. (2018) studied context-aware blocking on smartphones, in which a lock screen was displayed when a user was stationery for more than 5 minutes, and the user was asked to report purpose for use when unlocking the device. Participants said this intervention was particularly helpful for making them aware of the ways in which they often used their device without purpose.

In terms of perceived *ability to focus* and *be in control* during device use, benefits have in particular been reported in studies of distraction blocking. For example, most participants (74%) in the deployment of Kim, Jung, Jung, et al. (2017)'s blocking app *Let's FOCUS* for smartphones said the tool helped them focus better on class, and in Mark et al. (2018)'s study of the blocking tool *Freedom*, participants who struggled with social media distractions significantly increased feeling of control over computer use with distractions blocked. Kim, Cho, et al. (2017)'s study of *PomodoLock* provided a hint about underlying mechanisms, as participants reported that distraction blocking helped them be in control by alleviating the mental effort ordinarily needed to resist the temptation to check distracting functionality.

In terms of *preventing chains of distraction*, this benefit has been mentioned in several studies. For example, in Mark et al. (2018)'s study of *Freedoom*, participants explicitly said distraction blocking helped them avoid engaging in cascading distractions. Underlying this, Kovacs, Gregory, et al. (2019) noted that many apps and websites that users wish to reduce time on contain 'content aggregators' (e.g., Facebook's newsfeed) that point the user towards a multitude of other potential distractions, and so reducing time on target sites may therefore prevent cascading distraction and more broadly reduce time spent.

2.3.4 From one-size-fits-all to bespoke interventions

As more studies have been conducted, the findings from, especially, later studies have begun to unravel more specific questions related to when and for whom particular interventions are beneficial (cf. Klasnja et al. 2017). We have nowhere near enough evidence to answer such questions conclusively, but the existing findings do allow

us to put together a preliminary picture of some of the considerations for design patterns that relate to (i) level of friction/user flexibility (where a fine balance needs to be struck), (ii) emotional state (where the usefulness of the same tool for the same user may vary over time), and (iii) individual differences (where, in particular, distraction blocking seems to be more useful for people who struggle more with distractions at the outset).

In relation to *level of friction/user flexibility*, the evolving evidence suggests that more intrusive strategies such as blocking need to strike a delicate balance. Some studies have found that when users need to self-initiate blocking of distractions, they simply do not engage with it and fail to benefit. For example, Marotta and Acquisti (2017) found that enforced blocking of Facebook and YouTube during working hours improved MTurk crowdworkers' productivity and earnings, but when participants actively had to choose which websites to block and for how long, there was no effect. A version of Kim, Jung, Ko, et al. (2019)'s *GoalKeeper*, however, which strictly locked out users from target apps for the rest of the day after the daily limit was reached, seemed to be *too* restrictive and was experienced very negatively by many users, eliciting stress and anxiety, partly because it did not accommodate "out of routine" incidents where participants needed to use a particular app after being locked out. By contrast, Tseng et al. (2019)'s *UpTime* was viewed very positively by users — and reduced self-reported stress — despite applying automatic blocking of distractions, perhaps because users here could negotiate an override of the blocking via a chatbot. There may not be a simple answer to how blocking tools can strike the right design balance — whereas participants in Kim, Jung, Ko, et al. (2019)'s study of *GoalKeeper* preferred a medium level of friction where they still retained some control, some also said they would find the strong-lockout version highly useful in specific situations where a particularly high level of focus is required, such as during exam periods.

In relation to *emotional state*, the evolving evidence suggests that this affects strategies' usefulness, in somewhat complex ways. Thus, some participants using *PomodoLock* (Kim, Cho, et al. 2017) to block distractions said they used the tool

when they were 'in a relaxed state without time pressure' — when they were pressed for time, the tool was not necessary because the perceived external pressure already forced them into a state of concentration high enough to avoid self-interruptions (perhaps somewhat in contradiction to those of Kim, Jung, Ko, et al. (2019)'s participants who wanted strong-lockout during stressed exam periods). Similarly, Kim, Park, et al. (2019)'s study of varying levels of effort before target apps could be opened found that the effect of discouraged use was particularly strong when users were tired. More evidence needs to be collected, but findings here may usefully be compared to research from the self-control literature on how emotional states influence the ability to avoid temptation (e.g., Facebook users find it more difficult to self-regulate use of the network when in negative mood, Ryan et al. (2014); cf. Tice et al. (2001)).

Finally, recent studies have begun to investigate how design patterns' effectiveness depends on individual difference. Thus, exploratory findings from studies of distraction blocking suggest the biggest benefits accrue to users who struggle the most with handling distractions at the outset: Mark et al. (2018) reported that those participants who experienced the greatest increase in focus with distractions blocked were those who self-reported as being more susceptible to social media distractions. Similarly, Kim et al. (2017) reported that the biggest productivity increase from using *PomodoLock* accrued to those who performed worst at baseline. Though an alternative interpretation in these two studies is a 'ceiling' effect — if one already scores high on some measure, there may be less room for improvement when an intervention is applied — Kim, Park, et al. (2019) found complementary evidence: whereas requiring participants to type in a greater number of digits before being allowed to used an app led to the greatest decline in use for most participants, there was a subgroup for whom a simple pause-only intervention achieved the same effect size. Thus, there may be some spectrum of individual differences that predict how intrusive design patterns should be to be effective.

2.3.5 Guiding theory

In this section, we make a few remarks about use of theory in HCI before providing an overview of the theory existing studies have applied to guide development and/or evaluation of interventions, as well as of theory applied in HCI research on behaviour change more generally. To pre-empt the findings, around half of the existing studies did not specify a guiding framework. Among those that do, a wide range of conceptual frameworks have been applied, and specific constructs are often presented as being instrumental to the development of an intervention. However, conceptual frameworks that explicitly address internal struggle between longer-term goals and conflicting impulses and habits — such as dual systems theories — have rarely been applied. More application of such frameworks has been called for by HCI researchers studying digital self-control as well as behaviour change more widely.

The role of theory

Research on design patterns for digital self-control represents a subset of HCI research on digital behaviour change interventions (Pinder, Vermeulen, Cowan, and Beale 2018). In HCI research on behaviour change, theory has been used for three main purposes (cf. Hekler et al. 2013): (i) to guide the design of digital systems, (ii) to guide evaluation of such systems, (iii) to define target users. Using theory for these purposes is not trivial, as theories' level of specificity leave greater or lesser room for interpretation when using them to e.g. provide guidance on which functionality to support and how to implement it.

Hekler et al. (2013) suggest that behavioural theories reside on a spectrum of generality, from *meta-models* to *empirical findings*: *Meta-models* represent the highest level of generality and are theories that organise multiple levels of influence on individuals' behaviour. For example, the 'social ecological model' (Sallis and Owen 1997) is a popular model in health-related behavioural science, which organises influences on behaviour into micro-level factors such as a person's genetics, meso-level factors such as interpersonal relationships, and macro-level factors such as public policy and culture. Meta-models are useful for identifying the 'lens' through

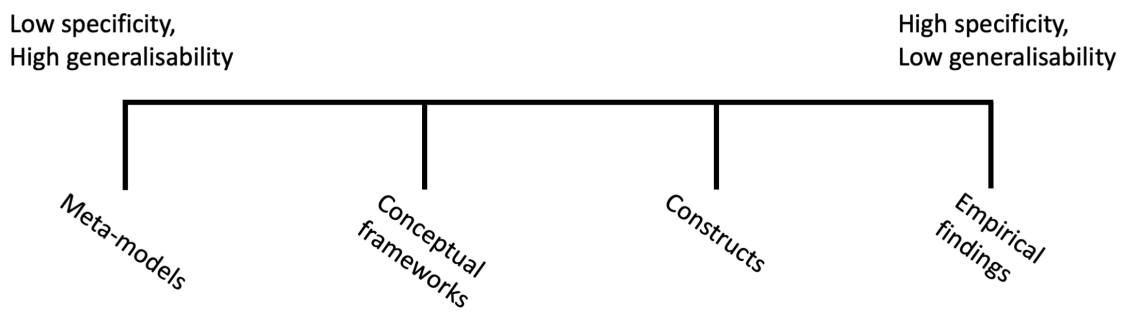

Figure 2.1: Spectrum of specificity in behavioural theories. Adapted from Hekler et al. (2013).

which a researcher considers a given phenomenon in their application of more specific theories.

Conceptual frameworks zoom in on one or two levels of influence and provide a more specific account of how fundamental building blocks, or *constructs*, of a theory are interrelated. Conceptual frameworks applied in existing work on design patterns for digital self-control include Social-Cognitive Theory (Bandura (1991); applied by Ko, Chung, et al. (2015) in developing *NUGU*) and Prospect Theory (Kahneman and Tversky (1979); applied by Kim, Jeon, et al. (2016) in developing *TimeAware*).

Constructs are the basic mechanisms postulated by a conceptual framework as influencing behaviour. For example, Social-Cognitive Theory postulates the construct of 'self-efficacy' — a person's assessment of their ability to perform a given behaviour in a given context — as one of the key determinants of self-regulation.

Empirical findings reside at the lowest level, as some empirical work —– often ethnographic and other qualitative approaches — is carried out to produce concrete and contextually-specific data where previously developed theories are insufficient to guide research. In turn, such data can provide a starting point for creation of new constructs and theories, allowing specific findings to be abstracted to create generalised knowledge (Hekler et al. 2013).

This spectrum may be useful as we consider the use of theory in previous studies, as it helps clarify which influences on behaviour are being excluded from a given conceptual framework.

Application of behavioural theory in existing studies of digital self-control design patterns

Table 2.1 includes the conceptual frameworks applied in existing studies. In 14 out of 29 studies, no conceptual framework was specified, with tool development and/or evaluation informed only by user-centered design methods such as surveys and interviews with target users and/or design experts, or (in the case of reviews of existing tools) bottom-up clustering of design features. The remaining studies referred to a wide range of frameworks drawn from psychology (e.g., Social-Cognitive Theory, classical conditioning, the strength model of self-control, dual systems theory), cognitive neuroscience (e.g., attentional resource theory, cognitive load theory, inhibitory brain function), (behavioural) economics (e.g., rational choice, expectancy-value theory, prospect theory), behaviour change (e.g., goal setting theory), and addiction research (e.g., the relapse prevention model). In some studies, constructs from these frameworks have directly informed design. For example, Kim, Jeon, et al. (2016)'s comparison of effects of visualising time spent in 'productive' vs. in 'distracting' applications drew on prospect theory's construct of 'loss aversion' which describes differential sensitivity to gains and losses.

Applying a meta-model lens, we may observe that all conceptual frameworks applied in existing studies focus on the individual level. For example, even Social-Cognitive Theory, in which social influences on behaviour feature prominently in the form of social learning, views such influences through the lens of individual cognitive processes. To make sense of the challenge of digital self-control, we do need to keep in mind how larger dynamics in the attention economy incentivise design patterns which nudge users to behave in ways that are often in conflict with their personal usage goals (cf. section 2.1.3). However, since the focus of the present thesis is how to support individuals' ability to exert self-control over device use, we similarly consider those dynamics in terms of how the resulting designs affect individuals. Therefore, the use of individual-level conceptual frameworks in existing studies aligns with the goals of the present thesis.

Within these individual-level frameworks, however, we may consider which aspects are included and which are left out. From the point of view of self-control research, the central phenomenon to be addressed is how designs may support users in resolving situations of conflict between momentary urges and more enduringly valued goals in line with the latter (Duckworth and Steinberg 2015). Here, the empirical work in self-control research suggests that key components relate to interactions between different goals, impulses, and unconscious habits (Duckworth, White, et al. (2016); cf. Lukoff et al. (2018); Oulasvirta et al. (2012))

Considering the conceptual frameworks applied in existing research, however, most do not focus on interactions between habits and conscious intentions. For example, whereas Kim, Jeon, et al. (2016)'s use of framing effects from prospect theory was useful to their design of *TimeAware*, this framework provides a highly zoomed-out view of overall influence of gains and losses on behaviour that excludes underlying cognitive mechanisms. By contrast, Mark et al. (2018) applied an Attentional Resource model (Wickens 1980) to explain why distraction blocking can be helpful (blocking frees up resources ordinarily used to attend to distractions), which provides a highly zoomed-in view of specific constraints on working memory capacity that excludes the bigger picture of goals and impulses.

Whereas these conceptual frameworks have proven useful for guiding intervention development and evaluation, a framework which explicitly includes the internal struggles described in self-control research might be useful for the purpose of considering the broader design space for design patterns for digital self-control. Among existing studies, only the dual systems framework used by Kim, Jung, Ko, et al. (2019) to frame the challenge addressed by their tool *GoalKeeper* provides this. Previous conceptual work in HCI on how 'design frictions' or 'microboundaries' may be used to support self-control over device use (Cox et al. 2016) have suggested that dual systems theory, which conceptualises human behaviour in terms of interactions between rapid, automatic 'System 1' processes and slower, more deliberate 'System 2' processes, could prove useful. Kim, Cho, et al. (2017) referred to the 'strength model of self-control' in interpreting the results of their evaluation of *PomodoLock*,

which has affinity with dual systems theory and postulates that the ability to inhibit impulses via conscious self-control fluctuates over time due to the depletion of a limited resource. However, in recent self-control research, the strength model is being replaced by motivational accounts based instead of fluctuations in the 'expected value of control' (see Chapter 3).

Theory in digital behaviour change interventions

A large body of HCI work exists on how digital tools can assist behaviour change in general (cf. Consolvo et al. 2009; Epstein et al. 2015; Kersten-van Dijk et al. 2017; Yardley et al. 2016). A main focus within such research on 'Digital Behaviour Change Interventions' (DBCIs, Pinder, Vermeulen, Cowan, and Beale (2018)) is health, for example in relation to how digital interventions may help users exercise more (Consolvo et al. 2009), quit smoking (Abroms et al. 2011; Heffner et al. 2015), eat more healthily (Coughlin et al. 2015), cope with stress (Gimpel et al. 2015), or manage chronic conditions (Wang, Wang, et al. 2014).

Since digital self-control tools can be seen as a subset of DBCIs, which focuses specifically on behaviour change in relation to digital device use, application of theory within this research area is relevant to the present thesis. One recent review of 85 DBCI studies (Orji and Moffatt 2018) found the Transtheoretical Model (or Stages of Change, Prochaska et al. (1993)) to be the most commonly referenced (13/85 papers), followed by Goal Setting Theory (Locke and Latham 2002) (5/85) and Social Conformity Theory (Asch 1955; Epley and Gilovich 1999) (3/85). 60% (51/85) did not specify any theoretical basis (cf. Schueller et al. 2013; Wiafe and Nakata 2012), and none specified dual systems theory (cf. Pinder, Vermeulen, Cowan, and Beale 2018). The review also found that among studies which did specify underlying theories, most only mentioned them without explaining how the theoretical constructs informed the design and/or evaluation of actual intervention components (Orji and Moffatt 2018).

Another recent comprehensive review (Pinder, Vermeulen, Cowan, and Beale 2018) noted that most theories applied in DBCI research assume a rational,

deliberative process as a key determinant of behaviour (e.g., the Transtheoretical Model, Prochaska et al. (1993), or the Theory of Planned Behaviour, Ajzen (1991)). The authors argued (after extensive review and discussion) that dual systems theory could be well placed to guide DBCI research aimed at long-term behaviour change through breaking and forming habitual behaviour (Pinder, Vermeulen, Cowan, and Beale 2018; Stawarz, Cox, et al. 2015; Wood and Rünger 2016; cf. Webb et al. 2010).

2.4 Research gaps

In considering current limitations and research opportunities, we may keep advice from HCI work on behaviour change in mind: in assessing the state of HCI research on health behaviour change, Klasnja et al. (2017) pointed out that the goal is to generate *usable evidence*, that is, 'empirical findings about the causal effects of behaviour change techniques and how those effects vary with individual differences, context of use, and system design'. In other words, our findings should enable researchers, designers, and even end-users to make decisions about which design elements to include in new systems and how to implement them to maximise their potential to be effective for specific user groups. To generate such evidence, and allow for effective knowledge accumulation, studies should be carefully designed to allow us to infer whether observed changes in behaviour are due to an intervention of interest rather than other factors (Klasnja et al. 2017; cf. Cockburn et al. 2018; Kay et al. 2016; Orben 2019).

With this in mind, we highlight four areas of limitations and corresponding research opportunities motivating the research presented in this thesis.

2.4.1 (*Theoretical*) Exploring the usefulness of dual systems theory

As noted, frameworks which explicitly address interaction between conflicting goals, impulses, and habits have rarely been applied in existing studies. This is somewhat surprising, as such interactions are at the very core of self-control struggles. Among currently used frameworks, only Kim, Jung, Ko, et al. (2019)'s use of dual

systems theory explicitly focuses on such interactions. Existing theoretical work on digital self-control (Cox et al. 2016) and digital behaviour change interventions (Pinder, Vermeulen, Cowan, and Beale 2018) have called for wider application of dual systems theory.

Chapter 3, 4, 5, and 6 of this thesis explore this research opportunity, by summarising a modern version of dual systems theory and applying it as a lens for organising, evaluating, and generating hypotheses in relation to design patterns for digital self-control.

2.4.2 (*Empirical*) Broad assessment of design patterns and implementations

Ideally, we want in hand clear evidence of the effects of representative examples of all plausible strategies and implementations across the entire design space of digital self-control interventions (Kim, Jung, Ko, et al. 2019; Mark et al. 2018). The existing studies have made a good start, but some intervention ideas that are prominent among digital self-control tools in online stores (e.g., associating device use with the well-being of a virtual creature, as illustrated by *Forest* which has over 10 million users on Android alone, Seekrtech (2018)) have yet to be evaluted in HCI research. More generally, whereas controlled studies are appropriate and feasible for evaluating and comparing a small number of strategies, they are difficult to scale to broadly assess large numbers of strategies and implementations.

One opportunity for a complementary approach, which might help scope the range of strategies and implementations to explore in controlled studies, is to investigate the landscape of digital self-control tools on app and web stores. Here, widely available tools potentially represent hundreds of thousands of natural 'micro-experiments' (Daskalova 2018; Lee, Walker, et al. 2017) in which individuals self-experiment with apps that represent not only one or more intervention strategies, but particular designs of those strategies. Other areas of HCI research have fruitfully taken this approach (e.g. research on mental health, Bakker et al. (2016); Lui et al. (2017)), but it has so far been under-explored in relation to digital self-control.

Chapters 3 and 4 explore this approach by analysing design features, user numbers, ratings, and reviews for a large sample of digital self-control tools on the Google Play, Chrome Web, and Apple App stores. Chapter 6 further explores how a broad sample of existing interventions can be used to elicit personal needs for such interventions in a workshop setting.

2.4.3 (*Empirical*) Understanding individual differences

Another research opportunity relates to understanding individual differences, where open questions include, e.g., whether some types of interventions are only effective for some people, and how widely people's definitions of 'distraction' in relation to digital device use vary (Cecchinato, Rooksby, et al. 2019; Lukoff 2019; Mark et al. 2018). Existing research does not yet allow us to confidently answer such questions, and so additional collection of evidence is required to substantiate exploratory findings from intervention studies (e.g., Hiniker, Hong, et al. 2016; Kim, Cho, et al. 2017; Mark et al. 2018) and ethnographic work (e.g., Lukoff et al. 2018; Tran et al. 2019).

Chapters 4, 5 and 6 contribute to this task: In Chapter 4, thematic analysis of user reviews for DSCTs in online stores contributes evidence on how people vary in the types of design patterns they seek; in Chapter 5, we draw out some of the individual variation emerging from, in particular, the semi-structured interviews with participants in a study of UI interventions for Facebook; and in Chapter 6, we present findings from workshops in which we investigated personal digital self-control struggles and used a card sorting task to elicit individual differences in preferences among potential interventions.

2.4.4 (*Methodological*) Improving evaluation to generate usable evidence

Ensuring experimental studies allow for causal inference

Following Klasnja et al. (2017)'s assessment of HCI research for health behaviour change, we may consider the degree to which exiting studies allow us to infer which components of interventions for digital self-control are effective. To this effect,

I examined whether existing studies using an experimental design (20 out of 29 studies) included control conditions in their study designs. That is, whether they compared the effects of an intervention not simply to its absence, but to some alternative intervention, which is important, because some effects result simply from how participants believe they are expected to behave ('demand characteristics', Nichols and Maner (2008)). Indeed, many of the outcomes we are most interested in (e.g., perceived control) may be highly sensitive to demand characteristics ('come to think of it, I think I *did* feel more in control, now that you ask. Yes, I really did!', Nichols and Maner (2008)). Moreover, asking participants to report on what components of an intervention made a difference to their behaviour is subject to biases and limitations of self-report (e.g., people may not remember clearly how they felt during specific moments of device use, some effects may occur outside of conscious awareness, etc., Gibbons (1983)).

We may try our best to infer causal components of an intervention by triangulating different types of data — for example, comparing evidence from behaviour, survey responses, and qualitative interviews (Mathison 1988; Munafò and Davey Smith 2018). However, interpreting findings is much more straightforward when appropriate control conditions are included at the outset (cf. Klasnja et al. 2017).

Examining the designs of current studies, progress has been made from 2018 and later — just like there is a move away from proof-of-concept studies of a single interventions towards comparing different implementations of the same design pattern, study designs have become more carefully controlled. Thus, before 2018, only 1 out of 10 experimental studies (namely Marotta and Acquisti 2017) included a control condition in their study designs. These concerns are beginning to be addressed in studies from 2018 onwards, where 7 out of 10 experimental studies included control conditions.

Moreover, concerns have been reported over how the use of null-hypothesis significance testing (NHST) to infer effects of an intervention, in combination with a bias towards rejecting studies for publication that fail to report positive results, may lead experimenters to engage in problematic forms of 'HARKing', or Hypothesising

After the Results are Known (Kerr 1998). That is, researchers may conduct a large number of analyses and report only those that obtain significant results, without disclosing how many tests were run, while — consciously or unconsciously — reframing the experimental intention to match the outcome (Cockburn et al. 2018; Orben and Przybylski 2019a). Whereas exploratory research is essential to the scientific process, presenting results of exploratory data analyses as if they were confirmatory tests of an a priori hypothesis commits the 'Texas sharp shooter' fallacy (firing ones bullets and then drawing the target afterwards) and invalidates the ability of NHST to draw reliable and repeatable inferences (Frankenhuis and Nettle 2018; Simmons et al. 2011).

A simple remedy is to distinguish clearly between exploratory and confirmatory work — ideally through public pre-registration of planned analyses in advance of data collection and/or analysis (Cockburn et al. 2018). Another is to conduct replication studies, testing the reliability of previously published findings. Of the 20 experimental studies, 2 studies were explicitly exploratory (Roffarello and De Russis (2019a) and Mark et al. (2018); the latter called for future confirmatory studies of their findings) while the remainder provided no explicit considerations of exploratory vs confirmatory findings. No studies referred to expected effect sizes as guiding their participant sample sizes, and none were replication studies (Tseng et al. (2019) did include a version of Kim, Cho, et al. (2017)'s *PomodoLock* as a control condition in their study of *UpTime*, but this was a re-implementation that excluded core design features from the original study).

Open and transparent research

As called for in related research on digital well-being (Orben 2019), research on digital self-control may benefit from adopting open science practices: making materials, data, and analysis pipelines openly and transparently available can facilitate faster progress, reduce errors, and increase quality of research (cf. Schimmack 2019). In the case of digital self-control research, when considering the multitude of ways a design pattern may be implemented, knowledge accumulation between

studies will be much improved if researchers are able to start out with the source code used by others rather than starting from scratch, as this may reduce noise from superficial implementation differences when comparing interventions. Only 1 (*HabitLab*, Kovacs (2019)) out of the 29 existing studies made materials, data and/or analysis scripts openly available.

In this thesis, Chapter 5's mixed-methods study of interventions for self-control on Facebook attempts to improve on the methodology of existing studies by including a control condition and triangulating evidence from usage logging, survey responses, and qualitative interviews. Chapter 3 and 5, which represent published work, make their materials, anonymised data, analysis pipelines, and manuscript source files (in R Markdown) available for other researchers via the Open Science Framework. Finally, this thesis itself is written as a reproducible document using R Markdown (via the R package `oxforddown`, Lyngs (2019c)), and its source files, supporting data, and materials are available via the Open Science Framework on osf.io/ed3wh/.

2.5 Summary

In this chapter, we have reviewed background literature relevant to this thesis' investigation of how existing digital self-control tools can help us identify effective design patterns, grouped into four areas: (i) current evidence on the prevalence of self-control struggles in relation to digital device use, (ii) how to define the goal that design patterns for supporting self-control should strive to achieve, (iii) empirical insights generated by existing studies of specific interventions, (iv) theory applied in existing studies to guide development and/or evaluation of interventions. We then highlighted the limitations and opportunities that motivate the research presented in subsequent chapters.

In terms of evidence on struggles, a growing body of survey and qualitative evidence suggest a substantial proportion of people routinely struggle with exercising self-control over digital device use, with most recent studies focusing on smartphone use. Such struggles often takes the form of engaging in overly frequent check-ins

with minimal awareness, or feeling 'sucked in' by one's devices and using them for longer than intended. These struggles are reflected in a growing niche for 'digital self-control tools' on app and browser extensions stores which provide distraction blocking, visualisation tools, goal reminders, gamification, and other interventions meant to help people exercise self-control over device use. Increasing public debate on the topic recently led Apple, Google, and Facebook to begin incorporating similar 'digital wellbeing' features into their services. Two immediate causes of digital self-control struggles are that (i) smartphones and laptops make endless information, entertainment, and social connectivity available instantly and permanently, which existing psychological work on self-control suggests will come with substantial self-control challenges, and that (ii) the dynamics of the 'attention economy' incentivise companies to design services that nudge users into frequent and extensive use.

In terms of defining the goal of digital self-control strategies, several researchers have argued that simply helping people reduce 'screen time' is not helpful: as more and more activities become digitally mediated, screen time becomes a less and less useful indicator of whether people's use aligns with their intentions. HCI research on decision support and recommender systems, which has tried to bridge the gap between what users 'actually' do and what they 'really' wanted, has found that relying purely on behavioural indicators to understand users' intentions is problematic, but tended to avoid specifying what better alternatives look like. Standard definitions from fundamental research on self-control suggest that designing for digital self-control means to **design in ways that help users align their device use with enduringly valued goals in the face of momentarily conflicting impulses and goals**. Despite its shortcomings (which we discuss in Chapter 7), we adopt this as our working definition in the present thesis.

In terms of findings so far, current studies have established a solid potential for specific design patterns to assist people in aligning their device use with their longer-term goals. A range of approaches has been studied, mainly visualising use, goal setting and reminding, blocking access to distractions, or 'nudging' users by varying friction to distractions. The studies have found that such design patterns can

significantly influence behaviour in a targeted way, and improve people's awareness of their patterns of use, as well as their perceived ability to stay in control and maintain focus. Moreover, reducing time on sites and apps that people wish to spend less time have been found to not simply 'spill over' to other distractions. However, we are in the early days of collecting evidence on the potential impact across the design space of such interventions, the contexts in which they are useful, and the extent to which their effectiveness depends on individual difference.

In terms of application of theory, around half of existing studies did not specify any conceptual frameworks as guiding their work. Among those that do, a wide range of frameworks have been applied, with specific constructs often presented as instrumental to the development of an intervention. However, frameworks that explicitly address internal struggle between longer-term goals and conflicting impulses and habits have rarely been applied. HCI researchers working on digital self-control, as well as on behaviour change more widely, have suggested that dual systems theory — which only one existing study explicitly referred to — might be useful in future research as a framework which readily address conflicting goals, habits, and impulses.

On the basis of this review, we highlighted four areas of current limitations (and corresponding research opportunities) which motivate the thesis research:

1. (*Theoretical*) **Exploring the utility of dual system theory**
   Even though interactions between conflicting goals, impulses, and habits are at the core of self-control struggles, conceptual frameworks that explicitly address such interactions have rarely been applied.
   Chapter 3 summarises a modern version of dual systems theory, and Chapter 3, 4, 5, and 6 apply it as a lens for organising, evaluating, and generating hypotheses for design patterns.

2. (*Empirical*) **Broadly assessing possible design patterns and implementations**
   The design space for digital self-control interventions is vast, but controlled

studies are difficult to scale to broadly assess large numbers of design patterns and implementations.

Chapter 3 and 4 explore a complementary approach: investigating the landscape of DSCTs on app and web stores, which represent hundreds of thousands of natural 'micro-experiments'. Chapter 6 further uses a broad sample of existing interventions to elicit personal needs for such interventions in a workshop setting.

3. (*Empirical*) **Investigating individual differences**

   A few studies suggest the effectiveness of their tested strategies is contingent on personality differences, but more evidence is needed to assess how reliable the initial findings are, and how much people's definitions of 'distraction' vary in the first place.

   Chapter 4 contributes evidence via thematic analysis of user reviews of digital self-control tools in online stores, Chapter 5 presents evidence from semi-structured interviews in a study of UI interventions for Facebook, and Chapter 6 presents results from four 'Reducing Digital Distraction' workshops which includes elicitation of individual preferences among existing interventions in a card sorting task.

4. (*Methodological*) **Improving evaluations to generate usable evidence**

   There is room for improvement in relation to making evaluation studies robust and embracing open science practices.

   Chapter 3 and 5, which represent published work, make materials, data, analysis pipelines, and manuscript source files openly available. Moreover, this thesis' source files, supporting data, and materials are available as a repository on the Open Science Framework, osf.io/ed3wh.

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3

Characterising the Design Space

Contents

3.1 Introduction

To answer this thesis' main research question of how existing digital self-control tools can help us identify effective design patterns for supporting self-control over digital device use, we begin in this chapter by drawing on dual systems theory and exploring how it can be used to systematise and classify existing tools. We start by outlining the basics of the underlying psychological research. In doing so, we extend current applications of dual systems theories in research on digital behaviour change interventions (DBCIs) (Adams et al. 2015; Cox et al. 2016; Pinder, Vermeulen, Cowan, and Beale 2018; Pinder, Vermeulen, Cowan, Beale, and Hendley 2017) with the concept of 'expected value of control', which the neuroscience literature considers central in explaining why success at self-control fluctuates over time and with emotional state (Botvinick and Braver 2015; Hendershot et al. 2011; Inzlicht, Schmeichel, et al. 2014; Ryan et al. 2014; Shenhav et al. 2013; Tice et al. 2001). An overview of the resulting model is shown in Figure 3.1.

Subsequently, we review current digital self-control tools on the Chrome Web, Google Play, and Apple App stores, and apply the dual systems framework to organise and explain common design features, before pointing out gaps and opportunities for future work.

3.2 An integrative dual systems framework for digital self-control

3.2.1 System 1 and System 2

The core of dual systems theories is a major distinction between swift, parallel and non-conscious 'System 1' processes, and slower, capacity-limited and conscious 'System 2' processes (Cooper, Ruh, et al. 2014; Kahneman 2011; Miller and D'Esposito 2005; Miller and Cohen 2001; Shea et al. 2014; Shiffrin and Schneider 1977; Smith and DeCoster 2000).[1]

[1]The related 'Nudge theory' (Sunstein and Thaler 2008) draws upon dual systems theories to describe how to exploit System 1 and sometimes System 2 processes to guide people towards a

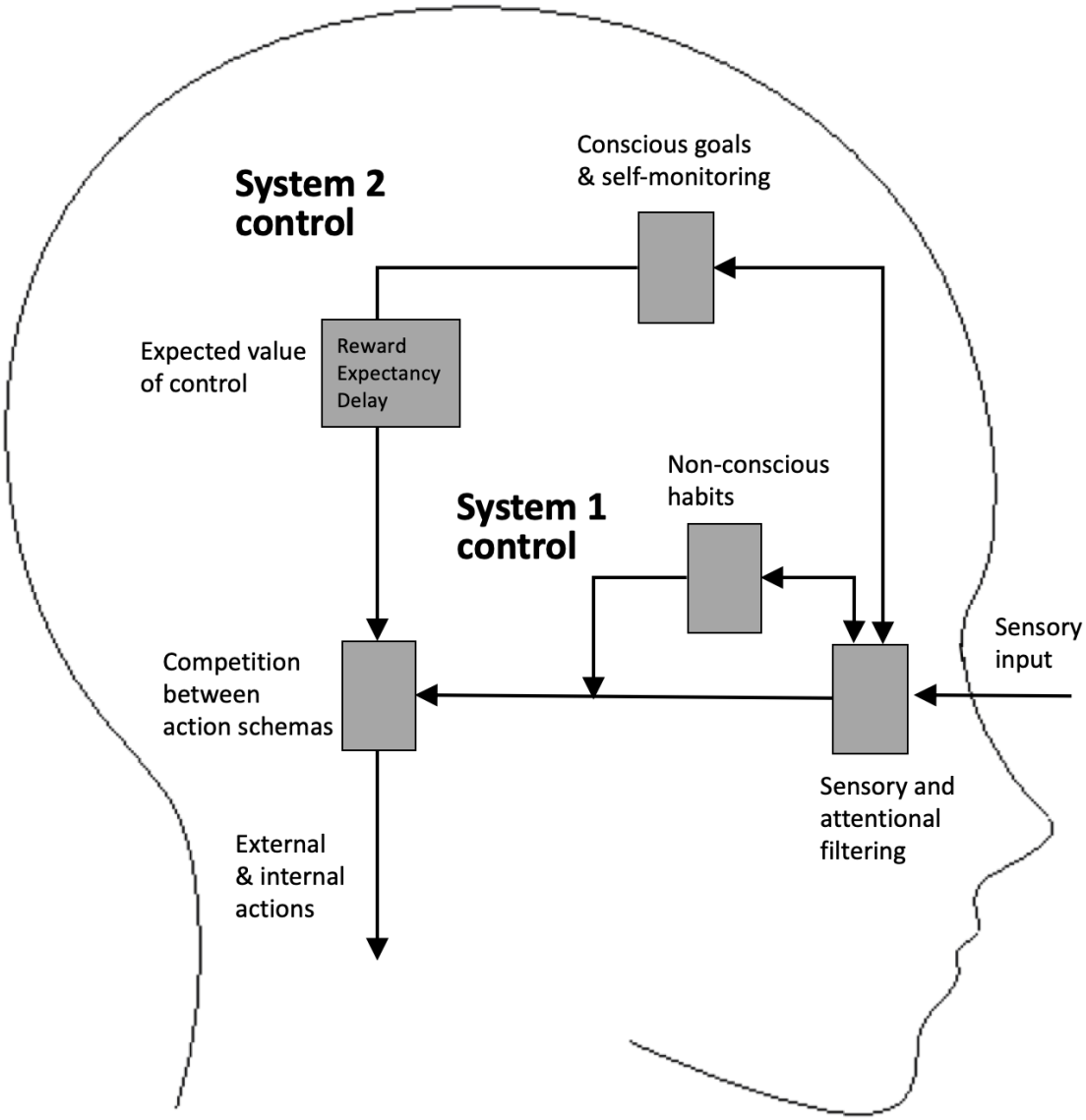

Figure 3.1: An extended dual systems model of self-regulation, developed from Shea et al. (2014) and Norman and Shallice (1986). System 1 control is rapid and non-conscious, whereas System 2 control is slower, conscious, and capacity-limited. The strength of System 2 control is mediated by the expected value of control. Both systems influence competition between action schemas, the outcome of which causes behaviour.

System 1 control is driven by environmental inputs and internal states along with cognitive pathways that map the current situation to well-learned habits or instinctive responses (Miller and Cohen 2001). Behaviour driven by System 1 is often called 'automatic', because System 1 control allows tasks to be initiated or performed without conscious awareness and with little interference with other tasks (Norman and Shallice 1986). Instinctive responses like scratching mosquito bites, or frequent patterns of digital device use like picking up one's smartphone to check for notifications, can happen automatically via System 1 control (cf. Botvinick and Braver 2015; Oulasvirta et al. 2012; Van Deursen et al. 2015).

System 2 control is driven by goals, intentions, and rules held in conscious working memory (Baddeley 2003; Miller and D'Esposito 2005). From these central representations, signals are sent to cognitive systems that process sensory input, memory retrieval, emotional processing, and behavioural output, to guide responses accordingly (Miller and Cohen 2001). System 2 control is necessary when a goal requires planning or decision-making, or overcoming of habitual responses or temptations (Norman and Shallice 1986), for example if one has a goal of not scratching mosquito bites or not checking a smartphone notification.

3.2.2 Action schema competition

From a neuroscience perspective, the building blocks of behaviour are hierarchical *action schemas*, that is, control units for partially ordered sequences of action that achieve some goal when performed in the appropriate order (Cooper and Shallice 2000; Norman and Shallice 1986). Action schemas exist at varying levels of complexity, from simple single-action motor schemas for grasping and twisting, to higher level schemas for, e.g., preparing tea by filling and boiling a kettle (Botvinick 2008; Shallice and Cooper 2011). The schemas compete for control over behaviour in a 'competitive selection' process in which schemas act like nodes in a network, each with a continuous activation value (Shallice and Cooper 2011), and the 'winner' is the node with the strongest activation (Knudsen 2007; Pinder, Vermeulen, Cowan,

desired action (cf. Adams et al. 2015).

and Beale 2018). Schema nodes are activated by a number of sources, including sensory input via System 1 processes ('bottom-up'), 'parental' influence from superordinate schemas in the hierarchy, and top-down influence from System 2 control (Cooper and Shallice 2000; Shallice and Cooper 2011).

3.2.3 Self-regulation and self-control

Following others, we use *self-regulation* as umbrella term for regulatory processes in the service of goal-directed behaviour, including automatic System 1 habits, and *self-control* more restrictively for conscious and deliberate System 2 control in situations where immediate impulses conflict with enduringly valued goals (Baumeister, Vohs, et al. 2007; Duckworth, Gendler, et al. 2014; Hagger, Wood, et al. 2010; Milyavskaya and Inzlicht 2018). For example, if a person wishes to be less distracted by her smartphone in social situations, and through repetition has acquired a habit of turning the phone face-down to the point that she now does it without conscious attention, this counts as self-regulation. If in a given moment she feels an urge to flip it over and check for notifications, but consciously suppresses this impulse and does not act on it, this counts as self-control.

Self-regulation and self-control are mediated by feedback functions for monitoring the state of oneself and the environment, comparing this state to goals and standards (cf. Shea et al. 2014), and acting to modify the situation accordingly (Carver and Scheier 1981; Powers 1973; cf. cybernetic models of behaviour control, cf. Baumeister and Exline 2000; Carver and Scheier 1998; Inzlicht, Legault, et al. 2014).

3.2.4 Attentional filtering

For goals, rules, or intentions to guide System 2 control, they must first enter working memory (Baddeley 2003; Miller and D'Esposito 2005). Entry of information from the external world, internal states, or memory stores into working memory is itself a competitive process, in which the signals with the highest activation values are given access by attentional filters (Constantinidis and Wang 2007; Knudsen 2007; Miller and Cohen 2001):

Automatic bottom-up filters look out for stimulus properties that are likely to be important, either through innate sensitivities (e.g., sudden or looming noises) or learned associations (e.g., a smartphone notification) and boost their signal strength (Knudsen 2007). In this way, some stimuli may evoke a response strong enough to gain automatic access to working memory even while we have our minds on other things (Egeth and Yantis 1997; Itti and Koch 2001). For example, clickbait may use headlines and imagery with properties that makes bottom-up attention filters put its information on a fast track to conscious working memory or trigger click-throughs via System 1 control (cf. Blom and Hansen 2015).

Conscious System 2 control can also direct attention towards particular internal or external sources of information (e.g., focusing on a distorted voice in one's cellphone on a crowded train), which increases the signal strength of those sources and makes the information they carry more likely to enter working memory (Corbetta et al. 1991; Knudsen 2007; Müller et al. 2005).

3.2.5 Self-control limitations and the Expected Value of Control

A central puzzle is why people often fail to act in accordance with their own valued goals, *even when they are aware of the mismatch* (Duckworth, Gendler, et al. 2016). According to current research on cognitive control, the two key factors to answer this question are (i) limitations on System 2 control in relation to *capacity*; and (ii) fluctuations due to *emotional state and fatigue* (Botvinick and Braver 2015).

Capacity limitations The amount of information that can be held in working memory and guide System 2 control, is limited (classically 'seven, plus or minus two' chunks of meaningful information, Cowan (2010); Miller (1956)). Therefore, self-control can fail if the relevant goals are simply not represented in working memory at the time of action (Kotabe and Hofmann 2015). This is one explanation for why people often struggle to manage use of e.g. Facebook or email — one opens

the application with a particular goal in mind, but information from the newsfeed or inbox hijacks attention and crowds out the initial goal (cf. section 5.5.8).

Fluctuations due to emotional state and fatigue System 2 control often suffers from fatigue effects if exerted continuously (Blain et al. 2016; Chance et al. 2012; Dai et al. 2015; Hagger, Wood, et al. 2010; Hockey 2013) and also fluctuates with emotional state (Tice et al. 2001). For example, negative mood is a strong predictor of relapse of behaviour people attempt to avoid (Hendershot et al. 2011; Miller, Westerberg, et al. 1996; Tice et al. 2001), and studies of Facebook use have specifically found that users are worse at regulating the time they spend on the platform when in a bad mood (Ryan et al. 2014; cf. Montag et al. 2017)

The emerging consensus explanation of these fluctuations is that the strength of System 2 control is mediated by a cost-benefit analysis of the outcome that exercising self-control might bring about (Botvinick and Braver 2015), known as the **expected value of control** (EVC) (Shenhav et al. 2013)[2]. The research suggests that EVC is influenced by at least three major factors:

First, EVC increases the more **reward** people perceive they could obtain (or the greater the loss that could be avoided) through successful self-control (Adcock et al. 2006; Botvinick and Braver 2015; Padmala and Pessoa 2010, 2011). To illustrate, consider 'phone stack', a game in which a group dining at a restaurant begin by stacking up their phones on the table. The first person to take out their phone from the stack to check it, has to pay the entire bill (Ha 2012; Tell 2013). This game aids self-control over device use by introducing a financial (and reputational) cost which adjusts the overall expected value of control (cf. Ko, Chung,

[2]The alternative and influential 'ego-depletion' explanation proposed in the 'strength model of self-control' (Baumeister, Vohs, et al. 2007) suggests that System 2 control relies on a limited resource that can be depleted, and which has a 'refraction period' before optimal self-control can again be exercised (Hagger, Wood, et al. 2010). This model has intuitive appeal but has not withstood scrutiny (Lurquin and Miyake 2017), as original studies have failed to replicate (Hagger, Chatzisarantis, et al. 2016; Xu, Demos, et al. 2014), depletion effects have been shown to be reversible by increasing the rewards for sustained performance (Hagger, Wood, et al. 2010; Muraven and Slessareva 2003), and the purported physical resource underlying the effect has failed to be discovered (Lange and Eggert 2014; Molden et al. 2012).

et al. (2015)'s app *NUGU*, which leveraged social incentives to help participants reduce smartphone use, see Table 2.1).

Second, EVC increases the greater the **expectancy**, or perceived likelihood, that one will be able to bring a given outcome about through self-control (Bernoulli 1954; Steel and König 2006; Vroom 1964; cf. 'self-efficacy' in Social Cognitive Theory, Bandura 1991). In the phone stack example, people may try harder to suppress an urge to check their phone, the more confidence they have in their ability to control themselves in the first place.

Third, EVC decreases the longer the **delay** before the outcome that self-control might bring about (cf. 'future discounting', Ainslie (2001); Ainslie (2010); Ariely and Wertenbroch (2002); Critchfield and Kollins (2001); Evans et al. (2016); McClure et al. (2007); O'Donoghue and Rabin (2001)). In phone stack, we should expect people to be worse at suppressing an impulse to check their phone if the rules were changed so that the loser would only pay the bill for a meal in a year's time.

3.2.6 A practical example

As a concrete illustration of the dual systems framework and the benefits of including EVC, consider a student who opens his laptop to work on an essay. However, he instead checks Facebook and spends an inordinate amount of time scrolling the newsfeed, experiencing feelings of regret having done so when he finally returns to the essay. This is not the first time it happens, even though his reflective goal is always to do solid work on the essay as the first thing, and to only allow himself to check Facebook briefly during breaks.

The dual systems framework suggests we consider this situation in terms of the perceptual cues in the context, automatic System 1 behaviour control, System 2's consciously held goals and self-monitoring, and System 2's expected value of control:

If the student normally checks Facebook when opening his laptop, this context may trigger a habitual check-in via System 1 control. His goal of working first thing might be present in his working memory, but he may fail to override his checking habit due to his expected value of control being low. This might be because he

does not get any *reward* from inhibiting the impulse to check Facebook; because he has little confidence in his own ability to suppress this urge (low *expectancy*); or because the rewards from working on his essay are *delayed* because it is only due in two months. Alternatively, his goal of working on the essay first thing might not be present in his working memory, in which case no System 2 control is initiated to override the checking habit.

After having opened Facebook, he might remember that he should be working on the essay, but attention-grabbing content from the newsfeed enters his capacity-limited working memory and crowds out this goal, leading him to spend more time on Facebook than intended.

3.3 A review and analysis of current digital self-control tools

To explore how this model may be useful in mapping digital self-control interventions, we conducted a systematic review and analysis of apps on the Google Play and Apple App stores, as well as browser extensions on the Chrome Web store. We identified apps and browser extensions described as helping users exercise self-control / avoid distraction / manage addiction in relation to digital device use, coded their design features, and mapped them to the components of the dual systems framework.

3.3.1 Methods

Initial keyword search and data clean up

For the Google Play and Apple App store, we used pre-existing scripts (Olano 2018a,b) to download search results for the terms 'distraction', 'smartphone distraction', 'addiction', 'smartphone addiction', 'motivation', 'smartphone motivation', 'self-control' and 'smartphone self-control'. For the Chrome Web store, we developed our own scraper (Slack 2018) and downloaded search results for the same key terms, but with the prefix 'smartphone' changed to 'laptop' as well as 'internet' (e.g. 'laptop distraction' and 'internet distraction'). We separately scraped apps and extensions on the US and UK stores, between 22nd and 27th August 2018. After excluding

duplicate results returned by multiple search terms and/or by both the US and UK stores, this resulted in 4890 distinct apps and extensions (1571 from Google Play, 2341 from the App Store, and 978 from the Chrome Web store).

Identifying potentially relevant apps and extensions

Following similar reviews (Shen et al. 2015; Stawarz, Preist, et al. 2018), we then manually screened the titles and short descriptions (if available; otherwise the first paragraphs of the full description). We included apps and extensions explicitly designed to help people self-regulate their digital device use, while excluding tools intended for general productivity, self-regulation in other domains than digital device use, or which were not available in English (for detailed exclusion criteria, see osf.io/zyj4h).

This resulted in 731 potentially relevant apps and extensions (219 from Google Play, 140 from the App Store, and 372 from the Chrome Web store).

Identifying apps and extensions to analyse

We reviewed the remaining tools in more detail by reading their full descriptions. If it remained unclear whether an app or extension should be excluded, we also reviewed its screenshots. If an app existed in both the Apple App store and the Google Play store, we dropped the version from the Apple App store.[3]

After this step, we were left with 380 apps and extensions to analyse (96 from Google Play, 60 from the App Store, and 224 from the Chrome Web store).

Feature coding

Following similar reviews, we coded functionality based on the descriptions, screenshots, and videos available on a tool's store page (cf. Shen et al. 2015; Stawarz, Cox, et al. 2014, 2015; Stawarz, Preist, et al. 2018). We iteratively developed a

[3] Apple's iOS places more restrictions on developer access to operating system permissions than does Google's Android, with the consequence that the iOS version of a digital self-control app is often much more limited than its Android counterpart (Mosemghvdlishvili and Jansz 2013). Because the purpose of this review was to investigate which areas of the design space these tools have explored (rather than differences between iOS and Android ecosystems per se), we excluded the iOS version when an app was available in both stores.

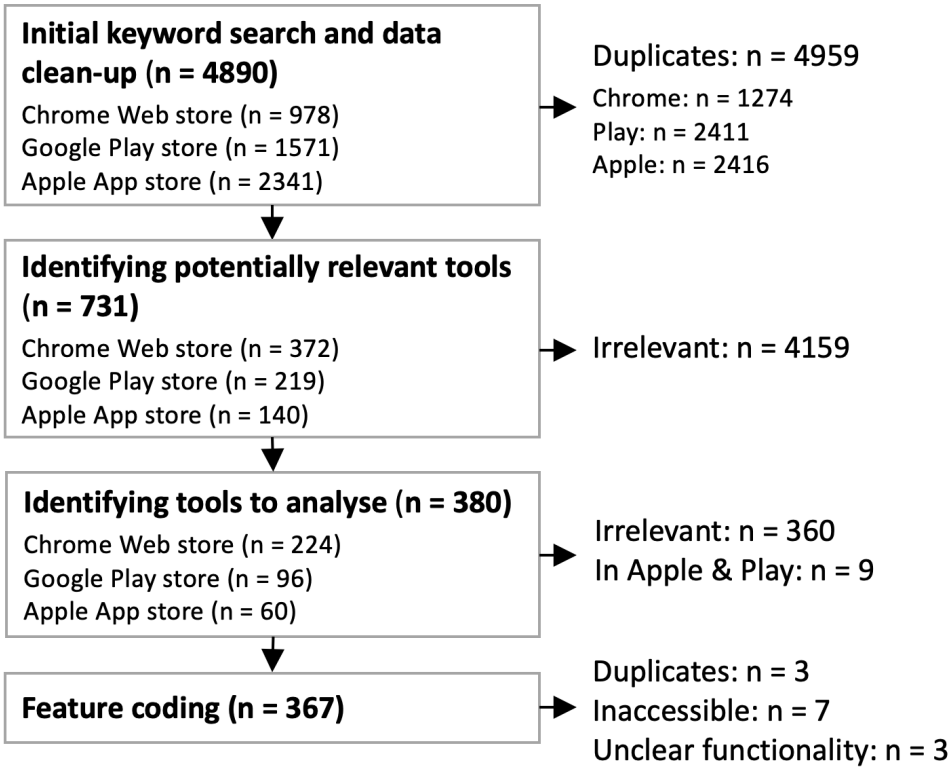

Figure 3.2: Flowchart of the search and exclusion/inclusion procedure

coding sheet of feature categories (cf. Bender et al. 2013; Orji and Moffatt 2018), with the prior expectation that the relevant features would be usefully classified as subcategories of the main feature clusters 'block/removal', 'self-tracking', 'goal advancement' and 'reward/punishment' (drawing on previous work, Lyngs (2018a)).

Initially, two collaborators and myself independently reviewed and classified features in 10 apps and 10 browser extensions (for a total of 30 unique apps and 30 unique browser extensions) before comparing and discussing the feature categories identified to create the first iteration of the coding sheet. Using this coding sheet, the two collaborators independently reviewed 60 additional apps and browser extensions each while I reviewed these same 120 tools, as well as all remaining tools. After comparing and discussing the results, we developed the final codebook, on the basis of which I revisited and recoded the features in all tools. In addition to the granular feature coding, we noted which main feature cluster(s) represented a tool's 'core' design, according to the guideline that 25% or more of the tool's functionality

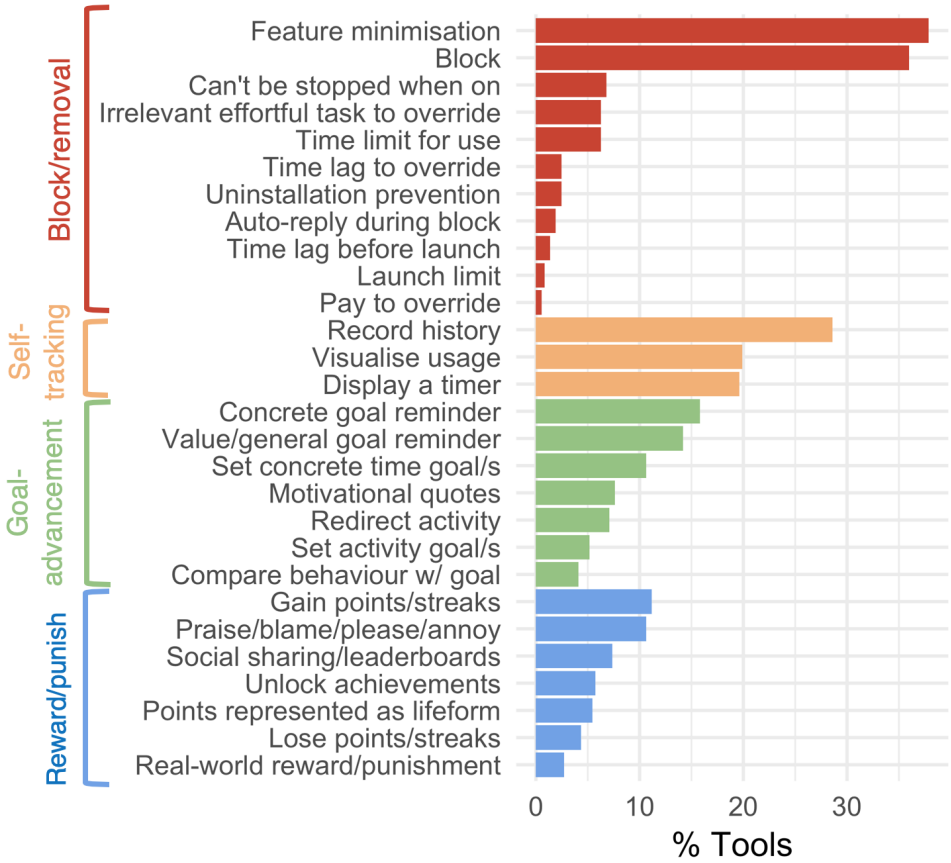

Figure 3.3: Functionality of digital self-control tools (N = 367)

related to that cluster (a single tool could belong to multiple clusters).[4]

During the coding process, we excluded a further 13 tools — 3 duplicates, e.g., where 'pro' and 'lite' versions had no difference in described functionality, 7 that had become inaccessible after the initial search, and 3 that lacked sufficiently well-described functionality to be coded. This left 367 tools in the final dataset.

3.3.2 Results

Feature prevalence

A summary of the prevalence of features is shown in Figure 3.3. The most frequent feature cluster related to **blocking or removing** distractions, some variation of which was present in 74% of tools. 44% (163) enabled the user to put obstacles in the way of distracting functionality by either blocking access

[4]For further detail, see osf.io/zyj4h.

entirely (132 tools), by setting limits on how much time could be spent (23 tools) or how many times distracting functionality could be launched (3 tools) before being blocked, or by adding a time lag before distracting functionality would load (5 tools). 14% (50 tools) also added friction if the user attempted to remove the blocking, including disallowing a blocking session from being stopped (25 tools), requiring the user to first complete an irrelevant effortful task or type in a password (23 tools), tinkering with administrator permissions to prevent the tool from being uninstalled (9 tools), or adding a time lag before the user could override blocking or change settings (9 tools). For example, the *Focusly* Chrome extension (Trevorscandalios 2018) blocks sites on a blacklist; if the user wishes to override the blocking, she must type in correctly a series of 46 arrow keys (e.g., →↑↓→←→...) correctly to enter the blocked site.

Rather than blocking content per se, an alternative approach, taken by 38% of tools (139), was to reduce the user's exposure to distracting options in the first place. This approach was dominated by browser extensions (121 of these tools were from the Chrome Web store) typically in the form of removing elements from specific sites (67 tools; e.g., removing newsfeeds from social media sites or hiding an email inbox). The sites most frequently targeted were Facebook (26 tools), YouTube (17), Twitter (11) and Gmail (7). Also popular were general 'reader' extensions for removing distracting content when browsing the web (27 tools) or when opening new tabs (24). Other notable examples were 'minimal-writing' tools (22 tools) which remove functionality irrelevant to, or distracting from, the task of writing. Finally, a few Android apps (4 tools) limited the amount of functionality available on devices' home screen.

The second most prevalent feature cluster related to **self-tracking**, some variation of which was present in 38% of tools (139). Out of these, 105 tools recorded the user's history, 73 provided visualisations of the captured data, and 72 displayed a timer or countdown. In 42 tools, the self-tracking features included focused on the time during which the user managed to *not* use their digital devices, such as the iOS app *Checkout of your phone* (Schungel 2018).

The third most prevalent feature cluster related to **goal advancement**, some variation of which was present in 35% of tools (130). 58 tools implemented reminders of a concrete time goal or task the user tried to complete (e.g., displaying pop-ups when a set amount of time has been spent on a distracting site or replacing the content of newsfeeds or new tabs with todo-lists) and 52 tools provided reminders of more general goals or personal values (e.g., in the form of motivational quotes). 58 tools asked the user to set explicit goals, either for how much time they wanted to spend using their devices in total or in specific apps or websites (39 tools), or for the tasks they wanted to focus on during use (19 tools). 15 tools allowed the user to compare their actual behaviour against the goals they set.

The fourth most prevalent feature cluster, present in 22% of tools (80), related to **reward/punishment**, i.e., providing some form or rewards or punishments for the way in which a device is used. Some of these features were gamification design patterns such as collecting points/streaks (41 tools), leaderboards or social sharing (27), or unlocking of achievements (21). In 20 tools, points were represented as some lifeform (e.g., an animated goat or a growing tree) which might be harmed if the user spent too much time on certain websites or used their phone during specific times. 10 tools added real-world rewards or punishments, e.g., making the user lose money if they spend more than 1 hour on Facebook in a day (*Timewaste Timer*, Prettymind.co (2018)), allowing virtual points to be exchanged to free coffee or shopping discounts (*MILK*, Milk The Moment Inc. (2018)) or even let the user administer herself electrical shocks when accessing blacklisted websites (!) (*PAVLOK*, Pavlok (2018)).

Finally, 35% of tools (129) gave the user control over what counted as 'distraction', e.g., by letting the user customise which apps or websites to restrict access to. Among tools implementing blocking functionality, 101 tools implemented blacklists (i.e., blocking specific apps or sites, allowing everything else), while 22 tools implemented whitelists (i.e., allowing only specified apps or sites while blocking everything else).

Feature combinations

65% of tools implemented only one type of feature cluster in their core design, most frequently blocking/removing distractions (53%). 32% (117 tools) combined two main feature clusters, most frequently block/removal in combination with goal-advancement (40 tools; e.g., replacing the Facebook newsfeed with a todo list, or replacing distracting websites with a reminder of the task to be achieved) or self-tracking in combination with reward/punishment features (30 tools; e.g., a gamified pomodoro timer in which an animated creature dies if the user leaves the app before the timer runs out). Block/removal core designs were also commonly combined with self-tracking (24 tools; e.g., blocking distracting websites while a timer counts down, or recording and displaying how many times during a block session the user tried to access blacklisted apps). Only two tools (*Flipd*, Flipd Inc. (2018), and *HabitLab*, Stanford HCI Group (2018)) combined all four feature clusters in their core design, with the Chrome extension HabitLab (developed by the Stanford HCI Group) cycling through different types of interventions to learn what best helps the user align internet use with their stated goals (cf. Kovacs, Wu, et al. 2018).

Store comparison

Figure 3.4 summarises the prevalence of features, comparing the three stores. The differences between the stores appear to mirror the granularity of system control available to developers: Feature minimisation, in the form of removing particular aspects of the user interface, is common in browser extensions, presumably because developers here can wield precise control over the elements displayed on HTML pages by injecting client-side CSS and JavaScript. On mobile devices, however, developers have little control over how another app is displayed, leaving blocking or restricting access as the only viable design patterns. The differences between the Android and iOS ecosystems are apparent, as the permissions necessary to implement, e.g., scheduled blocking of apps are not available to iOS developers. These differences across stores suggest that if mobile operating systems granted more permissions (as some developers of popular anti-distraction tools have petitioned

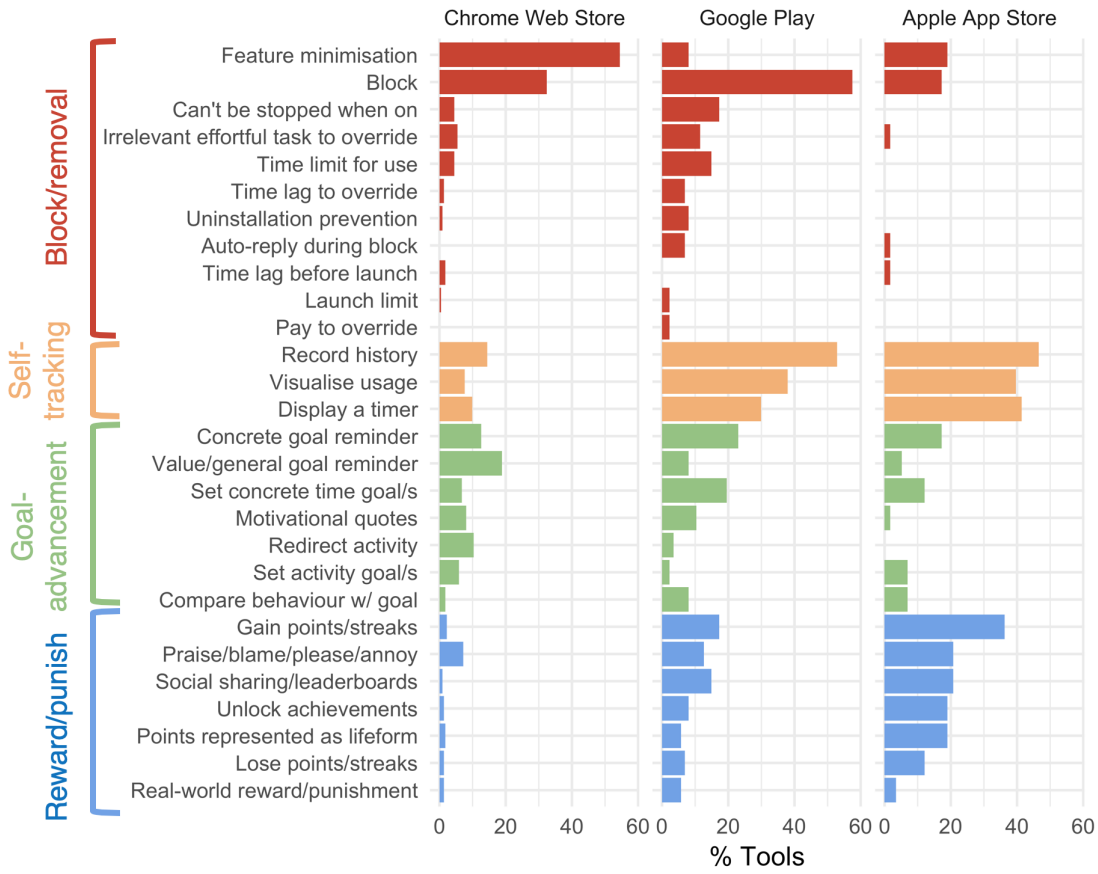

Figure 3.4: Functionality of digital self-control tools on Chrome Web (n = 223), Google Play (n = 86) and Apple App Store (n = 58)

Apple to do, Digital Wellness Warriors (2018)), developers would respond by creating tools that offer more granular control of the mobile user interface, similar to those that already exist for the Chrome web browser.

Mapping identified tool features to theory

Figure 3.5 shows a matrix of how the design features correspond to the main components of the dual systems framework, in terms of the cognitive components they have the most immediate potential to influence: *Non-conscious habits* are influenced by features that block the targets of habitual action or the user interface elements that trigger them, thereby preventing unwanted habits from being activated. *Non-conscious habits* are also influenced by features which enforce limits on daily use, or redirect user activity, thereby scaffolding formation of new habits. *Conscious goals & self-monitoring* is influenced by explicit goal setting and reminders, as

		Nonconscious habits (prevent)	Nonconscious habits (scaffold)	Conscious goals & self-monitoring	EVC: Reward	EVC: Delay	EVC: Expectancy
Block / removal	Block	√					
	Time lag to launch	√				√	
	Time limit		√				
	Launch limit		√				
	Feature minimisation	√					
	Effortful task to override				√		
	Time lag to override					√	
	Can't be stopped/uninstalled		√				
	Pay to override				√		
Self-tracking	Displays a timer			√		√	√
	Record history			√			
	Visualisation			√			
Goal advancement	Set activity goal/s			√			
	Set concrete time goal/s			√			
	Concrete goal reminder			√			
	Value/general goal reminder				√		
	Motivational quotes				√		√
	Compare behaviour w/ goal			√			
	Redirect activity		√				
Reward/punishment	Gain/lose points/streaks				√		
	Points represented as lifeform				√		
	Social sharing/leaderboards				√		
	Unlock achievements				√		
	Praise/blame/please/annoy				√		
	Real-world reward/punish				√		

Figure 3.5: Mapping design features to an integrative dual systems model of self-regulation

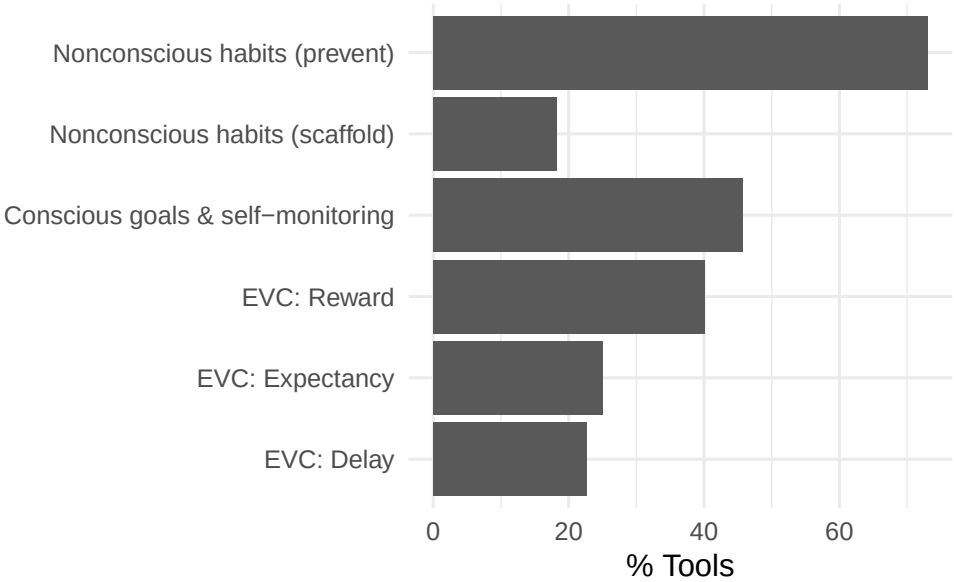

Figure 3.6: Percentage of tools which include at least one design feature targeting a given cognitive component of the dual systems framework.

well as by timing, recording, and visualising usage and comparing it with one's goals. The *reward* component of the expected value of control is influenced by reward/punishment features that add incentives for exercising self-control, as well as by value/general goal reminders and motivational quotes which encourage the user to reappraise the value of immediate device use in light of what matters in their life; the *delay* component is influenced by time lags or timers; and *expectancy* is similarly influenced by timers ('I should be able to manage to control myself for just 20 minutes!') as well as motivational quotes.

Given this mapping, the percentages of tools in which at least one design feature maps to a given cognitive component is shown in Figure 3.6. Similarly to DBCI reviews (Pinder, Vermeulen, Cowan, and Beale 2018; Stawarz, Cox, et al. 2015), we find the lowest prevalence of features that scaffold formation of non-conscious habits (18%), followed by features that influence the delay component of the expected value of control (23%). The current landscape of digital self-control tools is dominated by features which prevent activation of unwanted non-conscious habits (73%) and thereby stop undesirable responses from winning out in action schema competition by making them unavailable.

3.4 Discussion

In this chapter, we set out to map the landspace of current digital self-control tools and relate them to an integrative dual systems model of self-regulation. Our review of 367 apps and browser extensions found that blocking distractions or removing user interface features were the most common approaches to digital self-control. Grouping design features into clusters, the prevalence ranking was block/removal > self-tracking > goal advancement > reward/punishment. Out of these, 65% of tools focused on only one cluster in their core design; and most others (32%) on two. The frequencies of design features differed between the Chrome Web Store, Play Store, and Apple App store, which likely reflects differences in developer permissions. When mapping design features to the dual systems framework, the least commonly targeted cognitive component was unconscious habit scaffolding, followed by the delay and expectancy elements of the expected value of control.

We now turn to discuss how these empirical observations can inform future research by pointing to: i) widely used and/or theoretically interesting design patterns in current digital self-control tools that are underexplored in HCI research; ii) feature gaps identified the dual systems framework, showing neglected areas that could be relevant to researchers and designers, and iii) how the model may be used directly to guide research and intervention design. We then outline limitations and future work.

3.4.1 Research opportunities prompted by widely used or theoretically interesting design patterns

The market for DSCTs effectively amounts to hundreds of natural experiments in supporting self-control, meaning that successful tools may reveal design approaches with wider applicability. These approaches present low-hanging fruit for research studies, especially as many are so far lacking evaluation in terms of their efficacy and the transferability of their underlying design mechanisms. As an example, we highlight three such instances:

Responsibility for a virtual creature *Forest* (Seekrtech 2018) ties device use to the well-being of a virtual tree. Numerous variations and clones of this approach exist among the tools reviewed, but Forest is the most popular with over 10 million users on Android alone (Google Play 2017). It presents a novel use of 'virtual pets' that requires the user to abstain from action (resist using their phone) rather than take action to 'feed' the pet, and is a seemingly successful example of influencing the reward component of expected value of control.

Redirection of activity *Timewarp* (Stringinternational.com 2018) reroutes the user to a website aligned with their productivity goals when navigating to a distracting site (e.g., from Reddit to Trello), and numerous tools implement similar functionality. Such apps seem to be automating 'implementation intentions' (*if-when* rules for linking a context to a desired response, Gollwitzer and Sheeran (2006)), an intervention which digital behaviour change researchers have highlighted as a promising way to scaffold transfer of conscious System 2 goals to automatic System 1 habits (Pinder, Vermeulen, Cowan, and Beale 2018; Stawarz, Cox, et al. 2015).

Friction to override past preference A significant number of tools not only allow the user to restrict access to digital distractions, but also add a second layer of commitment, e.g., by making blocking difficult to override, as in the browser extension *Focusly* (Trevorscandalios 2018), which requires a laborious combination of keystrokes to be turned off. This raises important design and ethical questions about how far a digital tool should go to hold users accountable for their past preferences (cf. Bryan et al. 2010; Lyngs, Binns, et al. 2018).

3.4.2 Gaps identified by the dual systems framework

By applying the dual systems framework, we also identified three cognitive mechanisms that appear underexplored by current digital self-control tools. Focusing on these mechanisms might lead to new powerful approaches to digital self-control:

Scaffolding habits Similar to the situation in general DBCIs (cf. Pinder, Vermeulen, Cowan, and Beale 2018; Stawarz, Cox, et al. 2015), the least frequently targeted cognitive component relates to *scaffolding of new, desirable unconscious habits* (as opposed to preventing undesired ones from being triggered via blocking or feature removal). Habit formation is crucial for long-time behaviour change, and in the context of DBCIs, Pinder, Vermeulen, Cowan, and Beale (2018) suggested implementation intentions and automation of self-control as good candidate design patterns for targeting habit formation. We note that some such interventions are already being explored amongst current digital self-control tools: apart from the tools mentioned above that redirect activity, four tools allow blocking functionality to be linked to the user's location (e.g., *AppBlock*, Mobilesoft (2019), and *Bashful* Runnably (2019)). I expect this to be a powerful way to automatically trigger a target behaviour in a desired context.

Delay The *delay* component of expected value of control is also less commonly targeted: the number of tools including functionality targeting delay drops to 4% if we exclude the display of a timer (which raises time awareness rather than affecting actual delays). This is surprising from a theoretical perspective, because the effects on behaviour of sensitivity to delay are strong, reliable, and—at least to behavioural economists—at the core of self-control difficulties (Ariely and Wertenbroch 2002; Dolan et al. 2012). Even if rewards introduced by gamification features may have the side effect of reducing delay before self-control is rewarded, it remains surprising that only two of 367 reviewed tools directly focus on using delays to scaffold successful self-control (*Space*, Boundless Mind Inc (2018), increases launch times for distracting apps on iOS; *Pipe Clogger*, Croshan (2018), does the same for websites). As previous research has found people to be especially sensitive to delays in online contexts (Krishnan and Sitaraman 2013), I expect interventions that leverage delays to scaffold self-control in digital environments to be highly effective.

Expectancy The *expectancy* component (i.e., how likely a user think it is that she will be able to reach her goal through self-control exertion) was also less frequently targeted, and mainly through timers limiting the duration where the user tried to exert self-control. Given the crucial role of self-efficacy in Bandura's influential work on self-regulation (Bandura 1991), this may also represent an important underexplored area. One interesting approach to explore is found in *Wormhole Escaper* (Bennett 2018) which lets the user administer words of encouragement to themselves when they manage to suppress an urge to visit a distracting website. In so far as this is effective, it may be by boosting the user's confidence in their ability to exert self-control.

3.4.3 Using the dual systems framework directly to guide intervention research and design

The abstracted nature of the dual systems framework enables it to be utilised on different levels of analysis to inspire new avenues for research as well as drive specific design:

For researchers, the framework may be used to organise existing work on design patterns for digital self-control by the cognitive components they target, as well as a roadmap for future studies that focus on different components of the self-regulatory system. Whereas many theories and frameworks are on offer for this purpose, one advantage of the dual systems approach is that it provides HCI researchers with clear connections to wider psychological research on basic mechanisms of self-regulation, which can be utilised in design (cf. section 7.3).

As such, the framework may be used as a starting point for design consideration that is aligned with the cognitive mechanisms involved in self-regulation; its components can be readily expanded if inspiration from more fine-grained theoretical constructs and predictions is required. For example, the 'reward' component readily expands into more specific models explaining the types of stimuli that may be processed as rewards; how timing of rewards impact their influence; how the impact of gains differ from losses; and so on (Berridge and Kringelbach 2015; Caraco

et al. 1980; Kahneman and Tversky 1979; Schüll 2012). As we saw in Chapter 2, existing studies have already benefitted from use of more narrow theories, such as Kim, Jeon, et al. (2016)'s reliance on work on differential sensitivity to gains vs. losses in evaluations of their tool *TimeAware*.

3.4.4 Limitations

Our review has some limitations. First, the tool analysis presented in this chapter is focused on functionality — in Chapter 4, we supplement this with analysis of information drawn from user numbers, ratings, and reviews.

Second, the dual systems framework we have applied points to directions of future research, but its high-level formulation leaves its cognitive design space under-specified. How precisely one should be able to anchor details of specific interventions directly in causal theories is a point of longstanding debate (Ajzen 1991; Hardeman et al. 2005; Michie et al. 2008). As mentioned above, however, a main benefit of the dual systems framework is that while concise, it remains directly grounded in well-established basic research on self-regulation. As mentioned above, this means that each component of the model has substantial literature behind it, so that more detailed specifications and predictions can be found in lower-level theories on demand.

3.5 Conclusion

In this chapter, we have started to address the main research question of the present thesis in two ways: (i) by providing the first comprehensive functionality analysis of current apps and browser extensions for digital self-control on the Google Play, Chrome Web, and Apple App stores, and (ii) by applying a well-established framework of self-regulation to evaluate their design features and provide a mechanistic understanding of the problem they address.

In the next chapter, we extend this chapter's analysis of tool functionality with an analysis of these tools' user numbers, average ratings, and public reviews.

4

Surveying Current Digital Self-Control Tools' Effectiveness and Challenges

Contents

4.1 Introduction

As outlined in Chapter 2, existing studies developing and/or evaluating interventions for digital self-control have begun to build an understanding of how design patterns ranging from visualisations of time spent (Whittaker et al. 2016) to goal-setting with social support (Ko, Chung, et al. 2015) may support self-regulation of digital device use. However, we are in the early days of collecting evidence on the potential effectiveness across the design space of such patterns, the contexts in which they are useful, and the extent to which their effectiveness depends on individual differences (Kim, Jung, Ko, et al. 2019; Mark et al. 2018).

While controlled studies are appropriate and feasible for evaluating and comparing a small number of interventions, they are difficult to scale for broadly assessing a large number of design patterns and implementations. A complementary approach, which can help scope the range of design patterns and implementations to explore in controlled studies, is to investigate the landscape of digital self-control tools (DSCTs) on app and web stores (Lyngs, Lukoff, Slovak, Binns, et al. 2019; Roffarello and De Russis 2019a; van Velthoven et al. 2018). Here, widely available tools potentially represent hundreds of thousands of natural 'micro-experiments' (Daskalova 2018; Lee, Walker, et al. 2017) in which individuals self-experiment with apps that represent not only one or more design patterns, but particular designs for implementing those patterns. One indicator of the outcome of such micro-experiments is store ratings, user numbers, and reviews, which may provide information about user needs, contexts of use, and the relative utility of design patterns and implementations.

Other domains of research have benefitted from this approach, e.g., mental health (Bakker et al. 2016; Huguet et al. 2016; Lui et al. 2017; Sucala et al. 2017) where thematic analysis of public reviews has been used to explore factors important for optimising user experience and support engagement in apps for cognitive behavioural therapy (Stawarz, Preist, et al. 2018). However, few studies on digital self-control have taken this route: excluding the present thesis work, three

studies have described and/or categorised functionality in samples of digital self-control tools available online (Biskjaer et al. 2016; Roffarello and De Russis 2019a; van Velthoven et al. 2018): van Velthoven et al. (2018) presented aims and features in 21 tools identified via the software recommendation platform alternativeto.net; Biskjaer et al. (2016) presented a taxonomy of functionality based on 10 tools from Google Play, Chrome Web, and Apple App stores and online tech magazines; and Roffarello and De Russis (2019a) presented a taxonomy of functionality based on 42 mobile apps from the Google Play store. Only one study has analysed user reviews: Roffarello and De Russis (2019a), who conducted thematic analysis of 1,128 reviews from the 42 mobile apps they identified.

None of these studies incorporated store metrics of popularity, such as number of users, into their analyses. In research on digital tools for cognitive behavioural therapy, however, such information has fruitfully been used to investigate, e.g., whether store popularity correlates with presence of evidence-based features (Kertz et al. 2017). Similarly, combining functionality in digital self-control tools with metrics such as user numbers and average ratings could provide basic evidence allowing us to investigate whether feature types and combinations predict store popularity.

Moreover, thematic analysis of user reviews may yield different insights depending on how reviews are sampled across tools with different functionality, and depending on the specific strategy for analysing them (Braun, Clarke, et al. 2018; Chen, Lin, et al. 2014). The existing study of user reviews did not include information about how the reviews analysed were distributed across apps with different functionality (Roffarello and De Russis 2019a), and so conducting additional thematic analyses with transparent sampling of reviews would be helpful.

In the present chapter, we therefore extend Chapter 3's functionality analysis by using additional information from the publicly-available app and web store listings as a resource representing user self-experimentation with these tools. Specifically, we conduct a combined analysis of tool functionality, user numbers, average ratings, and the content of reviews for 334 DSCTs drawn from the work presented in Chapter 3.

In doing so, this chapter makes three research contributions:

1. An analysis of how design features and feature combinations are associated with popularity metrics (user numbers and average ratings), providing a reference point for relative popularity of design patterns and implementations
2. A thematic analysis of 961 user reviews sampled across tools with different types of functionality, drawing out contexts of use and key design challenges from the review content
3. A set of research materials comprising scrapers, analysis scripts, and data, including ~55,000 anonymised reviews, made available via the Open Science Framework on osf.io/t8y5h/

Our analysis of user numbers and ratings finds that DSCTs which combine two or more types of design patterns in their functionality receive higher ratings than tools implementing only one. Moreover, DSCTs that include goal advancement features rank higher on average ratings than on user numbers, suggesting that they might be effective but less likely to 'go viral'. Our thematic analysis of reviews finds that DSCTs are used in contexts where people focus on tasks that are important, but not immediately gratifying. Moreover, users search for tools which provide a level of friction or reward that is 'just right' for encouraging intended behaviour without being overly restrictive or annoying (with the 'just right' level differing between people), and which can capture their personal definition of 'distraction'.

This chapter's dataset may be used in future work as reference for 'better' or 'worse' implementations of specific strategies as judged by users on app and browser extension stores. In addition, reviews may be sampled from the full dataset in numerous ways for thematic analysis in relation to specific research questions, and therefore provide potential value for other researchers investigating, e.g., how best to implement specific design patterns such as lockout mechanisms (Kim, Jung, Ko, et al. 2019).

4.2 Methods

Materials and data for the paper on which the present chapter is based are available on osf.io/t8y5h/.

We investigated the same 367 digital self-control tools reviewed in Chapter 3, as this represented the largest review to date, and used Chapter 3's classification of four main types of design patterns expressed by the features of these tools:

- *block/removal* (features for blocking distractions, such as temporarily locking the user out of specific apps, or for removing them in the first place, such as hiding the newsfeed on Facebook)
- *self-tracking* (features for tracking and/or visualising device use)
- *goal-advancement* (features for reminding the user of their usage goals)
- *reward/punishment* (features that provide rewards or punishments for the way in which devices are used)

4.2.1 Collecting tool information and user reviews

In March 2019, we collected additional information about these tools (including number of users, average ratings, and their latest store descriptions), as well as user reviews publicly available on their store pages. For apps on the Google Play store, we used a pre-existing script (Olano 2018b) to download tool information and reviews. For apps on the Apple App store, we used a pre-existing script (Olano 2018a) to download reviews, and wrote our own script (using R packages `rvest` and `RSelenium`) to collect tool information. As the script for obtaining reviews from the Apple App store sometimes failed to retrieve all reviews visible on tools' store page, we wrote an additional R script for collecting reviews when manual inspection found some to be missing. For extensions on the Chrome Web store, we wrote an R script to download tool information and reviews.

4.2.2 Analysing user numbers and ratings

All stores displayed average ratings as well as number of ratings. However, the stores provided different types of information in relation to user numbers: The Chrome Web store provided an exact number of users for an extension, and the Google Play store provided a 'minimum number of installs' (e.g. '100,000+'). The Apple App store provided no direct information about user numbers. For tools on the Apple App store we therefore used number of ratings as a proxy for relative number of users in analyses where tools were ranked by number of users.

4.2.3 Thematic analysis

To cover the design space, we first sampled up to 20 reviews from each of the 5 tools with the highest number of users, from each store[1], from each main functionality type that were assigned to tools as their first category. As functionality types were not evenly distributed across stores (for example, blocking tools are rare on the Apple App store), we subsequently randomly sampled additional reviews, from tools targeting each type of functionality, for a total of 961 reviews (cf. Roffarello and De Russis 2019a).

Next, we conducted an inductive thematic analysis, following the 'reflexive' approach described in Braun and Clarke (2006) and Braun, Clarke, et al. (2018). First, we read through all the reviews and conducted an initial coding of recurrent patterns in the data relevant to our research aims. Subsequently, we read through all extracts associated with each code, recoded instances, and iteratively sorted codes into potential themes, and discussed emerging themes.

We used the Dedoose software for thematic analysis, and R for all quantitative analyses.

[1] On the Apple App store, we used number of ratings as a proxy for user numbers.

4.3 Results

33 tools had become unavailable since we conducted the review presented in Chapter 3. Hence, we were able to collect additional information for 334 tools: 212 extensions from Chrome Web, 71 apps from Google Play, and 51 apps from the Apple App store.

260 of these tools had received user reviews (160 from Chrome Web, 77 from Google Play, and 23 from the Apple App store). From these, we collected a total of 54,320 reviews (9,071 from Chrome Web, 44,701 from Google Play, and 548 from the Apple App store).

The dataset on the Open Science Framework includes user numbers, ratings, and functionality for all tools — including Chater 3's granular feature analysis which, e.g., breaks down 'block/removal' into specific features such as time limits, launch limits, and friction for overriding blocking — as well as all collected reviews.

4.3.1 User numbers and ratings

For DSCTs from the Google Play store, the median 'minimum number of installs' was 10,000 (min = 5, max = 5,000,000), from the Chrome Web store, the median number of users was 194.5 (min = 1, max = 1,736,018)), and from the Apple App store, the median number of ratings was 0 (min = 0, max = 14,900). The median average rating given to tools (for tools with more than 30 ratings) was 4.3 (individual ratings range from 1 to 5 stars on all three stores; 5 is best).

Figure 4.1 shows top tools in terms of number of users and their types of features (on the Apple App store, ranked by number of ratings; only 13 tools from this store had received any ratings). The distributions of feature types in top tools differed by store, mirroring differences between stores overall (cf. Chapter 3) — for example, block/removal functionality is rare on the Apple App store compared to the Google Play and Chrome Web store.

Figure 4.2 displays top tools in terms of average rating (to obtain a representative sample underlying the average, this figure includes only tools with more than 30 ratings; only 5 tools from the Apple App store had received more than 30

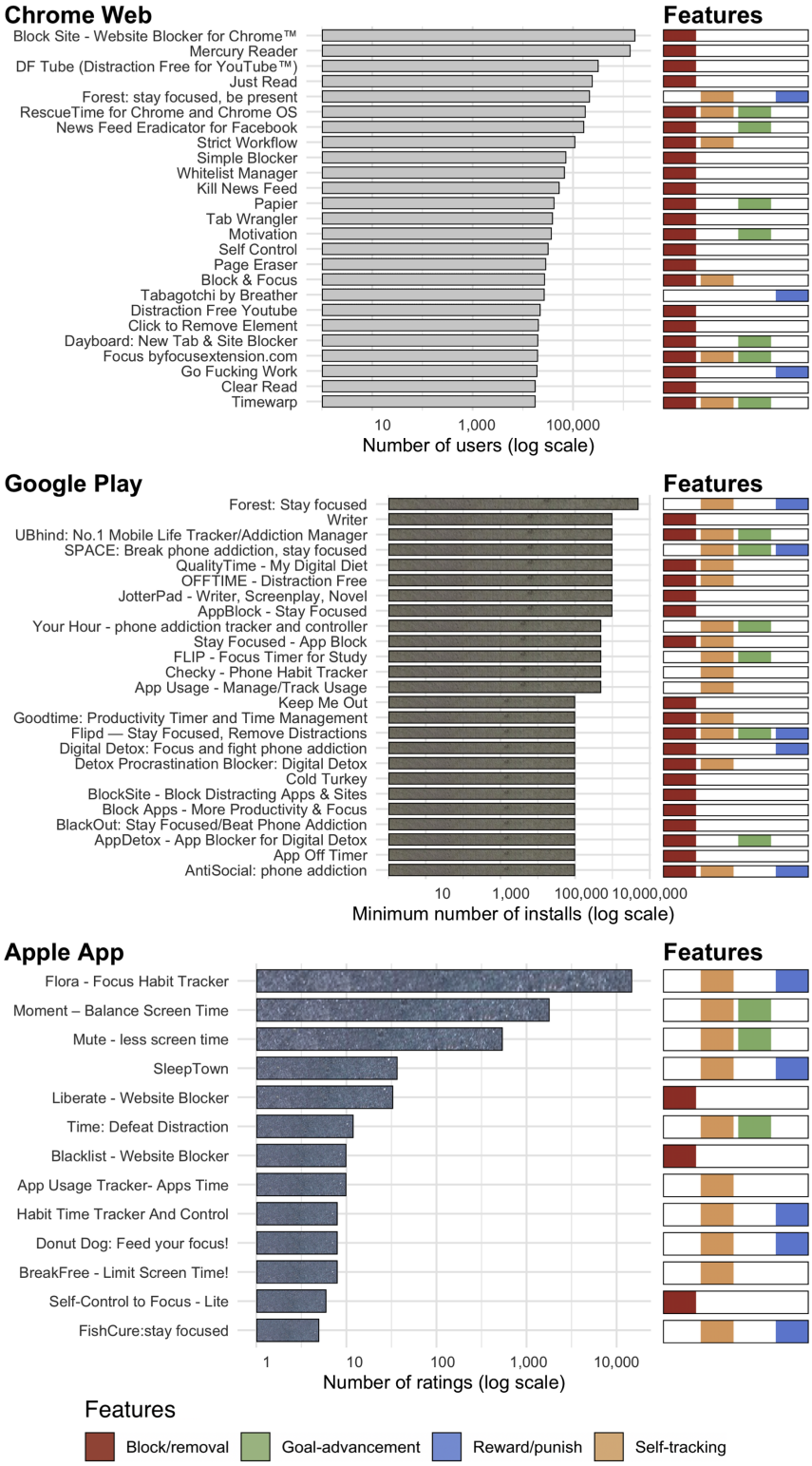

Figure 4.1: Top tools in terms of number of users (on Apple App store, ranked by number of ratings as this store provides no direct information about user numbers). Reward/punishment is the least common type of design feature among top tools, but two tools including such functionality (Forest and Flora, which gamify self-control by growing virtual trees) have the highest user numbers on Google Play and Apple App, and rank in top 5 on the Chrome Web store. Block/removal features are very common on Google Play and Chrome Web, but rare on the Apple App store.

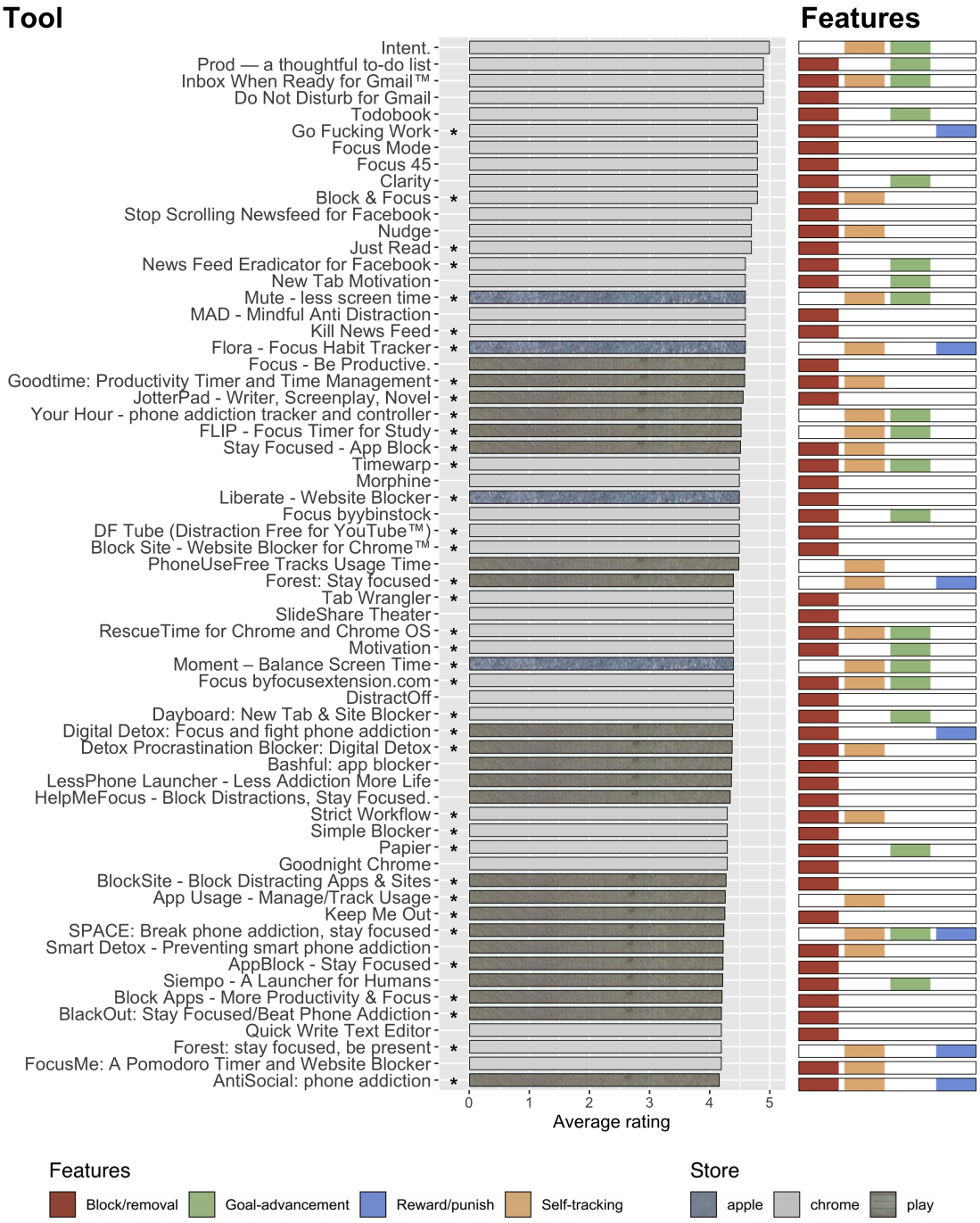

Figure 4.2: Top tools ranked by average rating (for tools with more than 30 ratings). Tools marked with an asterisk also appear on the plots of top tools ranked by user numbers (Figure 4.1). Tools that include goal advancement features are more common among top tools in terms of average ratings than they are in terms of user numbers.

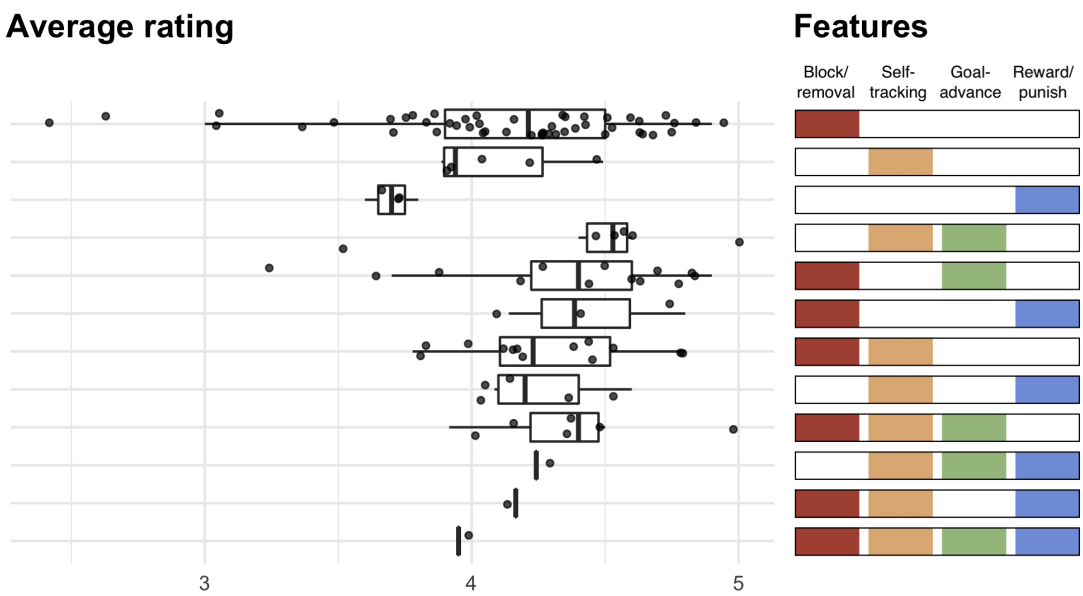

Figure 4.3: Average ratings by feature combination (for tools with more than 30 ratings). Tools combining more than one type of features have higher average ratings (median = 4.39) than do tools implementing a single type (median = 4.2, p = 0.008, Wilcoxon's rank-sum test).

ratings). 59% (37 out of 63) of tools shown in Figure 4.2 also appear in Figure 4.1, suggesting that tools with higher user numbers have a large overlap with tools with higher ratings.

Reward/punishment features were the least common in top tools, but some tools implementing such features ranked highly: Forest and Flora, which both gamify self-control by growing virtual trees or plants, topped the number of users on the Google Play and Apple App stores, and Forest was in the top 5 on the Chrome Web store.

Goal advancement features were more common among top tools ranked by average rating (32%, 20/63) than by number of users (25%, 16/63), and than the overall prevalence of this feature type (22% of tools, 75/334).

Across all tools, 64% implemented a single type of design pattern, whereas 32% combined two — very few combined three (3%) or all four (1%, cf. section 3.3.2). Tools whose features combined two or more types of design patterns had significantly higher average ratings than tools which implemented a single type (comparing tools with more than 30 ratings; median average rating with a single

Figure 4.4: Word cloud depicting frequencies of terms across all collected reviews (excluding the terms 'app/s', 'phone', and 'extension'). Font size indicate relative frequency. Colouring is aesthetic and does not map to any characteristics of the data.

type = 4.2, median for tools combining two or more = 4.39, $p = 0.008$ in Wilcoxon's rank-sum test, cf. Figure 4.3).

4.3.2 User reviews

The median number of reviews for a tool was 6 (min = 1, max = 4600), and the median number of words in a review was 14 (min = 1, max = 640). Figure 4.4 shows the overall frequency of terms used in reviews, excluding the terms 'app/s', 'phone' and 'extension'. Apart from 'app' (46% of reviews), the most frequent term was 'time', which was included in 17.5% of all reviews. The terms most commonly following or preceding 'time' included 'usage', 'limit', 'screen', 'spent', 'set', 'management', and 'wasting' (see Table 4.1), suggesting that managing time spent on digital devices was one of the most central topics.

Table 4.1: Terms most commonly directly following or preceding 'time' across all user reviews.

Number of occurrences	Phrase
257	**time** limit/s
226	usage **time**
175	screen **time**
172	**time** spent
137	waste/wasting **time**
103	**time** management
103	set **time**
72	break **time**
69	quality **time**
66	phone **time**
62	**time** wasting
58	**time** period
53	study **time**
51	specific **time**
44	focus **time**

Table 4.2: Reviews sampled for thematic analysis (n = 961).

Design pattern combination	Number of tools	Number of reviews
Block/removal	19	152
Reward/punish	6	146
Self-tracking	9	147
Goal-advancement	10	27
Block/removal + Reward/punish	1	20
Block/removal + Self-tracking	5	99
Reward/punish + Self-tracking	12	104
Block/removal + Goal-advancement	4	76
Goal-advancement + Self-tracking	6	75
Block/removal + Reward/punish + Self-tracking	1	21
Block/removal + Goal-advancement + Self-tracking	3	60
Goal-advancement + Reward/punish + Self-tracking	2	27
Block/removal + Goal-advancement + Reward/punish + Self-tracking	1	7

Thematic analysis

We conducted thematic analysis of 961 reviews from a total of 79 different apps (cf. Table 4.2). Our early codes resembled those reported by Roffarello and De Russis (2019a). Thus, our initial codes were grouped into 'positive', 'neutral' and 'negative', with frequently occurring codes including: generic praise or critique; bug complaints; feature suggestions; contexts of use; benefits of use; feedback on UI and performance; descriptions of functionality; comparisons to other tools; and privacy concerns.

An early observation, as we explored reported benefits of use, was that a substantial proportion of reviews expressed highly positive and important impact of use (n = 214, 22% of reviews). The review content commonly suggested that users felt a lack of control over ordinary digital device use, which resulted in using them in unintended ways, or in using them so much that it interfered with other goals. However, DSCTs were seen as effectively helping users take back control ("Helped me regain my time and attention on the web.", R328, *Intent*, "This app saved my life. It made me realise just how bad my addiction to my tablet was and motivated me to reduce my time on it and to spend more time doing other things, like reading.", R647, *Moment*), and many thanked developers for this ("Thank you again you saved my sanity", R768, *App Usage*). Some reviews expressed surprise or even embarrassment that particular tools had been useful to them ("A little embarrassed it works for me but hey I am more focused and thats all that matter", R614, *Tabagotchi*).

As we iteratively worked further with the codes and excerpts, in keeping with a reflexive approach to thematic analysis (Braun, Clarke, et al. 2018), our analysis revealed four key themes capturing more actionable insights in relation to DSCTs' use contexts and design challenges: (i) DSCTs help people prioritise important but effortful tasks over guilty pleasures, (ii) DSCTs are useful because many default designs overload users with information or tempting options, which leads to self-regulatory failure, (iii) DSCTs should provide a level of friction or reward that is 'just right' for encouraging behaviour change, (iv) DSCTs should adapt to personal definitions of 'distraction'.

Theme 1: DSCTs help people prioritise important but effortful tasks over guilty pleasures The contexts in which tools were used suggested that they are particularly helpful when people try to focus on tasks that are important, but not immediately gratifying, and are tempted to engage in alternative 'guilty pleasures' easily accessible on their devices (n = 84, 9% of reviews).

Some reviews expressed this as DSCTs helping overcome 'procrastination' ("This extension saved me from the procrastination monster", R816, *Block Site - Website Blocker for Chrome*). Others explicitly said the tools helped them resolve internal conflict between different urges and emotional states in line with their longer-term goals ("helps me untangle my internal conflicts around my internet usage", R405, *Intent*; "helps control the impulse to constantly and unnecessarily control my mailbox", R545, *Inbox When Ready for Gmail*; "If you unconsciously glide from necessary info surfing to unnecessary stuff OR If you unconsciously open browser because you are getting bored", R724, *Guilt*).

In terms of more specific contexts, many reviews contributing to this theme (54%) said DSCTs helped them in *productivity* or *work* contexts ("I don't wish to waste my time on social media but somehow I skip the track of time and so many work gets pending", R463, *HelpMeFocus*; "Only installed it a couple hours ago, and I already completed 7 to do items that I had be putting off for week", R664, *PAVLOK Productivity*). Other contexts commonly mentioned included *studying* (24%), *writing* (11%) and *going to sleep* (10%). In terms of studying, reviews said tools were used by students to focus on schoolwork, and by teachers to make students more focused in class. In terms of writing, reviews expressed that a distraction-free digital environment helped writers complete their tasks ("I recommend this for writers everywhere who just want an elegant and interruption-free tool to get their stuff done", R700, *Just Write*). In terms of sleep, reviews expressed that device use often interfered with going to bed at the intended time ("I always used to stay up really late on my phone until I got this app", R163, *SleepTown*), but that digital self-control tools helped users adjust their habits in favour of the sleep patterns they wanted ("I use it to stop myself from using my phone at least 30

minutes before bed", R804, *AppBlock*; "I love that this app has helped me curb my late-night phone habits", R386, *Off the Grid*; "This has genuinely helped get into a better sleeping habit for me!", R819, *SleepTown*).

Sub-theme: DSCTs are particularly useful for people for whom self-control struggles are more acute

A sub theme implied by some reviews was that digital self-control tools are particularly useful for people for whom self-control struggles over digital device use are more acute (n = 26, 2.6%).

Most often (81% of reviews contributing to this subtheme), this was expressed in the form of people labelling themselves 'addicts' to digital technology, as easily addicted in general ("I'm a kid and I can get addicted to things really quick and this has helped me a lot", R817, *SPACE*), or as general 'procrastinators' ("I am a horrible procrastinator and I will distract myself with anything", R298, *Flora*). At a more clinical end of the spectrum, a reviewer who found the app Flora helped them focus on schoolwork also said they were "recently diagnosed with severe ADHD" (R303).

Theme 2: DSCTs are useful because many default designs overload users with information or tempting options, which leads to self-regulatory failure DSCTs sometimes received positive reviews because they were seen as directly countering information overload in default designs, or outright 'dark design patterns', that caused self-control problems (n = 46, 5% of reviews).

For example, some users felt default interfaces for email inboxes caused them trouble, which they could correct with the right DSCT ("Can't tell you how many times I just wanted to do one thing in my email and got lost in my inbox. Wish I had this years ago.", R190, *Inbox When Ready for Gmail*). Other reviews expressed that DSCTs helped them counteract tech companies' malevolent 'attention hacking' ("Mark Zuckerberg's evil masterminds only want to maximize the time you stay on Facebook by making you keeping scrolling, watching stupid videos and worthless news. Now there's nothing to scroll :)", R708, *News Feed Eradicator for Facebook*).

Many reviews contributing to this theme (80%) mentioned that a tool provided a piece of functionality or design tweak that users needed or had deliberately searched for ("Just What I Need... Now I can use Facebook for what it's useful for", R541, *Clar*, "This is exactly what I was looking for!", R830, *FocusMe*, "I googled 'chrome extension are you sure' hoping that someone had thought of this plugin. Sure enough, here it is", R358, *Are you sure?*, a Chrome extension that pops up a simple dialog box asking "Are you sure?" when the user navigates to a distracting website).

Theme 3: DSCTs should provide a level of friction or reward that is 'just right' for encouraging behaviour change Users searched for tools that provided a level of friction or reward which brought about their intended change in behaviour without being overly restrictive or annoying (n = 85, 9% of reviews). Reviews implied a spectrum of individual differences in where this 'Goldilocks level' was, with some reviews stating that simply tracking and visualising past behaviour was sufficient to change behaviour ("The visualization showing how many times I open my Twitter app has helped me change my habits on its own", R794, *Intent*), whereas others needed heavy-handed support and, e.g., wanted to make it impossible for themselves to override blocking of distractions ("Easy to bypass I've searched through the settings and there is no 'no manual exit' option", R960, *OFFTIME*).

Thus, for blocking tools, users sometimes complained that they were 'too strict', and made suggestions such as being able to pause blocking sessions ("It would be useful if it had an option to pause or reset a session. I know this breaks the rules but it should be enough that we know that", R865, *Strict Workflow*), and other times they complained that they were 'not strict enough' ("Too easy to bypass :(Will need to exercise a lot of self-control to stop myself from bypassing the timer", R961, *Strict Workflow*, "I would like the ability to set a password to turn the block on or off", R406, *Block Site*).

Similarly, for reward/punishment tools, users sometimes suggested increasing incentives for intended use ("would love if you could make it so you earned coins the longer the less tabs you had open and could buy things (hats,clothes, props,

ect) with the coins", R282, *Tabagotchi*), and other times they suggested decreasing them ("I hate the fact that we get a destroyed building ... I feel like it is too punishing and almost says 'you've failed' ", R883, *SleepTown*). Moreover, some users seemed to experience trouble when reaching the end of a reward scheme and wanted additional rewards to be added to keep the tool being useful to them ("reallllllllllly wish there were more than 3 phases to evolve into", R582, *Tabagotchi*).

Some reviews implied that users were aware of multiple tools and had actively tried out options with different levels of friction to find one that worked for them ("I used to favor the hard approach of something like StayFocusd, but I've lately found that that can just create weird incentives and reinforce existing internal tensions. Intent helps me untangle my internal conflicts around my internet usage", R405, *Intent*; "I bought Forest only to be disappointed because I thought I would like it more than Flora, but I ultimately didn't because it takes a really long time to raise money and buy different trees. In Flora, everthing is fast and much more rewarding", R174, *Flora*).

Finally, some users noted that the amount of effort involved in using the tool itself was important: a tool could become self-defeating if it was too demanding to use ("the reports are generated slowly to the point that i'm wasting time waiting for reports to generate. oh the irony", R495, *RescueTime for Chrome*; "the application can further be improved by reducing the switching time (lag) between daily, weekly and monthly options", R893, *SPACE*; "Would like a better way to block larger amounts of websites without much effort", R754, *Focus*).

Theme 4: DSCTSs should adapt to personal definitions of 'distraction'
Finally, tools needed to precisely capture the meaning of 'distraction' in the life of users to be helpful (n = 66, 7%), a theme often expressed in the form of feature suggestions.

One aspect involved getting tools to accurately capture *what* users defined as distraction (50% of reviews contributing to this theme). For example, feature suggestions sometimes involved being able to exempt particular apps from tracking

or restriction as they did not represent something the user struggled to control ("I use apps on my phone to study, such a math app, a dictionary and my notes I store on my phone. I found that by trying to work on an essay, I was killing the plants", R383, *Flora*; "I love the app, but I wish you could allow specific apps to run without affecting your phone usage time. For example, when I go on long walks I like to listen to YouTube playlists on my phone so it doesn't let me turn the screen off. I won't even look at my phone once, but while I'm on my walk it'll be racking up hours of usage", R665, *QualityTime*).

Another aspect involved getting tools to capture *when* specific activities counted as distractions (41%). For example, feature requests for tools aimed at curbing nightly use often involved being able to set different schedules for different days ("it needs to allow for the real life fact that people can't go to bed and wake up at the same time everyday. If it was done on your amount of sleep you get in hours that would be better", R659, *SleepTown*), and requests to blocking tools included allowing instances of use that did not represent distraction ("a peek feature, for quick access (maybe for 10 secs at most?) to 'blocked' websites, like Youtube, in case we need to change the song or skip something", R283, *Forest extension*). A final aspect involved *cross-device integration* (17%): some users expressed a need to curb distractibility on all of their devices at once. Thus, some reviews said that tools on different devices needed to sync with one another to be truly useful ("I wish it worked more in-sync with the app - e.g if you start a tree in the browser, it would also grow the same tree on your phone", R757, "Desperately needs to sync with the phone app so starting/failing on one starts/fails on the other", R119, *Forest extension*).

4.4 Discussion

To sum up, our analysis of user numbers and ratings found that tools combining two or more types of design patterns received higher ratings than tools implementing a single type; reward features were the least common type in top tools, but present in

tools with the very highest user numbers; and tools which included goal advancement features ranked higher on average ratings than on user numbers.

Our thematic analysis of user reviews found that DSCTs help people prioritise important but effortful tasks over guilty pleasures easily accessible on their devices (and are particularly useful for individuals for whom such self-control struggles are more difficult). Sometimes they do so by mitigating default designs that overload users with information. People seek out tools which provide a level of friction or reward that is 'just right' — a level which varies between people — for supporting intended behaviour without being overly restrictive or annoying, and they want tools to capture their personal definition of 'distraction'.

We now turn to discussing implications of these results, in terms of how the landscape of tools provides commentary on common designs, and conceptual and practical implications for finding the 'just right' level of friction and capturing contextual meanings of 'distraction'.

4.4.1 The landscape of DSCTs as commentary on default designs

The landscape of DSCTs available online provides a window into user needs and struggles in the face of common designs. The high average ratings given to these tools overall, as well as the content of user reviews, suggest that many people (at least among those that choose to try them out) find them very useful. Thus, tools on this market foreshadowed generic user needs that Google and Apple recently begun to address in the form of 'Digital Wellbeing' (Google) and 'Screen Time' (Apple) tools for monitoring and limiting device usage (cf. section 2.1.4). They also suggest specific design solutions, such as browser extensions that tackle information overload by hiding one's email inbox until one makes a deliberate choice to see it (e.g., *Inbox When Ready*) or hiding Facebook's newsfeed (e.g., *Newsfeed Eradicator*).

Comparing popularity metrics, our results suggest some potential disconnect between tools' usefulness and how widespread they are. I speculate that our finding that tools which include goal advancement features rank higher on average ratings

than on user numbers, and that some reward/punish tools rank at the very top of user numbers despite being rare, can be explained by how attention-grabbing they are: for example, scaffolding self-control using virtual trees that die if one's device is used inappropriately might be more 'sexy' and likely to be shared with others than are tools which provide simple but useful reminders of the task one tries to focus on. This would match research on online virality which has found that content evoking high-arousal emotions are more likely to be shared (Berger and Milkman 2012; Pressgrove et al. 2017), as well as findings in behaviour change research where strategies' popularity and their efficiency often diverge (Kelly and Barker 2016). An implication is that whereas store metrics of popularity may provide useful clues about the utility of various design patterns, they should be used as a rough guide for subsequent controlled studies rather than taken as 'ground truth' (cf. Norman 1999).

4.4.2 Self-control struggles and the 'just right' level of friction

Our finding that DSCTs are used when people focus on important but effortful tasks matches findings from research using other methods with, e.g., Tran et al. (2019)'s recent interview study finding that engagement in tedious or effortful activities is a common trigger of compulsive smartphone use (also Reinecke and Hofmann 2016). Similarly, the search for tools that provide an optimal level of friction can be conceptualised as use of 'microboundaries' (Cecchinato, Cox, et al. 2017) and 'design frictions' (Cox et al. 2016) to promote goal-oriented engagement with digital technology, and aligns with wider research in personal informatics where, e.g., people planning for exercise try to set up a 'sweet spot' of contextual factors to succeed (Paruthi et al. 2018).

To understand the psychological mechanisms involved, the dual systems framework presented in Chapter 3 may provide a useful lens. To recap, according to this framework, behaviour results from internal competition between potential actions. Potential actions are activated either by automatic responses to internal and external cues ('System 1' control, e.g., checking one's phone out of habit) or

by conscious intentions ('System 2' control, e.g., taking out one's phone because one has a conscious goal to text a friend). What wins out in behaviour is the action with the highest activation value, which may or may not be in alignment with one's longer-term goals (e.g., checking one's smartphone in a social situation out of habit despite having a goal to not do so).

From this perspective, DSCTs are used in situations where the internal struggle between potential actions are often not resolved in line with one's enduringly valued conscious goals (cf. section 2.2.2). Users seek tools that provide a level of friction or motivation which biases this competition such that the actions that win out are in line with one's longer-term goals — for example by using blocking tools to prevent unwanted System 1 responses from being triggered, by using goal advancement tools to remind oneself of one's usage goals and thereby enable System 2 control, or by using reward/punish tools to provide extra incentives for System 2 control (cf. Chapter 3).

We suggest the finding that tools whose features combine more than one type of design pattern can usefully be interpreted through this lens: tools that combine two or more types of patterns (for example, a tool which does not simply remove Facebook's newsfeed (*block/removal*), but replaces it with a todo list (*goal advancement*)) may be more likely to bias internal action competition sufficiently to cause a change in behaviour without being overly restrictive or annoying, than are tools which implement a single type. This may be because by combining design patterns that target different psychological mechanisms, each can be implemented at a more 'gentle' level of friction or intrusiveness while still in aggregate provide sufficient bias to the self-regulatory system to bring about an intended behaviour change. By contrast, tools focusing on a single design pattern targeting a single psychological mechanism may need to ramp up the level of friction more highly before sufficient impetus for behaviour change is provided — and in so doing is at greater risk of being perceived as annoying or 'too strict' by the average user.

For example, *Forest* combines growing of virtual trees with a countdown timer, which influences both the expected reward for control and sensitivity to delays,

which seems to be effective, given this tool's popularity with over 10 million users on Android alone. A version which simply grew virtual trees without a countdown timer might need to correspondingly increase the magnitude of reward to remain useful, but in doing so be more likely to be perceived as too forceful or manipulative (cf. Lee, Kiesler, et al. 2011).

4.4.3 The meaning of distraction

An important user need emerging from the reviews is that users look for digital self-control tools that capture their personal definitions of 'distraction'. We suggest that this has implications in two domains: *customisation*, and *cross-device integration*.

In terms of *customisation*, many tools received a combination of excited reviews from users who felt it matched their needs well, and reviews from less satisfied users who wanted specific features to be added to capture their situation (e.g., exempting particular apps or subdomain from being blocked, limiting weekly rather than daily usage, or setting custom schedules). For example, the *Forest* app on iOS (Seekrtech 2018), which rewards users for not using their smartphone at all during focus sessions, addresses the concerns of a student who considers all phone use while studying a distraction, but not those of a student who wants to access math apps. A conceptual implication is that studies of digital self-control tools should focus on assessing effects on people's sense of using their devices in ways that align with their long-term goals, rather than on overall 'screen time' (cf. section 2.2). A design implication is that tools should include adequate controls for users to customise them to their needs *or* that the ecosystems of tools should be diverse enough for users to find tools that match their needs.

There may be a trade-off between customisation and friction in a single tool: providing more fine-grained control runs the risk of increasing the amount of effort involved in using the tool in the first place, which could undermine usefulness. Apple and Google may therefore be facing distinct challenges: Because Apple do not allow mobile developers the level of permissions required to implement proper usage logging and blocking tools (Digital Wellness Warriors 2018), only

their own Screen Time app is capable of providing many basic features of DSCTs. This implies that this single app needs to be carefully designed to accommodate a wide range of user needs. Google, however, provide less restrictive permissions to developers, and an accordingly diverse range of potent DSCTs are therefore available on Android. Therefore, Google may face less pressure to 'get it right' with their own Digital Wellbeing tools, because less common user needs could be addressed by their app ecosystem.

In terms of *cross-device integration*, reviews suggested that tools should be sensitive to the overall affordances provided by the devices people use in combination. A research implication is that studies of digital self-control tools should move beyond considering a single device in isolation and towards studying the ecology of devices that people use, and what 'distraction' means in this context (cf. section 2.2). A design implication is that tools should be able to sync between devices, to accommodate a need to curb the availability of all digital distractions. This has been explored in two previous studies (cf. section 2.3.4) with, e.g., Kim, Cho, et al. (2017) finding that multi-device blocking reduces amount of mental effort required to manage self-interruptions.

4.4.4 Limitations

Many user reviews provide little depth and may consist of only generic praise or critique, an angry bug report, be very short, or intend to paint a tool in a specific light for marketing purposes. Furthermore, we may not have an equal amount of data for all areas of the design space, and lack of reviews could represent poor marketing efforts or bad luck, rather than design ideas with low utility. Therefore, care must taken when interpreting evidence from user reviews and ratings (cf. Panichella et al. 2015).

In this chapter, we sampled reviews from top tools across the design space, similar to previous research (Roffarello and De Russis 2019a). The fact that our findings from reflexive thematic analysis resonated well with findings from studies using other methods such as surveys and interviews (Ko, Chung, et al. 2015; Tran et al. 2019)

suggest that this approach did provide valid evidence. However, future research may wish to leverage e.g. automated ways of identifying high-informative reviews in advance of thematic analysis (Chen, Lin, et al. 2014; Panichella et al. 2015).

4.5 Conclusion

The landscape of DSCTs available online amounts to hundreds of thousands of natural 'micro-experiments' in supporting self-control over device use. As such, it provides a running commentary on user needs and struggles in the face of common design, as well as concrete suggestions for solutions. Therefore, studying characteristics of tools on this landscape represents a useful complementary approach to evaluating interventions in controlled studies, as the latter is difficult to scale to broad assessment of design patterns and implementations across the design space.

Extending Chapter 3's functionality analysis, this chapter investigated how design features relate to metrics of store popularity, as well as what user reviews reveal about digital self-control tools' contexts of use and design challenges, using data from 334 tools on the Google Play, Chrome Web, and Apple App stores. Our findings raise new hypotheses and avenues of investigation, which may inform future prototype tools:

We found that tools which combine multiple types of design patterns received higher average ratings than do tools implementing a single type. A possible explanation is that targeting multiple psychological mechanisms makes it easier for a tool to encourage an intended behaviour change without being perceived by users as excessively restrictive or annoying. We also highlighted that user reviews express a need for tools to capture personal definitions of distraction and adapt to multi-device ecologies. This does not only resonate with current calls in related HCI research, but also raises practical implications for how major tech companies can deal with evolving user needs within the constraints they place on their app ecosystems.

Together with Chapter 3, the present chapter provides the first steps toward answering this thesis' main research question of how existing digital self-control

tools can help us identify effective design patterns, by reporting, at scale, how tools in online stores have explored the design space and how users have responded in ratings and reviews. In the next chapter, we turn our attention to how such investigations can drive targeted studies of promising design patterns.

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5

A Controlled Study of Interventions for Self-Control on Facebook

Contents

5.1 Introduction

Beyond being the world's largest social network, Facebook is also one of its greatest sources of digital distraction. Indeed, research on 'Problematic Facebook Use' has investigated correlations between Facebook use and negative effects on outcomes such as level of academic achievement (Gupta and Irwin 2016) and subjective well-being (Marino et al. 2018a,b). Here, a cross-cutting finding is that negative outcomes are associated with subjective difficulty at exerting self-control over use, as well as specific use patterns including viewing friends' wide-audience broadcasts rather than receiving targeted communication from strong ties (Burke and Kraut 2016; Marino et al. 2018a). Much of this work has focused on self-control over Facebook use in student populations (Al-Dubai et al. 2013; Khumsri et al. 2015; Koc and Gulyagci 2013), with media multitasking research finding that students often give in to use which provides short-term 'guilty pleasures' over important, but aversive academic tasks (Meier et al. 2016; Rosen et al. 2013; Xu, Wang, et al. 2016).

In the two previous chapters, we took a broad approach to our main research question of how existing digital self-control tools (DSCTs) can help us identify effective design patterns, and analyse a large number of tools in online stores. In the present chapter, we focus in on how this can inform subsequent targeted studies of promising design patterns. Thus, in surveying existing DSCTs, we encountered many examples of tools providing interventions aimed specifically at supporting self-control over use of Facebook (e.g., *Newsfeed Eradicator*, JDev (2019)). However, no existing studies have evaluated their effectiveness. This chapter presents a

controlled study exploring how UI interventions drawn from popular DSCTs on the Chrome Web store affect patterns of use and perceived control over Facebook use. We randomly assigned 58 university students to one of three intervention conditions: goal reminders, newsfeed removed, or white background (control). Their Facebook use was logged for 6 weeks, with interventions applied in the two middle weeks, and we administered biweekly surveys as well as post-study interviews.

We found that both goal reminders and removing the newsfeed helped participants stay on task and avoid distraction. In terms of use patterns, goal reminders led to less scrolling, fewer and shorter visits, and less time on site, whereas removing the newsfeed led to less scrolling, shorter visits, and less content 'liked'. However, goal reminders were often experienced as annoying, and removing the newsfeed made some participants fear missing out on information. In post-study interviews, participants suggested a range of design solutions to mitigate self-control struggles on Facebook, including controls for filtering or removing the newsfeed, reminders of time spent and use goals, and removing features that drive engagement.

5.2 Background

5.2.1 Struggles with Facebook use

Whereas many uses of Facebook offer important benefits, such as social support, rapid spread of information, or facilitation of real-world interactions (Ryan et al. 2014), a substantial amount of research has focused on negative aspects (Marino et al. 2018a). For example, studies have reported correlations between patterns of Facebook use and academic achievement (Rouis et al. 2011; Wang and Mark 2018), low self-esteem, depression and anxiety (Labrague 2014), feelings of isolation and loneliness (Al-Dubai et al. 2013), and general psychological distress (Chen and Lee 2013).

As mentioned in Chapter 2, such 'Problematic Facebook Use' (PFU) has been studied under various names (including 'Facebook dependence', Wolniczak et al. (2013), and 'Facebook addiction', Andreassen, Torsheim, et al. (2012)), but a

recent review summarised a common definition across papers as 'problematic behavior characterized by addictive-like symptoms and/or self-regulation difficulties related to Facebook use leading to negative consequences in personal and social life' (Marino et al. 2018a).

A large number of studies have in turn correlated measures of PFU with patterns of use and personality traits. Here, researchers often distinguish between use that is more 'active' (creating content and communicating with friends) and use that is more 'passive' (consuming content created by others without actively engaging), with the former being linked to more positive correlates of subjective well-being (Burke, Marlow, et al. 2010; Ellison et al. 2007; Gerson et al. 2017; Grieve et al. 2013) and the latter to more negative (Krasnova et al. 2013; Verduyn et al. 2015).

Moreover, most studies have found that 'problematic users' tend to spend more time on Facebook (Marino et al. 2018a), including a recent study by researchers at Facebook with direct access to server logs: users who experienced their use as problematic (i.e., reported negative impact on sleep, relationships, or work/school performance, plus a lack of control over use) spent more time on the platform, especially at night, as well as more time looking at profiles and less time browsing the newsfeed, and were more likely to deactivate their accounts (Cheng, Burke, et al. 2019).

As we saw in Chapter 2, prevalence estimates of 'problematic' Facebook use vary widely depending on the specific tools and thresholds used, from 3.1% in a representative sample of US users (Cheng, Burke, et al. 2019) to 47% in a study of Malaysian university students (Jafarkarimi et al. (2016), see also Bányai et al. (2017); Khumsri et al. (2015); Wolniczak et al. (2013)). The upper bounds of such estimates suggest that, at least at a mild levels, it is very common for people to struggle with using Facebook in accordance with their goals (Guedes et al. 2016). This is supported by the studies of multitasking and media use finding that people very often perceive their use of digital media to be in conflict with other important goals (61.2% of use occurrences in an experience sampling study by Reinecke and Hofmann

(2016) (cf. section 2.1.2), and that Facebook in particular is one of the most common sources of media-induced procrastination (Rosen et al. 2013; Xu, Wang, et al. 2016).

5.2.2 Self-control interventions for Facebook

Among DSCTs in online stores (see Chapters 3 and 4), many browser extensions focus on adjusting Facebook in ways intended to help self-control. Such tools may, for example, enable users to remove the newsfeed (JDev 2019) or hide numerical metrics such as like count (Grosser 2019).

No studies have assessed how interventions found in these tools may alleviate self-control struggles on Facebook. However, recent studies have investigated how temporarily deactivating or not logging in to Facebook affect subjective well-being (Allcott et al. 2019; Mosquera et al. 2019; Tromholt 2016; Vanman et al. 2018). The findings from these studies have largely been in agreement, with Allcott et al. (2019) the largest to date: in a study where 580 participants were randomly assigned to deactivate their accounts for four weeks and compared to 1,081 controls, Facebook deactivation increased offline activities (including socialising with family and friends and watching TV) and subjective well-being, and decreased online activity (including other social media than Facebook). Moreover, Facebook deactivation caused a large and persistent reduction in Facebook use after the experiment.

For many users, however, deactivating or deleting one's Facebook account present too tall a barrier to action for tackling problematic use. Most users have more targeted non-use goals than "abstinence", such as reducing time scrolling the newsfeed, but not time posting in a university social group, or reducing time spent on Facebook during final exams, but not during vacations (cf. Cheng, Burke, et al. 2019; Wang and Mark 2018). Some existing research similarly supports positive effects on well-being of targeted non-use, including research on active versus passive social media use (Burke and Kraut 2016; Hiniker, Hong, et al. 2016; Verduyn et al. 2015). Therefore, investigating interventions found in digital self-control tools for Facebook presents an exciting research opportunity, as they represent less extreme measures than deactivation that may have positive effects.

5.3 Overview of study

On this background, we set out to study how two interventions found in popular browser extensions for scaffolding self-control on Facebook — specifically, *adding goal prompts and reminders* and *removing the newsfeed* — affect patterns of use and perceived control on Facebook among university students. We designed a mixed-methods study that attempted to address common limitations in related studies:

- Most studies rely on self-reported Facebook use, which complicates interpretation because self-report often correlates poorly with actual use of digital devices (Ellis, Davidson, et al. 2019; Ellis, Kaye, et al. 2018; Orben and Przybylski 2019b; Scharkow 2016). Therefore, we combined surveys and interviews with logging of use, to triangulate subjective self-report and objective measurement.
- Nearly all studies, apart from deactivation studies, have used cross-sectional designs, making it very difficult to interpret causality (Marino et al. 2018a). Therefore, we randomly assigned participants to intervention groups and compared an initial baseline to a subsequent intervention as well as post-intervention block.

Our choice of interventions is described in the 'Pre-study' section below. Based on existing research on self-control struggles in relation to Facebook use, our research questions were as follows:

- RQ1 (Amount of use): How do goal reminders (C_{goal}) or removing the newsfeed ($C_{no\text{-}feed}$) impact time spent and visits made?
- RQ2 (Patterns of use): How do goal reminders (C_{goal}) or removing the newsfeed ($C_{no\text{-}feed}$) impact patterns of use (e.g. passive / active)?
- RQ3 (Control): How do goal reminders (C_{goal}) or removing the newsfeed ($C_{no\text{-}feed}$) impact perceived control?
- RQ4 (Post-intervention effects): Do the effects (RQ1-3) of goal reminders (C_{goal}) or removing the newsfeed ($C_{no\text{-}feed}$) persist after interventions are removed?

- RQ5 (Self-reflection): Do the interventions enable participants to reflect on their struggles with Facebook use in ways that might inform the design of more effective interventions?

Whereas RQ1-4 follow from the background literature reviewed, RQ5 was a generative research question pointing towards new design solutions. We did not envision participants being 'vessels of truth' in relation to which interventions would solve their struggles, but were interested in what suggestions the interventions might inspire as design probes.

5.4 Methods

Study materials, anonymised data, and analysis scripts are made available via the Open Science Framework on osf.io/qtg7h.

5.4.1 Pre-study: Review of Facebook self-control tools

In February 2018, we searched for browser extensions for supporting self-control on Facebook on the Chrome Web store and identified 50 such extensions implementing a range of design patterns (see open materials or Appendix A). Most (36/50) let the user remove or alter distracting elements, with more than half (27 out of 50) specifically hiding the newsfeed (e.g., 'Newsfeed Eradicator', JDev (2019), removes it and optionally replaces it with a motivational quote). Others implemented design patterns such as time limits (e.g., setting a daily limit and prompting the user to stop using Facebook, or as in the case of *Auto Logout*, Labs (2019), force closing it when the time has passed), goal reminders (e.g., *Focusbook*, Forst (2016), asks the user what they need to do on Facebook and subsequently provides reminders) or providing rewards or punishments (e.g., transferring money out of one's bank account if use is above a set limit, *Timewaste Timer*, Prettymind.co (2018)).

To categorise these interventions, we relied on Chapter 3's grouping of design patterns in DSCTs into the main types *block/removal*, *self-tracking*, *goal advancement*, and *reward/punishment*, and mapping to psychological mechanisms in a dual

systems framework. To recap, this framework distinguishes between behaviour under non-conscious 'System 1' control, i.e., when the external environment or internal states trigger habits or instinctive responses; and behaviour that is under conscious 'System 2' control, i.e., when goals, intentions, and rules held in working memory trigger behaviour. 'Self-control' is the capacity of conscious System 2 control to override System 1 responses when the two are in conflict. For example, one might have a conscious goal to not check one's phone at the dinner table and need to use self-control to suppress an automatic checking habit to align one's behaviour with this goal.

Viewed through this lens, removing the newsfeed represents a *block/removal* design pattern which scaffolds self-control by preventing unwanted System 1 control from being triggered by the newsfeed, and supporting System 2 control by preventing distracting information from crowding out working memory and make one forget one's intentions for use. We chose this intervention for our first experimental condition, as it was by far the most common among the extensions reviewed.

To compare this to a different design pattern, we selected a *goal advancement* pattern as a second experimental condition, specifically the one implemented by *Focusbook* (Forst 2016), which prompts the user to type in their goal when visiting Facebook and then periodically reminds them of this goal. This design pattern scaffolds self-control by keeping the goals the user wishes to achieve present in working memory, thereby enabling System 2 control. We chose this particular option because it had the highest number of users among the extensions reviewed that implemented alternatives to *block/removal* patterns.

5.4.2 Materials

Study conditions

The study conditions are shown in Figure 5.1. In addition to the experimental conditions *goal reminder* (C_{goal}) and *no newsfeed* ($C_{no\text{-}feed}$), we included a control condition ($C_{control}$). In $C_{control}$, we changed the background colour of Facebook

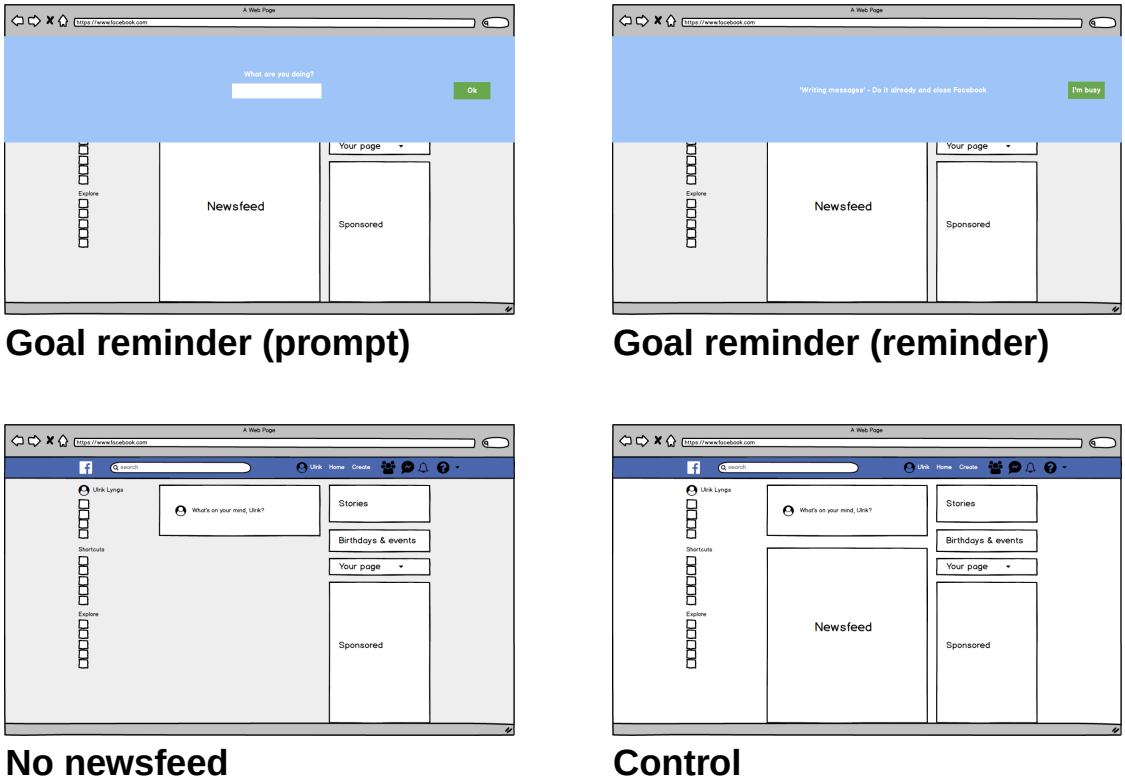

Figure 5.1: Mockup of study conditions: C_{goal} (adding a goal prompt when visiting the site that every few minutes pops up a reminder), $C_{no\text{-}feed}$ (removing the newsfeed), and $C_{control}$ (white background). Screenshots are available on osf.io/qtg7h.

from light grey to white, which we did not hypothesise to have any significant effect on behaviour.

We implemented the interventions as Chrome extensions written in JavaScript and CSS:

For $C_{control}$, the extension script turned the background colour of Facebook white during the intervention block. For $C_{no\text{-}feed}$, the extension script hid the webpage elements containing the newsfeed. For C_{goal}, the extension script was a modified version of *Focusbook* (the source code for which is available on GitHub, Forst (2016)), where we forced safe-for-work-mode (i.e., avoiding foul language in reminders) and altered prompts that expressed disapproval to neutral reminders (e.g., changing "Fine, just tell me why you needed to open Facebook" to "Tell me why you needed to open Facebook"). The extension prompted the user to type in why they opened Facebook when they went to the site, and after 1-3 minutes popped up a reminder of what they typed, along with a snooze button. Until the snooze button was

pressed, the banner containing the prompt slowly expanded to take up more and more screenspace.

Logging of use

Following recent work (Wang and Mark 2018), we used the open-source browser extension 'Research tool for Online Social Environments' (ROSE) (Poller 2017; Poller et al. 2014) to log Facebook use in the Google Chrome browser. We used this extension to record usage metrics (e.g., timestamps when a browser tab with Facebook was brought in and out of focus, number of clicks) and specific interactions (e.g., viewing a profile, liking content). To preserve privacy, the extension gave interactions (e.g., content liked) an anonymous identifier in stored data without storing any identifying information about the actual content engaged with. The ROSE extension was installed on participants' laptop in addition to the extension for their intervention condition.

Surveys/interviews

Opening survey The opening survey included (i) demographic information, (ii) basic information about their use of Facebook (when they got an account, devices they use to access the site, prior use of self-control tools for Facebook), and (iii) two individual difference measures (susceptibility to types of distraction, adapted from Mark et al. (2018), and a Big Five personality measure, adapted from Gosling et al. (2003)).

Repeated surveys The survey adminstered after each study block included the three following measures:
(i) The Passive and Active Facebook Use Measure (PAUM; Gerson et al. (2017)), which assesses frequency of activities on Facebook. The measure is factored into the usage dimensions 'active social' (items including "Posting status updates", "Chatting on FB chat"), 'active non-social' (e.g., "Creating or RSVPing to events", "Tagging photos"), and 'passive' (e.g., "Checking to see what someone is up to",

"Browsing the newsfeed passively (without liking or commenting on anything)").
(ii) The Multidimensional Facebook Intensity Scale (Orosz et al. 2016), which assesses agreement with statements about Facebook use (e.g., "I feel bad if I don't check my Facebook daily") and is factored into the dimensions 'persistence', 'boredom', 'overuse' and 'self-expression'.
(iii) The Single-Item Self-Esteem Scale (Robins et al. 2001), a commonly used measure of self-esteem in psychological research.

In addition, the survey after the intervention block included items on whether the changes affected perceived control, or how participants accessed Facebook on laptop vs smartphone.

Interviews After the study, we conducted semi-structured interviews with all participants. Main topics probed were (i) whether the interventions worked as expected, (ii) how participants experienced the interventions (example question: "When [changes in the participant's condition], what was that like?"), (iii) what changes participants might wish to make to Facebook to support their intended use (example question: "If you could build any extension you wanted to change the way Facebook appears and works to make it work better for you, what might you want to do?").

5-month follow-up survey Five months after the study, we sent participants an optional brief survey, assessing whether (and if so, how) the study had led to enduring changes in how they use Facebook.

5.4.3 Recruitment

Participants were recruited at colleges at the University of Oxford, using a combination of mailouts, posters, and Facebook posts. Recruitment materials described the study as a study on 'Facebook distraction', investigating 'which parts of Facebook

distract users, and what might be done about it'. Recruitment targeted non-first year students aged 18-30, who felt they were 'often distracted by Facebook'. Participation was compensated with a £20 Amazon gift card.

5.4.4 Procedure

A flowchart of the study procedure is shown in Figure 5.2.

Participants were randomly assigned to conditions. At an initial meeting, participants filled in the opening survey and installed two extensions on their laptop for the Chrome browser: the ROSE extension for logging use and our extension for modifying Facebook according to their assigned condition. Participants were instructed to use Chrome whenever they accessed Facebook on their laptop throughout the study period, and informed that the extensions would 'anonymously measure how you spend time on the site' and 'may change how Facebook appears at some point during the study period'. The logging period lasted six weeks, grouped into three two-week blocks. By the end of each block, participants were sent a survey link on Friday at 3pm and a reminder two days later. The first block served as a baseline, with no changes made to Facebook. In the second block, interventions were applied from Monday 9am (announced with a pop-up the first time participants visited Facebook) to Monday 9am two weeks later. The third block served as a new baseline measurement (post-intervention) with Facebook returned to normal. By the end of this block, a pop-up thanked participants for taking part and directed them to sign up for an interview and debriefing.

A subset of participants (n = 11) began the tracking period one week later than the others.

5.4.5 Data pre-analysis

Quantitative data On rare occasions, the ROSE extension did not correctly record entries to or exits from Facebook, which resulted in some instances where the calculated duration of active focus on a tab with Facebook was unrealistically long (more than 24 hours in one case). To handle such instances, we excluded

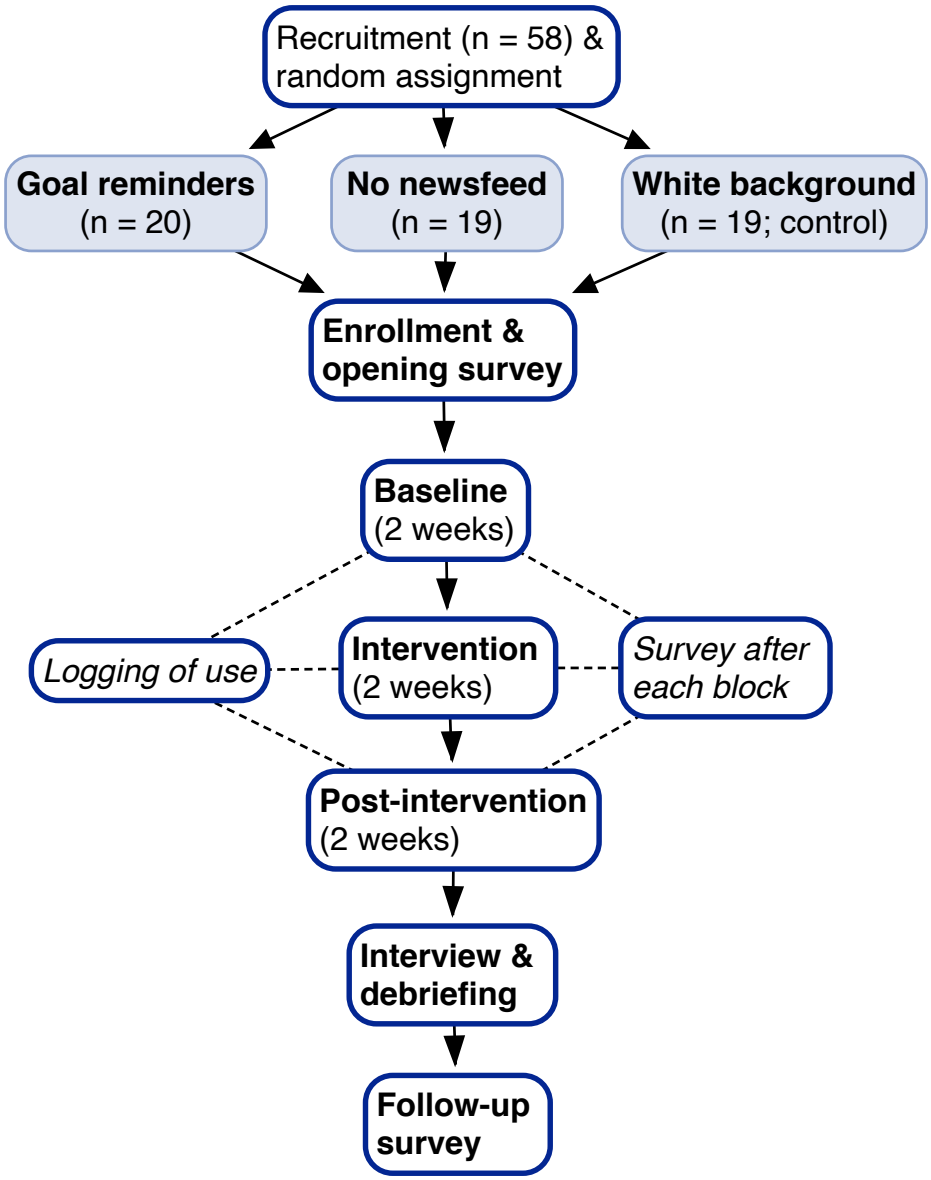

Figure 5.2: Flowchart of the study procedure

visits longer than one hour when analysing visit durations (144 tab visits out of a total of 120,002).[1]

Interview transcription and thematic analysis A collaborator and myself transcribed and conducted thematic analysis of all the interviews and free-text survey responses. The recordings were iteratively transcribed and analysed using an open-coding approach (cf. Tran et al. 2019). We reviewed transcripts and identified emerging codes individually, and regularly discussed emerging codes.

Thematic analysis was conducted in the Dedoose software; quantitative analyses were conducted in R.

5.5 Results

58 students (21 male) took part. For 8 participants, the intervention failed (on some Windows laptops, security settings prompted participants to turn the extensions off), and 1 participant deactivated his Facebook account during the study. Survey and logging data from these participants, as well as their interview statements about the interventions, were excluded from analysis. In addition, 2 participants deleted the ROSE extension before the debriefing - and with it their logged use - and for 1 participant the interview recording device failed. This left us with survey data from 49 participants (15 goal, 15 no feed, 19 control), logging data from 46 participants (15 goal, 14 no feed, 17 control), and interview data from 57 participants (20 goal, 19 no feed, 19 control) for analysis. Median interview length was 23m 51s (sd = 5m 5s).

In the following, we first report general characteristics of participants and their Facebook use, as well as introductory notes on how interventions were used and perceived. Afterwards, we report results grouped by research question.

[1]The precise data processing workflow from raw data to reported results can be found on osf.io/qtg7h.

5.5.1 Participant characteristics

Participants' median age was 22.5 (min = 19, max = 38) years. 90% had had a Facebook account for six years or longer, and the median number of Facebook friends was 900 (min = 200, max = 2200). All participants routinely used Facebook on their laptop. 96% also used it on their smartphone; most (78%) used the Facebook and Messenger apps, 8% used their smartphone's web browser (instead of the Facebook app) plus the Messenger app, 6% used only the Messenger app, and 2% (1 participant) used only their smartphone's web browser.

Most participants (71%) had never used digital self-control tools for Facebook. Among those who had, the most commonly used tools blocked access (7 participants) or removed the newsfeed (3 participants). 3 participants currently used such tools; one used *Newsfeed Eradicator* (which removes the newsfeed), another used *Self-control* (which blocks social media), and the third used an ad blocker (which we did not consider a self-control tool).

5.5.2 Overall Facebook use

Across all participants and the entire study period, the median number of daily tab visits to Facebook was 23 (min = 5, max = 138). The median break length between visits to Facebook was 69.5 seconds (min = 11, max = 445). The median of participants' average amount of daily time spent was approximately 21 minutes (min = 4m, max = 2h 56m).

Often, a number of successive tab visits were logged within a short span of time (e.g., if participants switched back and forth between active application windows). Following Cheng, Burke, et al. (2019), we calculated the number of 'sessions' as the number of times where the break between two visits to Facebook was longer than 60 seconds. The median number of daily sessions on Facebook was 11 (min = 1, max = 101).

5.5.3 Intervention use and perceptions

The C_{goal} extension did not record what participants typed when prompted for their goal, as we wanted to study effects of goal reminders without participants adapting or self-censoring from knowing responses might be read by the researchers. However, we asked in the interviews how they had used it. Most said they wrote short, descriptive, but generic notes for what they did ("I would type shorthand in for what I was about to do, so most of the time I would say something like 'reply to messages' or just 'messages' or 'post something on a group' or something like that", P4). Some also said they occasionally wrote meaningless or 'unsavory' things when they found the goal prompt annoying or disruptive ("I think sometimes I tried to type in, like, not really proper words and it said, 'give me a proper answer' and I was like 'dammit'!", P27). In $C_{no\text{-}feed}$, one participant said the newsfeed occasionally flashed on screen very briefly before being hidden by our script ("sometimes i saw like a millisecond of something and I was like 'oh that's interesting, I would like to see that' but then it wasn't there", P56).

In $C_{control}$, a couple of participants said the white background made content stand out less on their screen ("white background definitely makes it harder to... I don't think it's easier to read...", P1). Others, however, found it aesthetically pleasing ("I just liked Facebook more... it felt more... I mean it felt more Nordic, it wasn't grey and boring, it was white and nice...", P30) and wanted it to persist ("is there a way that I can keep the background white?", P15).

5.5.4 RQ1 (Amount of use): How do goal reminders or removing the newsfeed impact time spent and visits made?

The logging data and qualitative data suggested that C_{goal} led to less time spent and fewer and shorter visits, whereas $C_{no\text{-}feed}$ led to shorter visits (Figure 5.3):

Usage logging showed that in C_{goal}, average daily time on Facebook was significantly lower during the intervention block than in the baseline (Wilcoxon signed rank test, $p = 0.01$, median daily time in baseline: 27m 14s, median in

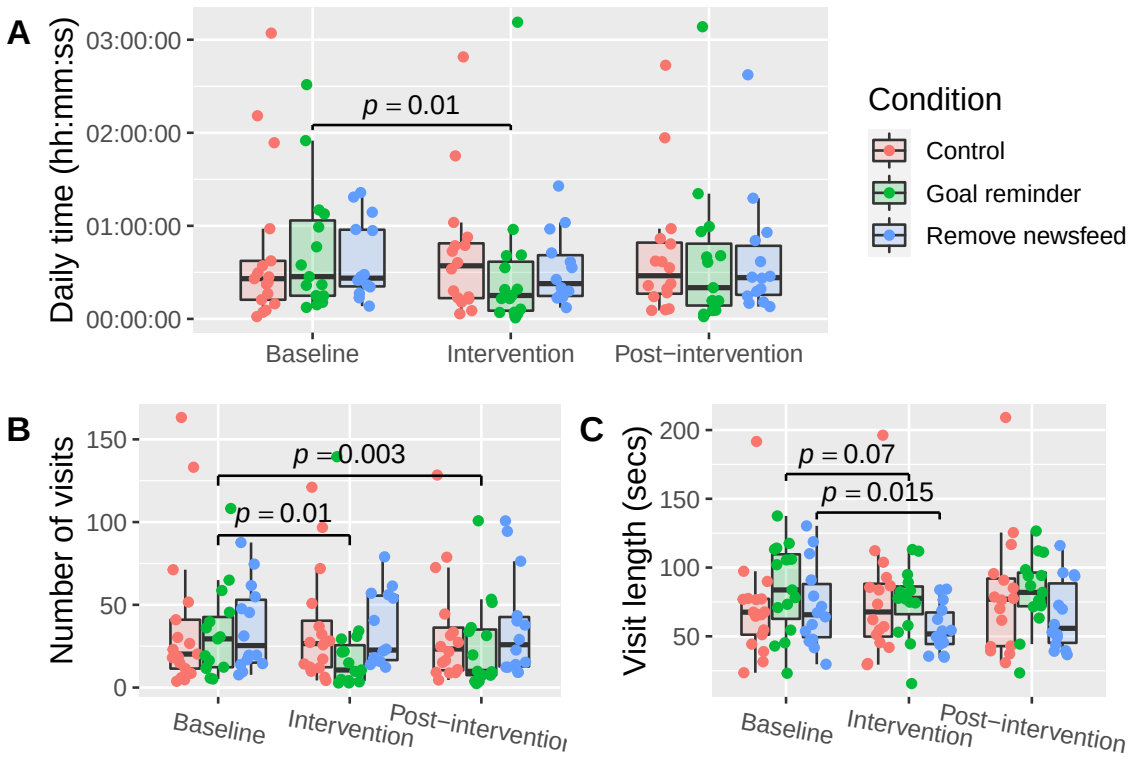

Figure 5.3: Time spent and number of visits made to Facebook. Comparing baseline and intervention, goal reminders were associated with less daily time (A), fewer tab visits (B), and a trend towards shorter visits (C). Removing the newsfeed was associated with shorter visits (C). Comparing the post-intervention block to baseline, goal reminders were associated with fewer visits, suggesting an enduring effect of the intervention.

intervention: 15m 5s); number of daily visits declined (Wilcoxon signed rank test, $p = 0.01$, median number of visits in baseline = 29.4, median in intervention = 10.6); and there was a trend towards shorter visits ($t(14) = 1.96$, $p = 0.07$; mean tab visit duration in baseline = 1m 25s, mean in intervention = 1m 15s). In $C_{\text{no-feed}}$, only visit length declined significantly ($t(13) = 2.81$, $p = 0.015$; mean visit length in baseline = 1m 12s, mean in intervention = 56s).

Participants' reports in the surveys and interviews agreed with the logging data: In C_{goal}, two common themes were that **the intervention reduced amount of time on Facebook on laptop** ("yeah I think I used it less and when I was using it I wasn't using it for very long, like a minute maybe", $P45_{\text{interview}}$[2]; "definitely used it a bit less", $P21_{\text{interview}}$) and that **reduced use was partly caused by the**

[2]Subscripts indicate whether quotes are from survey free text responses or from post-study interviews, and in some cases also show participants' study condition.

intervention being annoying/stressful ("This programme made me annoyed thus I would spent [sic] less time on Facebook", $P32_{survey}$; "The changes stressed me to get done with my task and then close facebook", $P40_{survey}$).

In $C_{no\text{-}feed}$, participants had **mixed opinions on whether or not it reduced amount of use**. Some felt it reduced their use ("limited overall usage", $P28_{survey}$, "I think I used it less erm for shorter periods of time", $P55_{interview}$) but others felt it only changed their newsfeed use without affecting amount per se ("The lack of newsfeed is welcome ... Facebook usage on my laptop has not changed/barely changed", $P27_{survey}$; "I spent a lot of time actually on facebook but messaging other people and not just looking through my wall", $P54_{interview}$).

5.5.5 RQ2 (Patterns of use): How do goal reminders or removing the newsfeed impact patterns of use?

The logging, survey, and interview data suggested that both C_{goal} and $C_{no\text{-}feed}$ affected patterns of use: C_{goal} selectively reduced passive scrolling of the newsfeed, whereas $C_{no\text{-}feed}$ (as expected) reduced all behaviour related to the newsfeed (Figure 5.4).

Thus, *usage logging* showed that average daily scrolling declined by 42% in C_{goal} (comparing intervention to baseline, $t(14) = 2.39$, $p = 0.03$), and by 73% in $C_{no\text{-}feed}$ ($t(13) = 4.15$, $p = 0.001$). Moreover, in $C_{no\text{-}feed}$, the number of times content was liked declined (Wilcoxon signed rank test, $p = 0.002$, median number of likes during baseline = 16, median during intervention = 7).

In the *surveys*, scores on the Passive and Active Facebook Use Measure dimensions showed that participants in $C_{no\text{-}feed}$ had substantially lower scores on 'passive' use in the intervention than in the baseline block ($t(13)$=4.79, $p = 0.003$). We explored effects on more granular elements of Facebook use by comparing baseline and intervention scores separately for each item of the PAUM.[3] Two items showed significant variation with condition: "Browsing the newsfeed passively (without

[3]Reported p-values are not corrected for multiple comparisons - these are exploratory results to be followed-up with confirmatory studies.

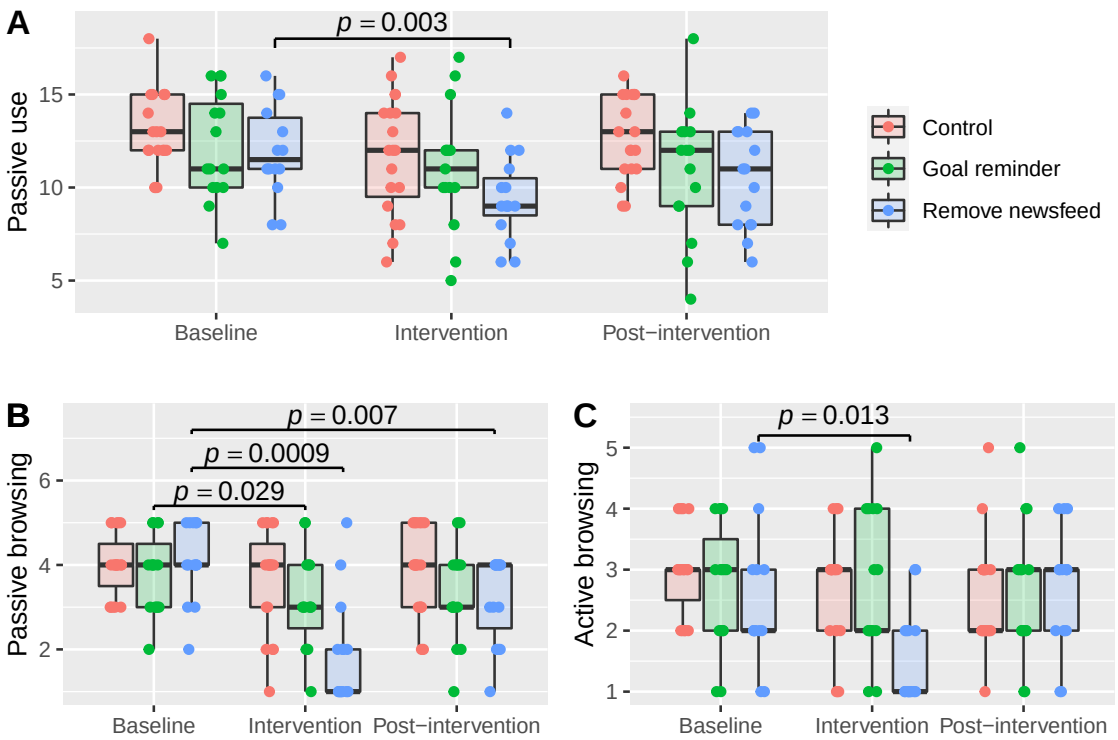

Figure 5.4: Scores on the Passive and Active Facebook Use Measure by condition. Comparing the intervention to the baseline block, goal reminders selectively reduced passive newsfeed browsing (B). Removing the newsfeed reduced scores on the 'passive' dimension (A), as well as (as expected) individual items 'Browsing the newsfeed passively (without liking or commenting on anything)' (B) and 'Browsing the newsfeed actively (liking and commenting on posts, pictures and updates)' (C). Comparing post-intervention and baseline, removing the newsfeed was associated with reduced passive newsfeed browsing post-intervention (B).

liking or commenting on anything)" and "Browsing the newsfeed actively (liking and commenting on posts, pictures and updates)": In C_{goal}, participants reported less passive, but not active, browsing of the newsfeed during the intervention block compared to baseline (Passive browsing: $p = 0.029$, Active browsing: $p = 1$, Wilcoxon signed rank test). In $C_{no\text{-}feed}$, participants reported less active as well as less passive newsfeed browsing (Passive browsing: $p < 0.001$, Active browsing: $p = 0.013$, Wilcoxon signed rank test). Moreover, participants in $C_{no\text{-}feed}$ showed a trend towards lower scores on "Commenting (on statuses, wall posts, pictures, etc)" ($p = 0.086$, Wilcoxon signed rank test).

The quantitative results were supported by the qualitative data:

For participants in both experimental conditions, a recurrent theme was that the

interventions caused **decreased browsing of the newsfeed** ("I did feel very aware when scrolling down my newsfeed, and cut it down", $P19_{goal\_survey}$; "definitely meant I spent less time scrolling on newsfeed on my laptop", $P55_{no\text{-}feed\_survey}$), and **increased use of Facebook for other, more deliberate purposes** ("a big facebook post or whatever not just passively... scrolling", $P41_{goal\_interview}$; "messaging other people and not just looking through my wall", $P54_{no\text{-}feed\_interview}$). In $\mathbf{C_{goal}}$, participants said the effects were driven by the intervention making them **search for reasons to justify being on the site** ("Being asked why I was opening Facebook was really helpful as it made me question why", $P41_{goal\_survey}$; "less likely to aimlessly browse, as I couldn't justify it", $P45_{goal\_survey}$). In $\mathbf{C_{no\text{-}feed}}$, participants said the lack of a newsfeed made them **seek out alternative options that were often more productive and deliberate** ("procrastination was more productive in that I was uhm seeking things out to read or to do that were more intentional, I suppose, and less kind of mindless which I guess the newsfeed is", $P12_{no\text{-}feed\_interview}$). (Changed patterns of use related to perceived control are reported below.)

5.5.6 RQ3 (Control): How do goal reminders or removing the newsfeed impact perceived control?

The qualitative evidence suggested that C_{goal} and $C_{no\text{-}feed}$ supported control in the sense of helping participants avoid unintended use and staying on task, but at the cost of being annoying/frustrating (C_{goal}) or leading to fear of missing out ($C_{no\text{-}feed}$).

Thus, in both C_{goal} and $C_{no\text{-}feed}$, it was a strong theme in the surveys and interviews that the interventions **helped participants stay on their intended task during use** ("used it less for stuff that I wasn't intending when I opened it", $P4_{goal\_interview}$; "I'll kind of forget that I'm doing work and start scrolling so it was useful to not be able to do that", $P47_{no\text{-}feed\_interview}$). A subtheme was that this included being **easier to disengage from use** ("it's good to get this reminder of 'hey you can get off this thing' ", $P31_{goal\_interview}$; "it was easier just to log out, just check what I had to and then leave facebook", $P54_{no\text{-}feed\_interview}$).

In $\mathbf{C_{goal}}$, participants said the reason the intervention helped them stay on task was that it **helped them snap out of automatic use**, that is, stop themselves when they engaged in unintended behaviour ("[the reminder] sort of snaps you out of that trance, you know what I mean?", $P21_{interview}$). In $\mathbf{C_{no\text{-}feed}}$, participants said it was because it **stopped unintended behaviours from being triggered** in the first place ("there is nothing here [referring to the newsfeed], like 'what did I want?', you know, so then I went and contacted the person or looked at the specific thing that I wanted, not what I saw and kinda wanted at the moment", $P56_{interview}$).

The downsides were that $\mathbf{C_{goal}}$ **was frequently annoying or frustrating**, especially because it was **not sensitive to context** ("I use facebook just to message people and I found this extremely annoying because I need to tell someone something and then this thing comes up and I'd just get annoyed. . . " $P32_{interview}$), and that $\mathbf{C_{no\text{-}feed}}$ **led to fear of missing out** ("missing out on a lot because actually a lot of the ways I interact with people on facebook is things I see on the newsfeed", $P12_{interview}$).

Perhaps reflecting this ambiguity, participants were more or less evenly split when asked directly in a survey item following the intervention block whether they felt the changes made to Facebook made them feel less or more in control of their use (Figure 5.5): When asked whether the interventions changed how they used Facebook on smartphone vs. on laptop, 86% of participants in C_{goal} and 57% in $C_{no\text{-}feed}$ answered 'Yes' (compared to 5% in $C_{control}$).

Unpacking this in the qualitative data, participants in both experimental conditions expressed that **cross-device access helped them manage the interventions' downsides, while still enjoying the positive effects** ("I could reap the benefits of the newsfeed but without being sucked into it on two platforms", $P28_{no\text{-}feed\_survey}$; "if I was scrolling through the newsfeed or checking events, then it wouldn't be annoying because I shouldn't be doing that on my laptop while I'm working, and if it was something like sending messages about work, contacting friends and asking for help then I could use my phone", $P40_{no\text{-}feed\_interview}$), and so they **sometimes used their smartphone for activities on Facebook the**

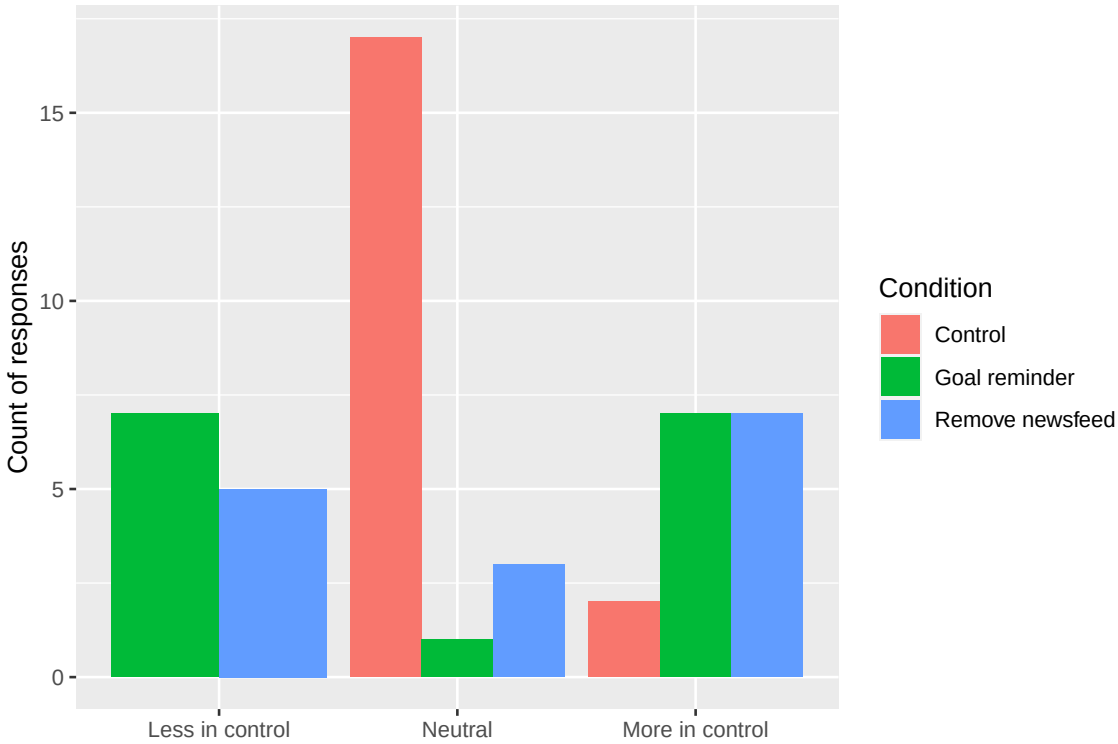

Figure 5.5: Responses from survey question on control included in the survey administered by the end of the intervention block: 'During the last two weeks, did the changes made to Facebook on your laptop affect how in control you felt over your use of the site on your laptop?'

interventions interfered with, but as a deliberate choice ("the time I did spend on my phone was more, like, focused because I was actually looking for things I missed out on on my laptop", $P55_{\text{no-feed\_interview}}$, "you're working on your laptop, uhm, and then it's very easy to just click new tab, but having to get your phone out...", $P19_{\text{goal\_interview}}$).

Finally, when exploring survey responses in the Multidimensional Facebook Intensity Scale, the only of its four dimensions that showed significant differences between the baseline and intervention blocks was *overuse*: Scores on this measure trended towards a decrease during the intervention in all conditions (C_{control}: $t(14) = 1.7$, $p = 0.037$, $C_{\text{no-feed}}$: $t(13) = 1.99$, $p = 0.07$, C_{goal}: $t(14) = 1.7$, $p = 0.1$), perhaps suggesting that simply taking part in the study made participants reflect on use. (Note that the benefits of staying on task and engaging less in unintended use were not expressed by any participants in the control condition.)

5.5.7 RQ4 (Post-intervention effects): Do the effects (RQ1-3) of goal reminders or removing the newsfeed persist after interventions are removed?

Comparing post-intervention to baseline, C_{goal} and $C_{no\text{-}feed}$ were associated with some persisting effects, with participants in C_{goal} engaging in fewer daily visits and some feeling that the intervention helped build a habit of more intentional use, and participants in $C_{no\text{-}feed}$ engaging in less passive newsfeed browsing.

Thus, in terms of *amount of use*, participants in C_{goal} made fewer daily visits post-intervention compared to baseline (median number of daily visits in first baseline = 29.4, median in post-intervention block = 10, Wilcoxon signed rank test, $p = 0.003$).

In terms of *patterns of use*, participants in $C_{no\text{-}feed}$ reported less passive browsing of the newsfeed post-intervention compared to baseline ($p = 0.007$, Wilcoxon signed rank test). In the interviews, some $C_{no\text{-}feed}$ participants expressed **feeling less attracted by the newsfeed when it returned** ("I found myself less interested in the newsfeed", $P10_{interview}$).

In terms of *perceived control*, some participants in C_{goal} said the intervention helped them build a persisting **habit of asking themselves what their intention of use was** when visiting the site ("from this week there is a habit being built... asking myself why I'm opening Facebook and that habit's perpetuated more or less to this week", $P34_{interview}$, "I'm still aware every time I open Facebook, I'm just a bit more aware every time... it's not the reflex anymore now that I've had that experience where I have to write everything down", $P1_{interview}$).

5.5.8 RQ5 (Self-reflection): Do the interventions enable participants to reflect on their struggles in ways that might inform the design of more effective interventions?

In the interviews, nearly all participants expressed feeling conflicted about Facebook, in that they found it too useful or engrained in their lives to do without, but also

an ongoing source of distraction and self-control struggles. They readily suggested a range of design solutions to mitigate self-control struggles. The extent to which interventions were perceived as freely chosen was important to how it was received, and participants did not trust Facebook to provide solutions.

Struggles with Facebook use

Too useful to do without, but source of distraction and self-control struggles On the one hand, Facebook provided functionality participants could not - or would not - do without, particularly messaging, events, groups, and pages. On the other, Facebook was frequently distracting and caused them to waste time and feel frustrated ("I just want... to hack myself to have the self-control to, like, not get distracted... I literally just use it as distraction", $P42_{\text{no-feed}}$). In particular, participants struggled to use Facebook in line with their intentions. Main aspects included (i) going to the site to do one thing, but then forgetting this goal ("there is one specific trigger that I need to open facebook, but because when I open the page immediately there is tons of information there, like erm notifications, and you scroll down endless streaming... so very easily I could be distracted", $P34_{\text{goal}}$), (ii) internal conflict between short-term gratification and longer-term goals ("might find them [videos] funny in the short term but when I think about it in the bigger picture it is a complete waste of time", $P48_{\text{control}}$), and (iii) using Facebook purely out of habit. In relation to the latter, emotional states, especially boredom, were mentioned as triggers of habitual use ("if I'm in that erm not very motivated state... I'll literally just find myself opening it, without even thinking that I'm doing it", $P17_{\text{control}}$).

Specific suggestions for design solutions

Four themes emerged in relation to specific design suggestions for mitigating these struggles:

Control over the newsfeed More than half of participants explicitly said the newsfeed did not give them what they wanted and desired easy ways to filter it, limit it, or turn it off. Some had tried customising their newsfeeds, but found Facebook's means of doing so tedious and ineffective ("I browse through shit that I don't want to see and I keep on clicking on 'I don't like this', 'this is not interesting' and of course it keeps on adding new stuff so that doesn't solve the problem basically", $P51_{control}$). Solution suggestions included simple ways to filter the newsfeed ("a slider to modify the amount you see people who are on your newsfeed at different percentiles", $P49_{goal}$, "two different ones, like you could have a 'friends' or like 'photos' or something", $P17_{control}$), reducing the amount of information ("maybe it should be limited to like ten posts and you wouldn't get another ten until the next hour", $P45_{goal}$, "if it was instead like blank and then you opt-in to who you actually wanna see on your newsfeed as opposed to opt-out", $P44_{no\text{-}feed}$), or being able to remove it altogether.

Raise awareness of time spent or usage goals Participants often lost track of time spent, or of their usage goals, and wanted reminders that raised awareness. These should be easily accessible ("you wouldn't want it to be buried in settings, something that was actively shown to you I think that would be useful", $P52_{control}$), and let users judge whether their use was appropriate ("if I saw like 'you've spent 2 minutes today', like 'great, i've got loads of time that i can waste tomorrow because i've been good today' ", $P6_{goal}$). Participants in C_{goal} said the timing and intrusiveness should be calibrated differently to the reminders they experienced in the study ("less in-your-face... so maybe more, longer intervals and not the expanding thing... if I could change it to longer intervals and maybe a bit less invasive then I think it would actually help", $P4_{goal}$).

Remove 'addictive' features Participants wished to remove or modify features driving them to use the site. Specific features mentioned included notifications ("get rid of notifications... if I didn't have things popping up every 30 minutes like 'this has happened' I don't think I would think about Facebook', $P6_{goal}$), viral

videos, and games (”things like game suggestions and like all that sort of stuff I would definitely get rid of cause... I don’t want to play games ... ‘stop bugging me’“, $P55_{\text{no-feed}}$). One interesting suggestion was to be able to display content as text-only (”limit it to like text-only posts when you’re working so that you’re not bothered by videos and algorithms and photos", $P45_{\text{goal}}$).

Flexible blocking to meet individual definitions of distraction Participants suggested blocking solutions that could adapt to the type — or timing – of use they found distracting. Thus, some said blocking access altogether was too inflexible to be useful (“there are useful uses of Facebook that aren’t just waste of time... a blanket, like, ‘don’t do anything on Facebook’... it’s not practical for those people who have to use Facebook”, $P41_{\text{goal}}$). Suggestions for more useful solutions included being able to block or allow only specific functionality within Facebook, block access only during specific times (“sync it with a timetable, like lectures or something”, $P45_{\text{goal}}$), or even automatically detect if activity is engaged with as a distraction.

Generic solution needs

People differ in what they seek on Facebook and the design solutions they prefer Some participants wanted to block or remove distractions, whereas others preferred less intrusive solutions, such as goal reminders. Similarly, even though most participants were dissatisfied with the newsfeed, some wanted it to prioritise close ties, whereas others wanted it to prioritise pages they follow (“I wouldn’t want to see anyone’s posts, I would only want to see posts by things I wanted to follow, whether that’s petitions or science papers”, $P20_{\text{no-feed}}$).

Interventions can ‘backfire’ if overly intrusive and/or not freely chosen Participants felt interventions could make people rebel against them if too intrusive and/or if they did not feel in charge. In terms of *intrusiveness*, some felt blocking tools could backfire for this reason (“I feel like most people in their nature, if you have something restrictive... then you kinda want to rebel against it”, $P56_{\text{no-feed}}$). In terms of *feeling in control*, some participants suggested this could change their

		C_{goal}	$C_{no\text{-}feed}$	$C_{control}$
RQ1 *Amount of use*	Daily time (L)	↓		
	Num. visits (L)	↓		
	Visit length (L)	↓	↓	
RQ2 *Patterns of use*	Liking content (L)		↓	
	Scrolling (L)	↓	↓	
	Passive newsfeed (S)	↓	↓	
	Active newsfeed (S)		↓	
RQ3 *Control*	Overuse (S)	↓	↓	↓
	Unintended use (Q)	↓	↓	
	Annoyance (Q)	↑		
	FOMO (Q)		↑	
RQ4 *Post-intervention effects*	Num. visits (L)	↓		
	Passive newsfeed (S)		↓	

Figure 5.6: Summary of RQ1-4 findings. Arrows indicate associated increases and decreases - blank fields indicate no change. 'L' = logged usage data, 'S' = quantitative survey data, 'Q' = qualitative data from surveys and interviews.

reaction to the very same intervention. For example, a participant in C_{goal} felt the goal reminders were too intrusive and led to resistance ("I got very used to clicking out of it and like, I'm just gonna stay on just out of spite", $P19_{goal}$), but thought she would react differently if she controlled the reminders herself ("it would be a bit different if it was me, if I could actually write the messages... I think that'd help me, and knowing it was me, so it wasn't anyone else").

Scepticism about design solutions coming from Facebook Participants did not trust Facebook to provide effective solutions for mitigating self-control struggles, because this was seen as going against their business interests ("you wonder how much they'd try to just give people the information that doesn't really reflect badly on them", $P36_{control}$; "Facebook's interest is for people to spend more time on it 'cause then then they'll get more ad revenue, so...", $P45_{goal}$).

5.6 Discussion

Figure 5.6 summarises findings from RQ1-4: Both C_{goal} and $C_{no\text{-}feed}$ reduced unintended Facebook use (RQ3), with the downside that C_{goal} was often experienced as annoying and $C_{no\text{-}feed}$ made some fear missing out on information (cf. "FOMO", Przybylski, Murayama, et al. (2013)). On amount of use (RQ1), C_{goal} reduced daily time, number of visits, and visit length, whereas $C_{no\text{-}feed}$ reduced visit length. On patterns of use (RQ2), C_{goal} and $C_{no\text{-}feed}$ reduced scrolling and passive newsfeed browsing, and $C_{no\text{-}feed}$ in addition reduced active newsfeed browsing and amount of content 'liked'. On post-intervention effects (RQ4), C_{goal} was associated with fewer visits and $C_{no\text{-}feed}$ with less passive newsfeed browsing.

In terms of reflections on struggles and solutions (RQ5), participants felt conflicted because Facebook was a source of distraction and self-control struggles but also vital to staying connected, i.e., too useful to avoid. They suggested specific design solutions related to control over the newsfeed, reminders of time spent and usage goals, removing 'addictive' features, and flexible blocking. Their preferred solutions (as well as the information sought on Facebook) differed, however, and they felt that solutions might 'backfire' if overly intrusive and/or not freely chosen. We now discuss design implications as well as some of the limitations and future work.

5.6.1 Evaluating the experimental interventions

Focusing specifically on the ability to use Facebook in line with one's conscious intentions — which is at the very core of self-control (Duckworth and Steinberg 2015) — which of the two experimental interventions is more effective? Goal reminders and removing the newsfeed represent contrasting, and potentially complementary design patterns. In our study, both interventions had a positive effect on perceived control and a significant effect on behaviour, with C_{goal} helping people 'snap out' of unintended behaviour and $C_{no\text{-}feed}$ preventing unintended behaviours from being triggered. While these results suggest that both interventions have potential, as an exploratory study with a restricted sample, further research with larger samples

will be needed to draw definitive conclusions about the robustness, effect sizes, and individual differences. However, contextualising our study within related research provides some predictions:

One possible approach is to, once again, apply Chapter 3's dual systems framework: From this perspective, **goal reminders are a 'System 2' intervention** which supports conscious self-control by bringing the goals into working memory that the user wishes to control her behaviour in relation to. **Removing the newsfeed is both a 'System 1' and 'System 2' intervention** which prevents unwanted automatic responses from being triggered by the newsfeed, and supports conscious self-control by preventing attention-grabbing information from crowding out working memory and making the user forget her goal.

As mentioned in Chapter 2, a recent, comprehensive review of digital behaviour change interventions found that providing information about the consequences of behaviour (a System 2 intervention) tends to be unsuccessful, despite being the most common technique. The authors argued that targeting unconscious habit formation (System 1) should be the focus for interventions that aim at long-term efficacy (Pinder, Vermeulen, Cowan, and Beale 2018). Similarly, psychological research has found that people who are better at self-control tend to develop habits that make their intended behaviour more reliant on automatic processes (System 1) and less on conscious in-the-moment self-control (System 2), and/or reduce their exposure to 'temptations' in the first place (Duckworth and Steinberg 2015; Duckworth, White, et al. 2016; Galla and Duckworth 2015). As outlined in Chapter 3, this may be because effective System 2 control depends not only on remembering longer-term goals, but also on the motivation to exert control relative to those goals, which can fluctuate with emotional state (cf. participants who said they were more likely to go on Facebook when bored or unmotivated Berkman et al. (2017); Inzlicht, Schmeichel, et al. (2014); Lee, Kiesler, et al. (2011)).

I therefore expect removing the newsfeed to be more generally effective than goal reminders, because it reduces the amount of potentially distracting information and thus the need for in-the-moment conscious control. In our study, qualitative

data did suggest that C_{goal} fostered a habit of asking oneself about one's purpose when visiting Facebook. However, given the above, the likelihood of effective control through a habit of goal awareness should depend on what content is available on Facebook and how that content is perceived: the more 'engaging' the content, the greater the risk that goal awareness will not by itself provide sufficient control motivation (Berkman et al. 2017; Lee, Kiesler, et al. 2011; Tice et al. 2001). Goal reminders should therefore exhibit greater variation in effectiveness, and may be less useful for individuals whose newsfeeds contain more attention-grabbing content and/or who struggle more with inhibiting distractions in general. This would align with recent findings that those who find Facebook more valuable are also (somewhat paradoxically) more likely to find their use problematic (Cheng, Burke, et al. 2019). Similarly, as mentioned in Chapter 2, blocking of online distractions has been found to be more effective for individual who are more susceptible to social media distractions (Mark et al. 2018; cf. Lee, Kiesler, et al. 2011; Miri et al. 2018).

Taken together, removing the newsfeed is likely to be more consistently effective than are goal reminders for helping people align use of Facebook with their conscious goals. However, for individuals who are less impulsive — or who are simply more concerned with missing out on information than occasionally failing to stay on task — goal reminders may be as appealing. Additionally, these design patterns are not mutually exclusive and can be combined in effective interventions, as is already the case in many digital self-control tools (e.g., *Todobook*, Yummy Apps (2019), which removes Facebook's newsfeed and replaces it with a todo-list reminding the user of her goals).

5.6.2 Designing future interventions

Broadly, participants' suggested design solutions related to either *altering the information landscape* (by filtering the newsfeed, removing features driving engagement, or blocking distracting elements) or *raising awareness to help navigation within this landscape* (by adding reminders of time spent or usage goals). These suggestions could be compared to the many existing interventions in online stores; analysed using

a dual systems or other framework; and design patterns more likely to be effective implemented and evaluated. Here, we discuss implications of the cross-cutting theme that interventions should be experienced as freely chosen and not overly intrusive to avoid 'backfiring' and motivate people to rebel against an intervention instead of being helped by it (cf. Lee, Kiesler, et al. 2011).

Given that participants preferred different interventions — with some wanting restrictive blocking tools — it is not a solution to only consider e.g. non-intrusive addition of user controls (Harambam et al. 2019). Rather, designers should keep in mind that the effectiveness of the exact same restriction or intrusion may depend on whether it is perceived by the user as self-imposed or externally imposed (Brook 2011; Bryan et al. 2010; Swim and Bloodhart 2013). The implication is that interventions should be carefully framed as being supportive of the user's personal goals (cf. Bandura 1982; Swim and Bloodhart 2013). For example, blocking tools may wish to remind the user why their past self decided to impose restrictions on their present self (Duckworth, Milkman, et al. 2018). Current examples 'in the wild' include browser extensions for website blocking that display motivational quotes or task reminders when users navigate to distracting sites (cf. Chapter 3).

One exciting avenue for future tools is systems that can learn the user's personal definition of distraction and in what contexts to, e.g., automatically impose or not impose limits. This was suggested by one of our participants, and is being explored in some HCI research, e.g., *HabitLab*, which rotates between interventions to discover what best helps a user limit time on specific websites (Kovacs, Wu, et al. 2018). A useful such system in the context of Facebook would not simply limit time, but rather assist the user in carrying out their goals, for example by dynamically blocking elements such as the newsfeed if the user's current goal is to create an event. Such a hypothetical system could be highly useful, but it would be crucial to its success that its interventions were perceived by the user as being in her own interest. In addition, it would need to *really* understand the user to be functional (Lyngs, Binns, et al. 2018), creating a possible trade-off between privacy and the 'fit' of the intervention. Facebook itself, with its deep knowledge of

user behaviour, might be in the best position to take this approach, but we note that participants in our study were deeply sceptical about Facebook's motivations and did not expect design solutions coming from Facebook to be 'on their side' (cf. Creswick et al. 2019; Perez Vallejos et al. 2017).

5.6.3 Limitations

This study has a number of limitations.

Confounding variables A possible criticism is that less scrolling and shorter visits from removing the newsfeed is simply because there was nothing to scroll. We note that removing the newsfeed did not make scrolling impossible — it remained relevant on all other pages than the home screen — and thus scrolling remained a useful measure. Moreover, reduced time is often an explicit goal for users, and so time spent in the face of reduced content is a relevant outcome.

Lack of cross-device tracking We investigated Facebook use on laptop only. We did assess participants' sense of how interventions affected cross-device use (as mentioned in Chapter 2, recent research has found that productivity interventions does not just displace procrastination from one medium to another, Kovacs, Gregory, et al. (2019)), but adding objective measurement of 'spillover' effects would be highly useful in future work (Lascau et al. 2019).

Retrospective self-report In the surveys and interviews, participants retrospectively reported their experience, which is subject to recall biases (Kahneman and Riis (2005); Redelmeier and Kahneman (1996)). As self-control often involves one's past self setting goals for one's future self (e.g., in blocking tools), retrospective reflection is highly informative (Lyngs, Binns, et al. 2018), but it would be interesting to include experience sampling in future work (cf. section 7.2.2).

Granular interventions and usage measures Standard measures of Facebook use were not optimal for assessing granular interventions on laptop only: most measures consider global use and factor into broad dimensions. For example, we found the overall dimensions of the Passive and Active Facebook Use Measure too broad to capture the behavioural changes our interventions introduced. We flag this as a consideration for future study designs.

Sampling Our participants were all students at the University of Oxford and our sample size limited to allow for interviews to be conducted with all participants. Future research with larger samples is needed to assess the replicability and generalisability of our results (Cockburn et al. 2018), how individual differences may predict the design patterns' relative usefulness, and how implementation details might minimise their downsides.

5.7 Conclusion

Imagining what success for digital self-control on Facebook looks like is not an academic exercise, but a practical and urgent concern as evidenced by the recent hearing on 'Persuasive Technology' in the US senate (*Optimizing for Engagement* 2019), and a UK All Party Parliamentary Group's call for a 'duty of care' to be established on social media companies (All Party Parliamentary Group on Social Media and Young People's Mental Health and Wellbeing 2019). We hope the work presented in this chapter illustrates how assessments of possible interventions, with open and transparent research methods, may help provide the evidence base needed to assist regulators in moving towards a benevolent future (Grimpe et al. 2014).

In relation to this thesis' main research question (*How can existing digital self-control tools help us identify effective design patterns for supporting self-control over digital device use*?), this chapter showed how tools in online stores can be used to drive focused studies of specific, promising design patterns, in this case for self-control on Facebook. In the next chapter, we zoom back out to explore how

a broader sample of existing tools might help us understand personal digital self-control struggles among university students, as well as their needs and preferences for potential solutions.

6

Understanding Personal Digital Self-Control Struggles in the 'Reducing Digital Distraction' Workshop

Contents

6.1 Introduction

Many of the design patterns HCI researchers have developed to help people stay in control of digital device use have the potential to influence time spent overall and in specific apps (e.g., Kovacs, Gregory, et al. 2019; Kovacs, Wu, et al. 2018), or help users feel more focused and in control (Kim, Jung, Jung, et al. (2017); Mark et al. (2018); see Chapter 2.3). However, existing studies also suggest that people's goals for changing their patterns of device use tend to be more targeted and context-dependent than what is supported by current interventions. For example, a user might wish to reduce time spent browsing Facebook's newsfeed, but increase time spent in specific groups on the platform. Such a goal is not easily met through interventions focused at the global or app level (cf. Hiniker, Hong, et al. 2016). As a result, users are often ambivalent towards current digital self-control solutions — especially lock-out mechanisms — because they address only one need (preventing unwanted compulsive use) while interfering with positive use of their devices (Kim, Jung, Ko, et al. 2019; Tran et al. 2019).

In answering this thesis' overarching research question (*How can existing digital self-control tools help us identify effective design patterns for supporting self-control over digital device use?*), the previous chapter focused in on what we might learn by investigating one specific approach among existing tools, namely browser extensions for self-control on Facebook. In the current chapter, we zoom back out to consider how the broader landscape of existing design patterns relate to people's struggles and goals, and how we might reduce discrepancy. To this end, we report results of a series of 'Reducing Digital Distraction' (ReDD) workshops developed in collaboration with the University of Oxford Counselling Service. In these workshops, we investigated students' struggles with controlling digital device use, and how they thought interventions drawn from recent reviews could help them achieve their usage goals. Similar to recent work taking a qualitative approach to studying 'compulsive smartphone use' (Tran et al. 2019), we took an active workshop approach to create

a space for participants to engage in deeper reflection and discussion around their experienced struggles, what success might look like, and how specific interventions could help. In so doing, this study also adds to recent work that has sought to understand effective design patterns by actively supporting struggling users in finding effective solutions among current interventions (Cecchinato 2018; Kovacs 2019).

Our study was guided by the following research questions:

- RQ1: What do students consider 'success' at digital self-control?
- RQ2: How do students think existing interventions can help them achieve 'success'?
- RQ3: How much do students' preferences among interventions vary?
- RQ4: What directions for future work are suggested by the ways in which the workshops are practically useful?

We conducted four workshops with a total of 22 students, in which participants reflected on their struggles and goals in relation to digital device use, explored a selection of solution interventions, and committed to trying out the options they were most interested in. The included interventions related to distraction blocking, self-tracking, goal setting, reward or punishment, as well as more general customisation of digital environments. They were drawn from research presented in chapters 3, 4 and 5, as well as from interventions discussed on prominent tech blogs (Center for Humane Technology 2019; Knapp 2013).

We found that participants wished to continuously use their devices in line with their intentions, and divide up their use according to time of day and/or location. They felt digital self-control interventions were important to achieve this, because instant access to distractions on their devices, combined with what they saw as deliberately 'addictive' designs, routinely led them to use their devices for other purposes than what they intended and/or to excessively interrupt themselves. Participants were particularly interested in interventions that would remain effective when they were less motivated to control themselves — such as distraction blocking — but wanted such interventions to be precisely targeted rather than crude bans. For

example, many wanted to try out interventions that would remove the newsfeed on Facebook, or video recommendations on YouTube, rather than block these services altogether. Finally, participants wished for tools that could serve as 'training wheels' for improving inner self-discipline over time. That is, they wished for tools they could use as external support initially, but which would later allow them to control themselves better in their absence. Responses from a two-month follow-up survey suggested that the workshops were effective at providing useful interventions for mitigating digital self-control struggles.

6.2 Motivation and background

While HCI researchers investigate possible interventions for supporting people's ability to stay in control of their digital device use, many user groups face an immediate need for guidance, including families, students, and information workers (e.g., Aagaard 2015; Duckworth, Gendler, et al. 2016; Gupta and Irwin 2016; Rosen et al. 2013). Before we are able to provide such guidance on a solid basis, there are important questions that need further study (see section 2.4).

One question relates to what our design patterns should aim to achieve in the first place, such that their influence on behaviour and perception aligns with users' goals (Lyngs, Binns, et al. 2018; Munson et al. 2020). As we highlighted in section 2.2, much debate has focused on 'screen time' and 'overuse' (Dickson et al. 2019; Przybylski and Weinstein 2017), and many studies have accordingly investigated interventions designed to limit time spent on devices (e.g., Kim, Jung, Ko, et al. 2019; Ko, Choi, et al. 2016; Ko, Chung, et al. 2015). However, as smartphones, tablets, and laptops come to mediate an ever-expanding range of activities and contents—and platforms such as Facebook come to integrate a vast range of functionality— time on devices becomes a poor indicator of whether people's use aligns with what they intended (Hiniker, Radesky, et al. 2019; Lukoff 2019; Orben, Etchells, et al. 2018; Orben and Przybylski 2019a). Therefore, we

may need to target interventions to just those aspects where users need support, to avoid interfering with digital experiences they value (see section 2.3.4).

Moreover, many users wish to make context-dependent changes according to time or space, such as spending more time in work-related apps when commuting (Hiniker, Hong, et al. 2016), and may also find different interventions effective depending on their immediate emotional state (Kim, Cho, et al. (2017); Kim, Jung, Ko, et al. (2019); Ryan et al. (2014); see section 2.3.4). These findings point to the need for a better understanding of how users understand 'success' at digital self-control and how we may design interventions that support their contextual needs.

Another question concerns the extent to which the interventions that are most helpful vary between individuals (see section 2.4.3). Previous studies have focused on mean effects in experimental study designs, but also reported that people often vary substantially in their preference for, and potential benefits derived from, specific interventions (Kim, Cho, et al. 2017; Kim, Jung, Ko, et al. 2019; Mark et al. 2018). For example, Mark et al. (2018) found in an exploratory study with information workers that participants differed in their self-reported ability to control distractions, and that only those who reported being less in control at baseline benefited from blocking online distractions. Hence, we should investigate how much individual variation there is in users' needs and preferences, and to what extent idiosyncratic needs can be met by current options.

Approach for this study In keeping with the overarching research question of the present thesis, we may attempt to answer these questions by drawing on the existing landscape of digital self-control tools as resource for eliciting how people's digital self-control needs are met by current interventions. Given the practical need for guidance, we may also consider collecting evidence by actively engaging with specific user groups in identifying effective solutions to struggles they face in their daily lives (cf. Hayes 2011, 2014; Mohr, Riper, et al. 2018), as recent research has started to do. For example, the research project *HabitLab* broadly targets people who wish to reduce their time spent on specific websites or

apps, and helps more than 12,000 daily Chrome and Android users meet their goals through interventions such as hiding content feeds or displaying timers (Kovacs 2019). Meanwhile, the platform allows researchers to study, e.g., the effectiveness of static vs rotating interventions (Kovacs, Wu, et al. 2018), or 'spill over' effects from one distraction to another (Kovacs, Gregory, et al. 2019). Another project conducted workshops with information workers in which they discussed challenges and ideal scenarios around work-life balance and digital device use and committed to trying out specific solutions (Cecchinato 2018). These workshops helped participants in the form of concrete interventions and support to follow through on their commitments, while generating research data through workshop recordings as well as follow-up interviews and surveys.

In this chapter, we draw on the range of digital self-control interventions reviewed in chapters 3, 4, and 5, while building on the active research approaches of recent projects, to advance our understanding of contextualised, personal digital self-control struggles and appropriate interventions. We collaborated with the University of Oxford Counselling Service, who work one-on-one with nearly 3,000 students each year, in developing a workshop that would serve as a local intervention for students struggling to manage their relationship with digital technology (Lyngs, Lukoff, Slovak, Freed, et al. 2020). While numerous studies have highlighted these struggles among students (e.g., Aagaard 2015; Gupta and Irwin 2016; Rosen et al. 2013), the work presented in this chapter is the first to focus on this demographic in a workshop intervention that embeds design patterns drawn from comprehensive reviews of existing digital self-control tools.

6.3 Methods

The workshop materials are available via the Open Science Framework on osf.io/hdvtm/.

6.3.1 Recruitment

Between May 2019 and March 2020, we conducted four workshops at the colleges of Merton, Corpus Christi, New, and St John's at the University of Oxford. The workshops were advertised with posters and mailouts distributed by student support administrators at the colleges, and broadly targeted students struggling with digital technology use (see Appendix B for an example of a recruitment poster). Sample content from recruitment emails include:

> Ever deleted Facebook only to come back on? Is Instagram driving you crazy? Do you have a love/hate relationship with your smartphone? Are there too many tabs open in your brain?
>
> If so, please come to a new "Reduce Digital Distraction" workshop developed by Computer Science DPhil student Ulrik Lyngs in collaboration with Maureen Freed from the University Counselling Service. This two-hour workshop will encourage some creative reflection on your digital life — what works and what doesn't — and will provide you with support to make real, practical changes for a happier, healthier digital life.

Interested students were directed to get in touch via email to reserve a space. There were no restrictions on who could take part among those who expressed interest.

6.3.2 Materials

Tools and interventions presentation A brief presentation introduced participants to the landscape of existing digital self-control tools and interventions, grouped into five types with representative examples:

1. *Block or remove distractions* (e.g., blocking distracting websites or removing Facebook's newsfeed)
2. *Track yourself* (e.g., tracking and visualising laptop use)
3. *Advance your goals* (e.g., replacing Facebook's newsfeed with a to-do list to remind users of their goals)

4. *Reward or punish yourself* (e.g., growing virtual trees that die if one's smartphone is used during a focus session)
5. *Change your digital environment* (e.g., rearranging the positioning of apps such that distracting options are harder to access).

The first four categories were drawn from research presented in chapters 3, 4 and 5, whereas the fifth was based on interventions discussed on popular tech blogs (e.g., Center for Humane Technology 2019; Knapp 2013). We condensed the diversity of design patterns and implementations within these five types into 17 categories based on what we judged to be an accurate summary of the main approaches explored within these types (see Figure 6.2; cf. chapters 3, 4 and 5).

From a dual systems perspective, the psychological mechanisms targeted by the 17 categories depend somewhat on the implementation details of a specific intervention; for example, an extension for blocking specific websites may also display motivational quotes. However, based on Chapter 3's guidelines for mapping design patterns to main components in the dual systems framework (see section 3.3.2), we view the psychological mechanisms that each intervention has the most immediate potential to influence as shown in Figure 6.1.[1] All mechanisms were covered by the interventions included, albeit with a frequency that mirrors the current balance in how existing DSCTs have explored the design space (cf. section 3.3.2).

[1]Compared to Chapter 3, where we focused on tools in online stores and excluded, e.g., use of broader OS functionality as self-control tool (e.g, grey scale or rearranging apps), the intervention type 'Change your digital environment' was a new addition. For interventions of this type, we therefore add a few comments on the reasoning behind the mapping shown. 'Go grey scale', 'Make only the apps you really need easy to access' (e.g., moving distracting apps away from the home screen and into folders away from sight (Center for Humane Technology 2019), and 'Schedule Do Not Disturb' are all mapped to 'nonconscious habits (prevent)', for the following reasons: 'Go grey scale' makes icons and content less perceptually salient and therefore less likely to gain unwanted access to conscious attention; 'Make only the apps you really need easy to access' moves potentially distracting apps out of sight to the same effect; and 'Schedule Do Not Disturb' prevent notification-driven habits from being triggered. In addition, 'Make only the apps you really need easy to access' is mapped to 'conscious goals & self-monitoring' because it also protects one's current intention from being crowded out of working memory by unrelated icons and notification markers (cf. removing the newsfeed on Facebook, see section 5.6.1); and 'Schedule Do Not Disturb' is mapped to 'nonconscious habits (scaffold)' because a recurrent schedule on which notifications and calls are muted helps scaffold a habit of not checking one's device during particular hours.

		Nonconscious habits (prevent)	Nonconscious habits (scaffold)	Conscious goals & self-monitoring	EVC: Reward	EVC: Delay	EVC: Expectancy
Block or remove distractions	Block distracting websites or apps	√	√				
	Remove distracting features from websites	√		√			
	Use minimal writing tools	√		√			
	Go monotasking/dumphone	√		√			
Track yourself	Understand how you use your devices			√			
	Work in bursts with a timer			√		√	√
Advance your goals	Put todo-lists or motivational quotes on new tabs			√			√
	Replace Facebook's newsfeed with a todo-list	√		√			
	Redirect yourself away from distracting sites	√	√				
	Be mindful of what you're supposed to do			√			
Reward / punish	Plant trees or protect virtual creatures by being focused				√	√	√
	Add time pressure to stop procrastinating				√	√	√
Change dig. environment	Go grey scale	√					
	Make only the apps you really need easy to access	√		√			
	Schedule Do Not Disturb	√	√				
	Allow only notifications you really need	√		√			
	Use full-screen and/or Focus mode on laptop	√		√			

Figure 6.1: Mapping digital self-control interventions included in the Reducing Digital Distraction Workshop to cognitive mechanisms in the dual systems framework.

Figure 6.2: Intervention cards

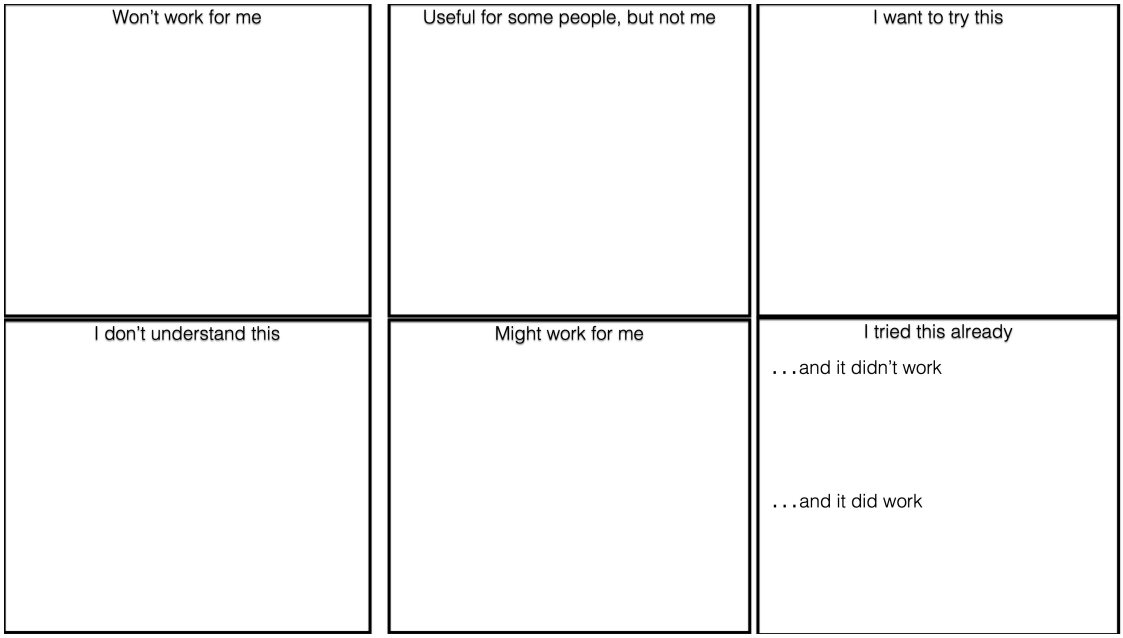

Figure 6.3: Card sorting background

Card sorting To help elicit information about how applicable and useful participants expected the interventions to be, we used card sorting, a common knowledge elicitation method in user experience design (Martin and Hanington 2012; Spencer 2009). Specifically, we used a 'closed card sort', in which we gave each participant a set of cards plus a set of pre-determined categories, and asked them to sort cards into categories as they saw fit. Each participant was given a set of 17 cards, which each represented a specific intervention with a caption and one or two screenshots (all cards are shown in Figure 6.2). Each card also had a heading that classified it within one of the five main types.

Participants sorted cards into the categories 'I don't understand this', 'Won't work for me', 'Useful for some people, but not me', 'Might work for me', 'I want to try this', and 'I already tried this and it did/didn't work' (Figure 6.3)[2]. Each card had a QR code pointing to the workshop website (see below). Cards were printed in colour on thick paper in size A6, and sorted into categories on a white A2 paper sheet.

[2]Based on participant feedback, we added the category 'I tried this already and it did/didn't work', and also changed the card caption 'go monotasking / dumbphone' to simply 'go monotasking', after workshop three.

Workshop website To provide participants with details and implementation instructions for the interventions, we developed an accompanying website. The website contained separate pages for each type of intervention, with tabs for the specific interventions within that type. Each tab in turn contained descriptions, screenshots, and links to the key implementation options available on laptop, Android, and/or iOS.

When many options were available for implementing an intervention, we chose tools to include based on which had the highest user numbers and average ratings on the corresponding app or browser extension store. Where available, we also included options that did not require participants to install additional software (e.g., when interventions were available via Android's 'Digital Wellbeing' or iOS' 'ScreenTime' features). In total, the website contained descriptions and pointers to 47 options across the 17 intervention cards. Descriptions and mapping of all options to dual systems theory is available via the Open Science Framework on osf.io/ed3wh/

The website was generated from an R Markdown source file and deployed via GitHub Pages on ulyngs.github.io/reducing-digital-distraction/. QR codes on the intervention cards pointed to the corresponding section of the website.

Two-month follow-up survey In the follow-up survey, participants rated each workshop component on a 5-point Likert scale ('Not at all useful' to 'Extremely useful'), with an additional 'I don't remember this part' response option. Afterwards, they answered questions about whether they followed through on the intervention/s they committed to, and whether they had been useful. The survey ended with feedback on the workshop format and website, and was built and administered using Jisc Online surveys. Survey items and layout is available in the supplementary materials.

6.3.3 Procedure

A workshop lasts about 2 hours and is divided into two parts (see Table 6.1).

Time	Program
16:00	*Welcome and consent forms*
16:05	INTRODUCTION *Facilitators and participants introduce themselves.* *Participant say why they came and what they hope to get out of it.*
16:10	INTRO PRESENTATION (facilitator) *- workshop philosophy (tech is not a problem; being out of control is)* *- commonly reported problems* *- commonly reported triggers of excessive use*
16:25	GROUP DISCUSSION (groups of 2-3) Prompts: *- what concerns you about your relationship with the internet / your laptop / your phone?* *- what external (e.g. notification) and internal (e.g. thoughts, emotions) triggers control your use?* *- have you tried 'taking' charge and doing something different? How did that go?*
16:55	BREAK
17:00	STRATEGY PRESENTATION (facilitator)
17:10	CARD SORTING: *Participants sort strategy cards into categories. They use the website to investigate strategies they are interested in. Facilitators float and answer questions.*
17:50	COMMITMENT *Participants state one or two strategies they would like to commit to trying out.*
17:53	WORKSHOP FEEDBACK

Table 6.1: Workshop procedure

First half Upon arrival, participants sign consent forms. The facilitator(s) introduce themselves, and ask the participants to each share why they signed up to the workshop and what they expect to gain. Then, the facilitator(s) present the workshop aims, along with introductory remarks on commonly reported struggles and triggers for problematic use of digital technology. Following this, participants are split into small groups (2-4 participants), with the facilitator(s) moving between groups. In these groups, participants engage in open-ended discussion prompted by the questions (i) *what concerns you about your relationship with the internet / your laptop / your phone?*, (ii) *what external and internal triggers control your use?*, (iii) *have you tried 'taking charge' and doing something different? How did that go?*

Second half After a break, a facilitator gives a brief presentation on interventions and tools for digital self-control, and introduces the card sorting task. After participants finish sorting cards, they investigate the interventions they are most curious to try out, with guidance from the website and the workshop facilitator(s).

A facilitator circulates and records how participants sorted the interventions and asks them to provide any comments they have on why they sorted the way they did. Finally, participants commit to trying out one or two interventions. The workshop ends with brief verbal participant feedback on the workshop.

Commitment reminder & follow-up survey One week after the workshop, participants are sent an email reminding them of the intervention/s they committed to trying out, alongside a link to details on the website. Two months after the workshop, they are sent a link to the follow-up survey described earlier.

6.3.4 Analysis

A collaborator (Kai Lukoff) and myself transcribed all workshop recordings. Subsequently, I conducted inductive thematic analysis of the qualitative data following the 'reflexive' approach described in (Braun and Clarke 2006) and (Braun, Clarke, et al. 2018). First, I read all transcriptions and free text survey responses and conducted initial coding of recurrent patterns relevant to our research questions. Afterwards, I read through all coded excerpts, recoded instances, iteratively sorted the codes into potential themes, and discussed emerging themes with two collaborators (Kai Lukoff and Petr Slovak).

As noted above, the sorting categories 'I already tried this and it did/didn't work' were added only after the third workshop. For the card sorting from the first workshops, if participants explicitly said in the video recording of their sorting that they had already tried a given intervention, and that it did or did not help them, we coded cards as placed in one of the corresponding categories, even though these categories were not available to them at the time of the workshop.

The thematic analysis was conducted in the Dedoose software; quantitative analyses were conducted in R.

6.4 Results

22 participants (9 women) took part across four workshops; 5 in the first (May 2019), 4 in the second (June 2019), 5 in the third (November 2019), and 8 in the fourth (March 2020).

6.4.1 Participants' overall device use and self-control struggles

Digital devices played an essential role in participants' lives, with laptops and smartphones mediating or interspersing all their daily activities. However, they struggled to control their use, mostly in relation to social media, email, and specific web content such as sports or news sites. In particular, more than half highlighted Facebook as one of their main challenges, which was related to the central role of this platform in coordinating university-related activities where *"everything here seems to be on Facebook and Facebook Messenger so that one site is pretty much everything, it's your connection to your whole Oxford community"* (P5).

In terms of devices, some participants said they struggled mostly with controlling their smartphone use, as *"when I'm on my computer I'm already quite focused"* (P17). Many others struggled equally on their smartphone and computer. No participants mentioned struggles in relation to other digital devices than smartphones and computers.

Their struggles mainly involved going to their devices and digital services with a specific intention in mind, but then getting distracted from their intention and doing something else, and/or excessively interrupting themselves:

> *"I get the phone to do X and... yeah I think it erodes me to, like, I read several articles and then check my Facebook and WhatsApp and Instagram and then put the phone away and [then] I am like 'oh shit'"* (P3)
>
> *"I often will go to check something and then before I go to, like, click on the necessary group or the necessary message I'm always scrolling and like I forgot what I was looking for"* (P4)
>
> *"I'll like constantly keep checking as a sort of mini-break"* (P7)

Most participants' struggles were 'self-control dilemmas', in that they struggled to stay focused on a task when more immediate gratification was available from doing other things on their devices. These struggles were driven by impulses or habits that conflicted with their better wishes (*"I know I shouldn't do it [...] it's just that there is this* urge *to check your phone"*, P3; *"sometimes I just get my phone without even the desire to use it [...] I was like 'what are you doing?'"* P1), or by a desire to escape from uncomfortable feelings when they worked on tasks that were effortful or boring (*"the second there is that academic intellectual pain then I [...] move immediately to the digital media"* P9). Some participants said their struggles were more about prioritising between multiple tasks that were all seen as important, particularly tasks involving social responsibilities:

> "*[My] self-control is kind of okay, I don't get super distracted [...] my biggest challenge is* splitting priorities, *so if I go in to do academic work, like welfare or JCR stuff, or something on Facebook or I'm in a conversation with someone [...] I feel if I don't answer those emails in that minute, or if I don't answer that message, something later on in the week, or the month, or that day won't happen"* (P1).

In addition, participants said it was more difficult for them to stay in control the more unstructured their schedules were. Thus, several participants emphasised that their loosely structured student life — where their accommodations generally functioned as "an all-purpose place" (P7) for both personal and work activities — made it particularly challenging to find effective interventions for managing use:

> *"When I was working [...] I could set hours, I could set expectations and it felt like the divide between my personal life and my working life was very clear, whereas here I think it's very difficult because they are very enmeshed and like everyone knows you're here just for this... and so it doesn't feel like you can draw a clear divide"* (P6)

Similarly, many participants said it was especially difficult to stay in control when they were working on tasks that did not have a clear goal: *"I find it quite easy to stay focused on basic like simple tasks [...] because there's a clear goal whereas thinking something through, thinking through and developing ideas I think it's easier to go off track"* (P15).

Finally, participants emphasised that social expectations around acceptable use in their immediate surroundings had an important influence, as *"I don't generally have problems when I've got people to interact with or something to do it's more... idle moments when you're by yourself that it really encroaches on my time"* (P1). Depending on the situation, this could work both for (*"if I work in a big open public library, the RadCam, you get sort of shamed into like... you feel so exposed if you go on Facebook"* P12) and against their ability to stay in control (*"you walk into any given library and there will be a couple of people with Facebook out on their laptop at any time so it's kind of like, 'oh yeah it's okay if everyone does it' "* P1).

These struggles left participants frustrated, because they wasted time (an instance of self-interruption or diversion often led to a spiral of further distraction), had their workflow interrupted, or missed out on sleep when they got distracted at bedtime. They were worried about compounding negative effects on their mental well-being, partly because *"it never really gives me a break... there's like this background noise the whole time"* (P1).

6.4.2 Participants' views of 'success' and the role of digital self-control interventions

We developed three themes through our analysis in relation to what participants considered to be 'success' for their digital device use and how they thought current digital self-control interventions might help: First, **success as intentional use that is divided up according to time and location**; second, **digital self-control as 'training wheels' for self-discipline**, and finally **overcoming low motivation through targeted blocking rather than blanket bans**.

Success as intentional use that is divided up according to time and location

No participants viewed success as getting off their devices altogether. Rather they wished to be more in control and use them purposefully and actively in line with their intentions, as opposed to merely out of habit or in response to momentary urges (e.g., to escape boredom). *"Every time I use my phone I'd like to do the*

thing that I intended to do and then leave it there [...] times when it's not so great is when I am purely passive" (P1). Some highlighted that they already felt in control over much of the functionality on their devices — *"music and podcasts [...] I don't really have a problem with that"* (P20) — and wished that they were similarly able to control their use of, e.g., social media.

When probed for specific implications of being in control, most participants said they wanted to 'timebox' better such that they would use their devices for certain things only at certain times and free up longer stretches of uninterrupted time:

> *"Success for me looks like being able to 'partition' in the sense of having a designated time to look at social media and emails and to deal with it and then for the rest of the day not."* (P7)
>
> *"Like wake up, pack up, check it over breakfast, then don't look at it for 4 hours."* (P18)
>
> *"If I'm gonna work I'm just going to work [...] I don't think I aim too high, really"* (P5)

Many also wanted to divide up their device use according to physical space, and for example not use smartphones in the bedroom. Some already tried to control their use in this way by making location-based rules for themselves such as *"phones don't go upstairs in my house"* (P6), by leaving their smartphone behind when going to the library to study, or by charging their phone in another room than their bedroom.

By using their devices in a more purposeful manner that was partitioned in time and place, they hoped that their use would feel more worthwhile and add enduring value beyond the individual instance of use:

> *"[Success is] using it productively and you don't feel like after you've used them for a number of hours that you've wasted your time, like you can actually remember what you've used them for and not just scrolling through [...] if you're kind of like actually concentrating on what you're looking at then I think it's probably worthwhile"* (P13)

Digital self-control tools as training wheels for self-discipline

To achieve their usage goals, participants felt they needed to find the right digital self-control interventions. The allure of instant access to huge amounts

of functionality on their devices, combined with deliberately addictive designs, was stronger than their willpower:

> *"It's easy to get a little bit pessimistic about just how good my self-discipline can really be, given that I know that there's like a billion-dollar economy in making sure that I am as addicted as possible"* (P20).
>
> *"I know I won't be able to control it once I open an app, you just will go down a rabbit hole... so I just, I understand that it's more like treating an alcoholic, like it's better to avoid it."* (P3)

Whereas several participants had found that simply putting their digital devices away therefore tended to be the most effective intervention, this approach failed when they *had* to use the devices that distracted them: *"I tried locking my phone away while I'm doing my work but in practice everything I would do on my phone I can also do on my laptop so [...] I don't think it makes actually that much difference"* (P20). Therefore, participants were keen to explore more technology-based solutions.

Importantly, many participants wanted such solutions to act as 'training wheels' for supporting their self-discipline rather than simply solve the problem for them and leave them vulnerable in their absence. For example, one participant said in response to the interventions presented in the workshops that they were *"treating the symptoms rather than dealing with the actual problem"*, as what he ideally wanted was to control his use only via "self-discipline", but then admitted *"I haven't figured out a way to deal with the actual problem so like any solutions that can begin to [help] are good solutions"* (P18). Echoing the same sentiment, another participant hoped that specific interventions could function as stepping stones to improve his self-discipline:

> *"In an ideal world I'd like to be able to do that without the need for artificial tools that sort of* make *me do it... using the apps that block websites for extended periods of time then sort of work my way off of those with time to just do it via self-control"* (P4)

Thus, participants seemed to identify being in control via 'self-discipline' with controlling themselves via their own inner resources as distinct from using external interventions to, e.g., block or remove distractions or provide rewards.

Similarly, some participants were reluctant to consider tools or interventions they felt were infantilising: *"Things that actually limit your [use] feel soooooo condescending... I'm a grown human I should be able to not check my email 57 times a day."* (P6) It therefore seemed important to our participants that design patterns were implemented in a way that would support and respect their sense of autonomy. Whether specific interventions were perceived as condescending varied substantially between participants, which one participant suggested was influenced by age: *"I think I'm more open, I've only really sort of rejected three [interventions]... I suppose being beyond the age of adolescence I don't mind as much the authority figure."* (P9)

Overcoming low motivation through targeted blocking rather than blanket bans

Participants highlighted that whether a specific intervention would be useful depended on their mental state. Some participants had found that simple, manual interventions like setting a timer and resolving to not use their phone for some period could be surprisingly effective (*"By the time the 15 minutes have ended I would be like into my work enough that I wouldn't have an urge to go back to my phone"*, P8), but the challenge for such interventions was that they required them to be in a psychological state where a certain level of control was available in the first place:

> *"There has to be like a base level of self-control to initiate that process, like I've got to be in that sort of mindset... I think that applies for most of the things I've tried, having that sort of, you* wanting *to do it in the first place and I don't necessarily want to."* (P4)

Therefore, many participants were interested in exploring interventions for *"removing choice or agency"* (P12), such as blocking distracting websites or apps, which they expected to be more helpful in the situations where they really struggled. However, several participants emphasised that such interventions needed to be precisely targeted:

> *"More forceful measures is basically the way forward I think for me because... even with things that block distractions I have to use them in order for them to work so I think it's more helpful to have things that either just keep me on one thing or keep me off other things and it matters that those things are erm as specific as possible as opposed to a blanket kind of ban"* (P16)

More 'specific' interventions would be targeted to just the elements they struggled to control. For example, in relation to Facebook many participants were interested in interventions that would remove the newsfeed or replace it with a to-do list, which might help them *"[use] it in a more focused way rather than completely blocking it out"* (P1) and therefore be more useful given the many uses they had for this platform. This approach appealed to many because it intervened only on *"an element of Facebook that directs my attention in a way that's not the way I want it to go"* (P21), without restricting them in relation to elements they did not struggle with. This intervention did, however, mean that they then had to find specific solutions for each distraction: *"[removing Facebook's newsfeed] that's been helpful for me but that's one... the problem is that's one app that's one platform, right? so that wouldn't work on Twitter"* (P21).

6.4.3 Individual variation

The qualitative data suggested a substantial degree of variation in participants' preferences among the interventions. For example, this was illustrated by the contrast between participants who were interested in blocking solutions and those who found this approach patronising, or between those who liked the gamification approach of Forest and those who found it plain silly:

> *"I have that tree-growing app, that's quite good cause it makes me feel good and safe"* (P13)
>
> *"it's a bit ridiculous [...] the more I think about the plant the more kind of... funny it feels, I don't know how seriously I would be motivated by a tree [...] I could just have done that with a timer"* (P10)

Keeping the limited sample size in mind, participants' sorting of the interventions supported this picture (Figure 6.4): About half of all interventions (9 out of 17) were

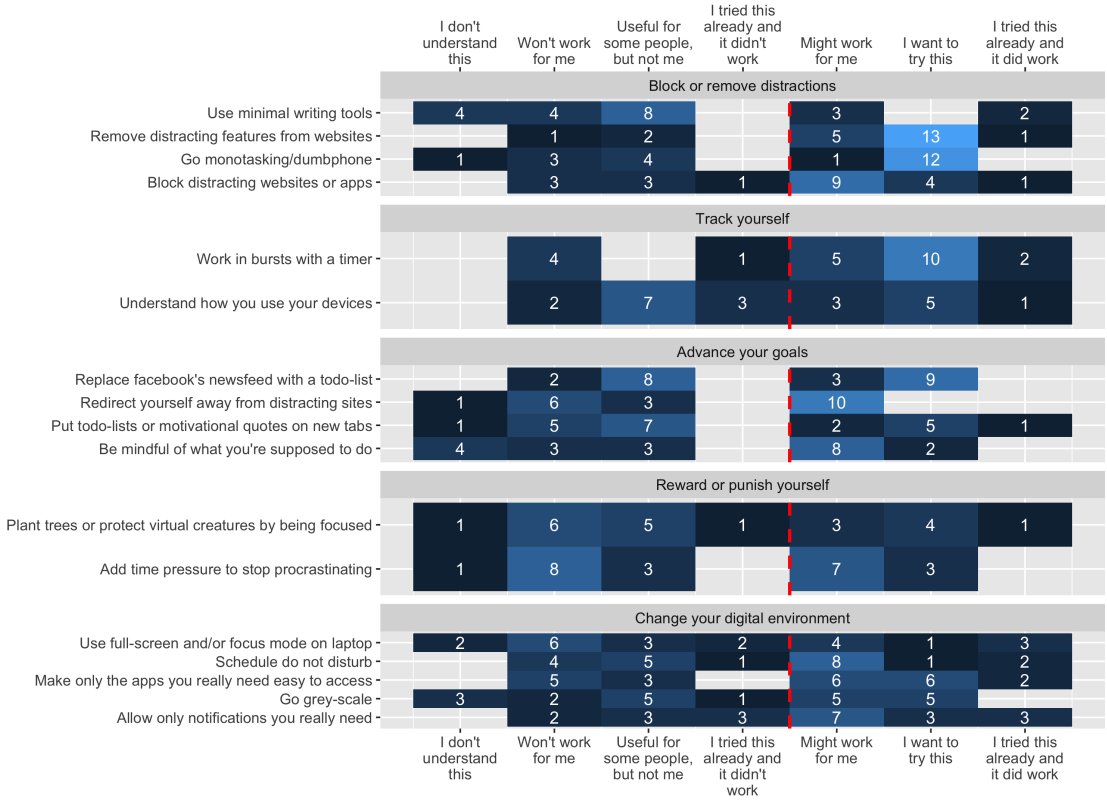

Figure 6.4: The number of times each intervention card was sorted into each category. The red dotted line separates categories suggesting rejection vs. acceptance as possibly useful. Note that the categories 'I tried this already and it did/didn't work' were added only after workshop three. Even though these categories were not available at the first workshops, if participants explicitly said in the workshop that they had already tried a given intervention, and that it did or did not help them, we coded cards in the corresponding category.

roughly equally likely (40-60%) to be placed in an 'accept' ('Might work for me', 'I want to try this', or 'I tried this already and it did work') as in a 'reject' ('Won't work for me', 'Useful for some people, but not me', or 'I tried this already and it didn't work') category. The card sorting also suggested that a few interventions were especially likely to be found useful: specifically, the two interventions 'Remove distracting features from websites' and 'Work in bursts with a timer' were placed in an 'accept' category by more than three quarters of participants.

When committing to specific options, participants on average chose 1.5 interventions (min = 1, max = 3, Figure 8), spread across 12 of the 17 options. The top three interventions were 'Blocking distracting websites/apps', 'Remove Facebook's

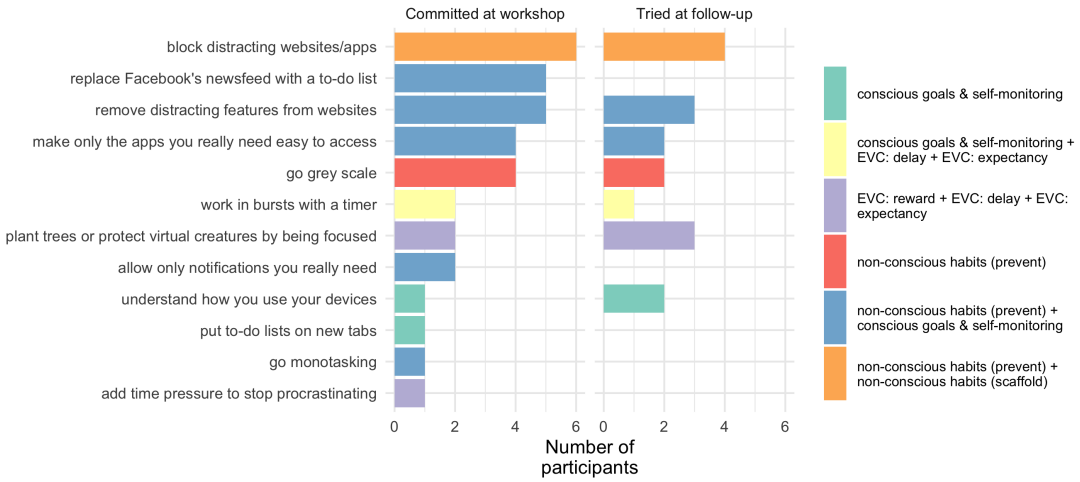

Figure 6.5: The interventions that participants committed to trying out in the workshop, and which ones respondents at the two-month follow-up had actually tried. Fill colour show intervention mapping to dual systems theory.

newsfeed with a to-do list', and 'Remove distracting features from websites' which all involved removing agency or habit triggers. No participants committed to the interventions 'Be mindful of what you're supposed to do', 'Redirect yourself away from distracting sites', 'Use minimal writing tools', 'Schedule Do Not Disturb', or 'Use full-screen and/or Focus mode on laptop'.

6.4.4 Workshop usefulness

50% of participants (n = 11) filled in the two-month follow-up survey.

When converting participants' ratings of the usefulness of each workshop component to numeric values from 1 ("Not at all useful") to 5 ("Extremely useful"), the mean rating for the initial presentation as well as for the card sorting task was 3.3 (SD = 0.6 for the initial presentation, SD = 1.0 for the card sorting), the group discussion 3.4 (SD = 0.8), the website 3.9 (SD = 0.9), and the tool presentation 4.0 (SD = 0.8). No components received any 'Not at all useful' responses.

10 out of 11 respondents said they followed through on the interventions they committed to, 8 out of 10 found them useful, 7 out of these 8 still used them, and all respondents said they had noticed changes in how they managed digital distraction after the workshop. The interest in targeted blocking that participants

expressed in the workshop was supported by the reported experiences of all three respondents who tried removing the newsfeed from Facebook and/or recommended videos from YouTube, all of which were positive (e.g. *"[It] completely changed the way I used Facebook and YouTube. I waste a lot less time on both, but still have the functionality when I want it"*).

Respondents' experiences also suggested that they benefited from exploring multiple interventions, as a couple of respondents noted that only one of the options they tried were useful (e.g. *"Restructuring my apps had very little impact [...] However, I did find that setting time limits on my apps made me stop to think about why I had accessed an app and if I really needed to use it"*).

Other themes in respondents' free text responses related to heightened awareness of their patterns of device use (n = 4, *"Even when I do allow myself to get distracted, I'm more aware of the fact that I'm getting distracted and have been working more mindfully to stop myself"*, respondent tried the 'Block Site' browser extension to block distracting websites plus a pomodoro timer), reduced time on digital distractions (n = 3, *"I've noticed that I spend less time on certain apps (notably facebook), although this is still ideally more than I'd like to"*, respondent tried rearranging apps plus setting time limits) and avoided use of distracting services (n = 2, *"I deleted Instagram"*, respondent tried an unspecified time tracker plus the *Forest* app).

6.5 Discussion

Through a workshop for helping address struggles with digital distraction, we examined what university students considered success for digital device use and how they thought digital self-control interventions might help. In a student life with constant digital connectivity and little separation between work time and personal time, participants struggled with being distracted from their intentions during device use, and with excessively interrupting themselves. They wished to be able to use devices more in line with their intentions (as opposed to merely out

of habit or to escape uncomfortable feelings) and divide up their use according to time and location. To achieve this, they felt digital self-control interventions were necessary because the easy access to digital distractions and the 'addictive' designs of their devices meant they were up against forces stronger than their willpower. Participants' preferences between interventions were varied. However, they were particularly interested in interventions that 'removed agency', especially when targeted to specific distracting elements (e.g., removing Facebook's newsfeed) instead of blocking apps or sites altogether. Finally, participants said that what they *really* wanted was interventions that over time would help them stay in control using just their inner self-discipline without need for external support.

In the following, we first discuss research implications of these findings before outlining some of the limitations and future work.

6.5.1 Moving closer to accommodating contextual needs via targeted, within-app interventions

The participants highlighted the crucial role of contextual factors in relation to their needs for digital self-control interventions. One broader factor that made it difficult for them to stay in control over their device use was lack of boundaries between work and personal life (Cecchinato 2018), as they felt unable to set clear working hours and expectations of availability and needed to use Facebook for social as well as academic communication. They also described specific situational factors related to their immediate task and mental state, including that control was more difficult when working on tasks that had loosely defined goals, or which were effortful or boring, or when they were otherwise low in motivation (Ryan et al. 2014). Whereas many participants thought simple, manual interventions like productivity timers would be useful, these situational factors raised a need for interventions that removed some of their agency and would remain effective in the face of low control motivation ('commitment devices' (Willigenburg and Delaere 2005)). How might we be able to provide such interventions without interfering with positive device use (Kim, Jung, Ko, et al. 2019)?

A couple of recent studies of interventions that lock the user out of their devices or block online distractions have attempted to make such interventions more useful by incorporating location-based reminders (Kim, Jung, Jung, et al. 2017), or by automatically blocking distractions at break-to-work transitions (Tseng et al. 2019) or when the user is sedentary and not using their device (which might imply that they are studying (Kim, Lee, et al. 2018)). In addition to such approaches, our study suggest that we investigate interventions that intervene specifically on interface elements that make it difficult for people to stay in control (cf. Chapter 5). The vast majority of existing digital self-control studies have focused on interventions that monitor or block device use at a global or app level. Little attention has been given to interventions that simply remove or redesign specific elements within a problematic app (see Lottridge et al. (2012) and Chapter 5 for exceptions). In our study, participants showed a strong interest in browser extensions that adjusted specific elements of frequently used services, namely removing Facebook's newsfeed or replacing it with a to-do list, as well as removing video recommendations on YouTube. As outlined in this thesis, hundreds of browser extensions that address self-control struggles in this way are available in online stores, and the research presented in Chapter 5 agrees with the present study that they can support people in meeting their goals with less collateral damage to positive use than global or app-level interventions.

6.5.2 Designing interventions to support self-discipline

A complementary research implication relates to participants' wish for digital self-control interventions that function as 'training wheels' to improve self-discipline. Such interventions would help participants work themselves up to being in control with less external support in the future. Approaches to addressing self-regulation struggles with this aim have long been studied in social-emotional learning (Slovak et al. 2017), but no existing digital self-control studies have investigated how interventions might make themselves superfluous over time. One way to clarify what this might mean, and consider if it is a sensible design goal, is by exploring

the idea from a psychological perspective. Whereas training people on tasks that require conscious control does not by itself translate into general improvement (Friese et al. 2017; Lurquin and Miyake 2017; Miles et al. 2016), our dual systems framework (Chapter 3) does suggest a few plausible routes by which design patterns could improve self-discipline over time:

First, as has already been suggested in digital behaviour change intervention research (Pinder, Vermeulen, Cowan, and Beale 2018), we may build tools that *support people in acquiring automatic habits that are aligned with the way in which they wish to use their devices.* Existing research, as well as findings from our workshops, shows a central role of *unwanted* habits in digital self-control struggles (e.g., Kim, Cho, et al. 2017; Oulasvirta et al. 2012). Yet, existing studies of design patterns for digital self-control have rarely focused on their potential to support *beneficial* habit formation over time. Chapter 5's study of supporting self-control on Facebook via either removing the newsfeed or adding goal prompts and reminders suggested some habit-formation effects: participants reported lower interest in the newsfeed or an enduring habit of asking themselves about their purpose of use, respectively, when the interventions were removed after a two-week intervention period. To investigate the potential to support self-discipline via habit formation, we should explicitly evaluate how effects persist after an intervention is removed, and how habit formation might be 'boosted' or sustained by varying when and how interventions are applied (Kovacs, Wu, et al. 2018; Miller, Shenhav, et al. 2019).

Second, we may design to *support people's confidence in their own ability to control their device use.* This would focus on the 'expectancy' component of the Expected Value of Control (EVC), i.e. on how likely we think it is that exercising conscious control will bring about a desired outcome (cf. 'self-efficacy' in Social Cognitive Theory, Bandura (1982); Bandura (1991)). Thus, participants in our workshops often expressed a lack of confidence in their ability to control themselves. This assessment can become self-reinforcing because the confidence in our ability to bring about a desired outcome by exerting conscious control influences how likely we are to try in the first place (Dixon and Christoff (2012); see section 3.2.5).

Hence, we might be able to scaffold self-discipline through interventions aimed at making people more confident in their own ability to control their use of digital devices. To design for this, we might consider interventions that at each training step provide a level of support that is 'just enough' for the user to succeed while providing a sense of achievement, which could over time increase general confidence in one's ability to control use (Deci and Ryan 2000).

Third, we might focus on how much *reward users expect to gain from exercising self-control* (Dixon and Christoff 2012), i.e. on the EVC's 'reward' component. Whereas some existing interventions such as *Forest* (Seekrtech 2018) provide extrinsic incentives to control use (e.g., a virtual tree that may flourish or perish), a similar route to self-discipline might be by cultivating a intrinsic reward from being in control (Deci and Ryan 2000). One potential approach to this focuses on personal identity, as a changed sense of identity can shift the cognitive evaluation of costs and benefits of the behaviours one has access to, and thus be a powerful means of promoting lasting behaviour change (Caldwell et al. (2018); see Nir Eyal's recent suggestion to cultivate a personal identity as being 'indistractable', Eyal (2019)). To design for this, we might help users associate particular patterns of use with specific, identifiable personas, and provide just-in-time reminders of how current use aligns or misaligns with the person they aspire to be.

6.5.3 The value of an active workshop approach

In digital mental health research more broadly, 'solution-focused' research approaches similar to our work in this chapter have been advocated as a remedy against the large research-to-practice gap in which interventions found to be effective in randomised clinical trials (RCTs) often fail to be useful in real-world implementation efforts (Mohr, Riper, et al. 2018). A solution-focused approach prioritises developing a working solution to a practical problem, which can then be adapted to other contexts (Mohr 2019). In digital mental health, this approach has in recent years been explored by the 'IntelliCare' project, a modular platform for Android that includes 12 apps which deliver psychological interventions for common mental health challenges.

Similar to *HabitLab* (Kovacs 2019), researchers have continuously improved the real-world usability of this platform, while conducting controlled studies of, e.g., effects of coaching assistance (Mohr, Schueller, et al. 2019; Mohr, Tomasino, et al. 2017).

In this chapter, our methods were in particular inspired by Cecchinato (2018), whose two-hour workshops for 'improving control over work-life balance as a result of communication technology' (conducted with 17 participants) included reflection followed by exploration and commitment to trying out specific interventions. Aside from a slight difference in framing of the workshops, the main differences were (i) the study population (Cecchinato (2018)'s participants were 'knowledge workers' with a mean age of 38 years, and included a UX designer & researcher and a communications consultant), and (ii) the interventions included (Cecchinato included e.g. broader social tips for 'expectation management'; we included only interventions related to digital environments, including the extensions for removing distracting website elements).

Whereas a couple of existing studies have evaluated DSCTs via practical field deployments (Kim, Jung, Jung, et al. 2017; Ko, Choi, et al. 2016; Löchtefeld et al. 2013), the workshops presented in Cecchinato (2018) and this chapter, as well as *HabitLab* (Kovacs 2019), are the first to include a broader range of research-informed interventions in a single, solution-focused intervention. Given current research gaps around how to tailor digital self-control interventions to personal device ecologies, lifestyles, and personalities, these approaches are likely to prove important for future research.

6.5.4 Limitations & future work

This study has a number of limitations.

First, it was a mainly qualitative case study with a small sample of self-selected students who already struggled with controlling their digital device use. As such, further studies are required to assess how our findings generalise to students or other populations, or to users who struggle at varying degrees. However, we expect many characteristics of our participants, such as lack of work-life separation, heavy

reliance on coordination of activities via social media, and frequent motivation to escape arduous work tasks via digital distractions, apply to information workers more broadly, as well as other populations transitioning to remote working.

Second, our results may be biased by demand characteristics (Nichols and Maner 2008). That is, whereas open-ended group discussion was an important feature of the workshops, participants' reported struggles and goals will have been influenced by what they felt was acceptable to report in the context of their groups and the presence of the facilitator(s).

Third, only half of participants responded to the two-month follow-up (for participants in the fourth workshop, the survey was sent amidst the COVID-19 pandemic). Therefore, the picture of the workshop's practical usefulness from the follow-up could be biased: for example, it might be that more enthusiastic participants were more likely to fill in the survey.

Fourth, the variation in preferences indicated by participants' sorting of digital self-control interventions may not be indicative of similar variation in the interventions that are actually effective. Further research is needed to assess how personal expectations around the usefulness of existing solutions relate to actual usefulness, and which factors might predict individual differences.

As will be laid out in section 7.5, we plan to address some of these limitations in future iterations of the Reducing Digital Distraction Workshop: we will explore how to scale the workshops by embedding them in the catalogue of well-being offerings at our partner universities, as well as by trialling specific elements in an online intervention. In a larger-scale deployment, we plan to incorporate measurements of personality and other relevant individual difference variables, and conduct formal efficacy evaluation of the workshops as a mental health intervention.

6.6 Conclusion

To ensure that digital devices have a net positive effect on mental well-being, users must be able to stay in control. To achieve this, we need to understand how to

provide interventions against digital self-control struggles that are appropriate to personal circumstances. The study presented in this chapter helps understand how contextual and individual needs influence effective interventions, by providing the first study of how existing design patterns meet the struggles and goals of a population of university students. Through four 'Reducing Digital Distraction' workshops, this chapter contributes (i) empirical evidence on the role of existing digital self-control interventions in addressing struggles among university students, (ii) open materials for an intervention format that uses a broad sample of existing interventions to elicit user needs for such interventions, (iii) design implications for tools that align more closely with users' wishes via focused, within-app interventions, or by supporting the development of self-discipline over time.

This chapter concludes the empirical work of this thesis. In the next chapter, we summarise and discuss the thesis' overall contributions, as well as some of the wider methodological and theoretical challenges for digital self-control research.

In order to survive and prosper in the 21st century, we need to leave behind the naive view of humans as free individuals... and come to terms with what humans really are: hackable animals. We need to know ourselves better.

— Yuval Noah Harari (2018)

7 Discussion

Contents

This thesis set out to examine how existing digital self-control tools can help us identify effective design patterns for supporting self-control over digital device use. How have our resulting investigations of the landscape of DSCTs in online stores, UI interventions for self-control on Facebook, workshops on digital distraction with university students, and the use of dual systems theory as a guide throughout, helped us answer this question? In this discussion chapter, we first summarise the findings from our investigations. We then reflect on some of the challenges in

relation to methodology and application of theory. Afterwards, we revisit what 'success' for design patterns for digital self-control might look like, recommending that our primary concern should be to empower users to sculpt their digital environments such that the amount and motivational pull of the information they are exposed to match their abilities and limitations. Finally, we consider a longer-term vision for the Reducing Digital Distraction Workshop as a tool for future research and practical impact.

7.1 Overview of results

As outlined in Chapter 2, the research presented in this thesis was motivated by current limitations and opportunities for digital self-control research in four areas: (i) a lack of application of conceptual frameworks that explicitly address interactions between conflicting goals and impulses, (ii) challenges around scaling controlled studies to large numbers of design patterns and implementations, (iii) a need for additional evidence on individual differences, (iv) a need for adoption of more robust, open, and transparent research practices.

Chapter 3 served two purposes: to introduce a dual systems framework and its potential usefulness for digital self-control research; and to characterise the design space for design patterns by analysing features in existing DSCTs in online stores. In introducing the dual systems framework, we extended existing applications in HCI with the concept of 'expected value of control' (EVC), which is considered central in the recent neuroscience literature as an explanation of why the ability to exercise self-control fluctuates over time and with emotional state. As a mediator of the strength of conscious self-control, EVC demystifies self-control and helps clarify how specific design features may work to scaffold it. In analysing DSCTs in online stores, we identified widely used and theoretically interesting design ideas under-explored in HCI research, such as tying device use to the well-being of a virtual creature. By applying the dual systems framework to the feature analysis, we also identified cognitive mechanisms under-explored in current tools, such as sensitivity to delay.

Whereas Chapter 3 analysed only the *functionality* of current tools, Chapter 4 added analysis of user numbers, average ratings, and reviews, which provide indicators of the outcomes of users' micro-experiments with these tools. Our analysis of the content of user reviews corroborated findings from previous research: DSCTs help people focus on important, but effortful, tasks in the face of readily available digital distractions. Moreover, users search for tools which provide a level of friction or reward that is 'just right' to overcome temptation without being overly annoying, but there is widespread variation among users on where this 'Goldilocks' level is. Our analysis of user numbers and ratings generated new findings and hypotheses: for example, tools which combine more than one type of design pattern receive higher ratings, which might suggest that targeting different psychological mechanisms is a more effective way to provide enough incentive to cause behaviour change without being annoying, compared to ramping up the intensity of a single mechanism. In combination, Chapters 3 and 4 provided the first larger-scale, rigorous investigation of the online landscape of DSCTs as a rich resource for digital self-control research.

We can use such investigations to scope the range of design patterns and implementations to explore in controlled studies. Chapter 5 presented a controlled study informed in this way: surveying the landscape of DSCTs showed that a sizeable number of tools target Facebook in the form of browser extensions that, e.g., remove the newsfeed, but no existing studies have investigated the potential of these interventions to help users struggling with self-control. Chapter 5's study demonstrated that two such interventions — goal reminders and removing the newsfeed — can potently influence behaviour and reduce unintended use, suggesting this as a fruitful avenue for research into remedies for problematic use that present a less tall barrier to action than deactivating or deleting one's account. Post-study interviews contributed qualitative evidence on more complex questions explored in recent studies of design patterns for digital self-control, such as how to accommodate individual differences in personalities and self-control needs, and how to avoid 'backfire' effects where users rebel against intrusive interventions rather than being helped by them.

Finally, Chapter 6 explored how we may use the landscape of existing tools to elicit personal needs for digital self-control interventions in specific populations: in a workshop format developed with the University of Oxford Counselling Service, students reflected on their struggles and goals, explored a broad sample of solution interventions drawn from previous chapters in this thesis, and committed to trying out their favourite options. Their preferences varied, but interventions that targeted specific distracting elements were found to be especially useful (e.g., removing Facebook's newsfeed). Hinting at avenues for future research, participants also wished for tools that could serve as 'training wheels' for improving self-discipline over time, i.e., that they could use as external support initially but which would later allow them to control themselves better in their absence.

7.2 Reflections on methodology

7.2.1 Challenges of defining the problem

As we saw in Chapter 2, it is challenging to precisely demarcate the problem that overlapping HCI research on 'addictive use', 'problematic use', 'non-use', and 'digital wellbeing' is seeking to address. In this thesis, we drew on basic self-control research and defined 'digital self-control' as the ability to align digital device use with one's enduringly valued goals in the face of momentarily conflicting goals and impulses. This definition applies an individual lens and suggests, for example, that spending an excessive amount of time playing video games is problematic only to the extent that it conflicts with one's longer-term goals (Lyngs 2019d).

This approach has limitations. First, effects of 'persuasive designs' are currently much discussed in relation to children and adolescents. For populations less capable of assessing the longer-term impact of their actions, focusing solely on people's self-perceived ability to align their device use with their enduringly valued goals is likely too narrow an approach. Though I would argue that focusing on individual self-control is the most practical approach when considering functional, adult users, when we consider individuals still undergoing developmental maturation, we cannot

avoid normative discussions about which patterns of device use are more likely to nurture or harm human flourishing. Here, high-quality research on the relationship between particular notions of well-being, device use, and design patterns is necessary to guide parents and decision-makers (Hiniker, Radesky, et al. 2019). In this thesis, we narrowed the focus of our investigations to design patterns for supporting self-control among functional, adult users, because the ability of adults to effectively align their device use with their longer-term goals should, arguably, be an uncontroversial minimum goal when 'designing for digital well-being' (Lyngs, Binns, et al. 2018).[1] Such a focus allows us to make research progress without getting caught up from the outset in disagreements over what constitutes a 'good life' and what role digital devices 'ought' to play in this respect (cf. Orben 2019). Moreover, experience sampling studies suggest that the ability to exert self-control mediates effects of media use (including ICTs) on well-being (Hofmann, Reinecke, et al. 2016), which provides additional reason to take digital self-control as our starting point.

A second limitation of our approach is that the meaning of 'enduringly valued' or 'longer-term' goals is not clearly defined (cf. parallel discussions between 'proximate' and 'distal' goals in HCI research on behaviour change, Klasnja et al. (2017)). In the self-control literature, its meaning tends to simply be illustrated through examples of prototypical self-control failure, such as giving into a momentary temptation to eat chocolate cake when on a diet, or procrastinating by scrolling through Instagram instead of writing the essay one is at the library to finish (cf. Duckworth, White, et al. 2016). However, just how long or how highly a goal should be valued to be considered 'longer term' or 'enduringly' valued is not clearly specified. Therefore, implications for, e.g., how designers can elicit users' 'true' preferences are widely open to interpretation (cf. Lyngs, Binns, et al. 2018). For example, imagine a university student watching her favourite TV show on Netflix. It is getting late, and she knows that she ought to go to bed, but feels tempted to watch one more

[1] Our finding in Chapter 4 that DSCTs seemed to be particularly useful for populations for whom self-control struggles were more acute, however, suggests that effective design patterns for digital self-control are especially important in relation to children and young adolescents (cf. Blakemore and Choudhury 2006; Casey 2015).

episode. She may even take a moment to reflect and conclude that, on balance, watching another episode is more valuable to her than getting her regular hours of sleep, before clicking 'play'. However, in the morning she feels exhausted and regrets her decision from the night before. Or imagine she remains happy with her decision in the morning, and only months later realises that a consistent pattern of nightly Netflix watching seriously harmed her longer-term goals because she often missed morning lectures and ended up getting a bad grade. Which time span of reflection and valuation should we design to support? Moreover, people might have a sense in the moment of whether they are focusing on a valued shorter-term goal (e.g., focusing on that work task one needs to complete; or being present and attentive with one's friends on a night out), but differ in how clearly they set longer-term goals and how consistently they hold them (cf. Duckworth, Peterson, et al. 2007).

In considering these questions, it is important that we do not let the perfect become the enemy of the good. Whereas real-life examples tend to be more ambiguous than the 'easy' case, in which people's in-the-moment and retrospective judgment are in perfect agreement, discussing how to resolve these tensions gets us asking the right questions, compared to the attention economy's status quo of equating 'enduringly valued goals' with 'behaviour which optimises ad revenue or data collection'. Thus, a somewhat vague definition will still do if it encourages the right line of thinking — as an example from industry, Nir Eyal proposed a 'regret test' as a practical guideline for designers to consider what "users do and don't want", and act in an ethically responsible manner:

> If people knew everything the product designer knows, would they still execute the intended behavior? Are they likely to regret doing this? If users would regret taking the action, the technique fails the regret test and shouldn't be built into the product, because it manipulated people into doing something they didn't want to do.
>
> Eyal (2018)

In so far as people regret actions because they diverge from their enduringly valued goals, this approach is similar to our conceptualisation of digital self-control. Whereas there is wide room for interpretation around what methods might be

favourable for eliciting 'correct' preferences, a simple option to explore in future research could be for systems simply to allow users to choose between possible ways to infer their 'enduringly valued goals' (cf. Harambam et al. 2019; Lyngs, Binns, et al. 2018).

7.2.2 Challenges of measurement

How we define the problem in turn has direct implications for what and when to measure in evaluation studies, which come with its own challenges.

What to measure As we saw in Chapter 2, existing studies have — depending on how researchers have framed the problem — applied measurement instruments ranging from perceived workload to subjective smartphone addiction. When focusing on the problem through the lens of self-control, the most relevant measurements relate to self-perceived ability to align usage with one's goals. This in turn prompts considerations around how broadly goal alignment should be construed: At one end of the spectrum, researchers may assess immediate goals for use of a specific service (e.g., in Chapter 5, participants in the *goal reminder* condition were prompted to type in their immediate usage goals for Facebook use) and subsequently assess whether they effectively achieved that goal (cf. Duckworth, White, et al. 2016). At the other end of the spectrum, researchers may assess a global sense of whether people feel able to align their use of digital devices with their longer-term goals (e.g., Ko, Chung, et al. (2015) and Roffarello and De Russis (2019a) adapted the General Self-Efficacy Scale, cf. Luszczynska et al. (2005), to the context of self-regulation of smartphone use). This methodological question has no 'correct' answer, but researchers should clearly specify their choice and discuss the theoretical implications. In our study of interventions for self-control on Facebook, we relied mainly on self-report measures of overall usage patterns and perceived control, drawn from existing research on Problematic Facebook Use and distraction blocking (Mark et al. 2018). We made this choice to allow our findings to be compared directly

with findings from previous work, but follow-up research may explore ways to more directly assess people's sense of using Facebook in accordance with their goals.

Moreover, most studies have focused on one device only, even though digital self-control struggles in the real world often involves cross-device use. This prompts similar questions over how to assess people's sense of their ability to use their combined devices in line with their goals. Only two existing studies of design patterns tackled cross-device interactions (Kim, Cho, et al. 2017; Kovacs, Gregory, et al. 2019), and so there is a need for further exploration of both effective design patterns and effective measurement approaches for assessing the impact on perceived self-control ability in multi-device contexts.

When to measure In accordance with the challenges of defining the problem — and similar to concerns in research on 'screen time' and well-being (Orben 2019) — researchers should clearly specify the *time frame* at which they measure effects of interest, and discuss the theoretical implications. At one end of the spectrum, people's in-the-moment reports of whether they are using their devices in line with their goals could be assessed using experience sampling methods. This approach has proven useful in studies of media use and self-control (Reinecke and Hofmann 2016) and is starting to be adopted in research on screen time and well-being (Johannes et al. 2019), as well as experience of 'meaningfulness' during smartphone use (Lukoff et al. 2018), but has yet to be applied in evaluations of design patterns for digital self-control. Thus, existing studies have focused on retrospective assessment at various time points, e.g., by the end of each day (e.g., Mark et al. 2018), or in post-study interviews (e.g., Whittaker et al. 2016). This thesis' controlled study (Chapter 5) also used retrospective assessment, via surveys after each 2-week study block, and post-study interviews. To help resolve theoretical and empirical questions, future digital self-control research will benefit from using experience-sampling methods to study how in-the-moment assessment compares to retrospective assessment of self-controlled device use, and how this is influenced by design patterns to support self-control.

How to measure As the self-control lens implies subjective judgment, careful consideration of how elicitation methods influence self-report is essential. We previously touched on some of the challenges in this respect (see section 2.4.4), such as memory biases (Kahneman and Riis 2005), inherent limits of introspection (Gibbons 1983), and demand characteristics (Nichols and Maner 2008). In Chapter 5's controlled study, we tried to address this challenge by collecting and triangulating multiple types of data, namely logging of actual behaviour, bi-weekly surveys, and semi-structured interviews, and including a control condition. Whereas this provides no methodological silver bullet, control conditions help us interpret self-report data by providing a means to assess how the study process itself influences self-report (e.g., we observed that survey scores on 'overuse' changed over time in all conditions, including in the control condition), and triangulating different data sources allow us to assess how self-report relates to measured behaviour.

7.2.3 Generating usable evidence through robust and open science

Digital self-control research should aim to generate 'usable evidence', that is, insight into causal effects of specific design patterns, and how such effects vary with implementation details, contexts of use, and individual differences (cf. Klasnja et al. (2017), see section 2.4). As outlined in section 2.4.4, this aim will be furthered by carefully designing experimental studies that include control conditions so that the appropriate comparisons can be made in the first place, as well as by following the current push in related disciplines for more robust and open research practices (cf. Haroz 2019). In digital self-control research to date, experimental methodology has matured in studies from 2018 onwards, but adoption of open science practices is lagging behind. To realise the potential of the existing studies, and build on it in ways that lead to robust, usable evidence, open science practices are key. Here, we reiterate the importance of open sharing of materials, data[2], and analysis scripts:

[2]With the caveat that not all data can, or should, be shared — the ethical and privacy issues relevant to a particular dataset should be considered, and appropriate anonymisation procedures followed (cf. Gilmore et al. 2018). However, even when data cannot be shared, sharing analysis scripts provides value in allowing others to identify errors and reuse work (cf. Orben and Przybylski

First, as mentioned in section 2.4.4, open science allows us to more effectively accumulate knowledge between studies, partly because starting from others' materials when replicating or extending previous studies helps reduce noise from implementation and analysis differences. This was a real concern for some of the work in this thesis. For example, Chapter 5's study of self-control on Facebook followed Wang and Mark (2018) in using the ROSE browser extension (Poller 2019) to log participants' use on their laptops. When analysing participant data collected with this extension, we had to make a large number of data processing decisions, from thresholds for excluding data points likely to be erroneous, to precisely how time spent should be calculated. Such analytical decisions amount to a rapidly growing 'garden of forking paths', where the results presented in the final paper show only one specific path (Orben and Przybylski 2019a)[3]. Directly comparing our findings to those of Wang and Mark (2018) required the exact detail of how they analysed their data, beyond the broader verbal description of the data wrangling provided in their paper. However, neither materials, data, or analysis scripts were available with their paper, and neither of the authors responded to repeated email inquiries.

A second motivation for open science practices in this research area is that the research space itself can be approached in many different ways, as discussed in the previous sections. Therefore, it is important that we make our materials and data openly and transparently available to others, because this will allow us to better reuse and reinterpret previous findings as we make progress on theoretical questions.

In this thesis, we attempted to follow open science practices throughout, by making materials, data and analysis pipelines openly available and writing the manuscripts as reproducible, plain text documents using R Markdown (Xie et al. 2018).

2019a).

[3]An novel alternative is 'Specification-Curve Analysis' in which researchers map and report the outcome of all theoretically defensible analysis pathways (Simonsohn et al. 2015).

7.3 Reflections on use of theory

7.3.1 Alternatives to dual systems theory

This thesis relied on the dual systems framework introduced in Chapter 3 to categorise and evaluate design patterns, interpret findings, and suggest new opportunities, in line with recent HCI research on digital self-control and behaviour change more widely (Cox et al. 2016; Pinder, Vermeulen, Cowan, and Beale 2018). This had some advantages: First, this framework explicitly addresses interactions between conscious goals and automatic habits and impulses, which are at the core of self-control struggles, and which HCI research on behaviour change has argued are key for guiding interventions aimed at long-term change (Pinder, Vermeulen, Cowan, and Beale 2018). Second, the framework readily connects to ongoing research on self-regulation in the cognitive neurosciences, as illustrated by Chapter 3's extension of previous HCI use of the framework with recent research on the 'expected value of control'. Therefore, the framework may be unpacked into more granular theories of, e.g., different constructs involved in processing of rewards, if design guidance from more specific constructs is called for (cf. Klasnja et al. 2017). In this way, the dual systems approach may both at a high level capture the main psychological mechanisms involved in digital self-control, and provide more detailed theoretical pointers, which gives the framework substantial mileage.

This is not to say that that the dual systems framework is necessarily 'better' than what has been applied in existing studies. Different frameworks direct attention and research efforts in different ways that can be more or less appropriate for a given research question, and existing studies have amply demonstrated that specific constructs drawn from other frameworks can guide effective design. However, for the purposes of the present thesis, the dual systems framework was particularly useful, because it provided a more inclusive view well suited to the initial chapters' broad characterisation of the design space. In our further investigations of the framework's potential in the controlled study of Facebook use, it also proved useful for guiding

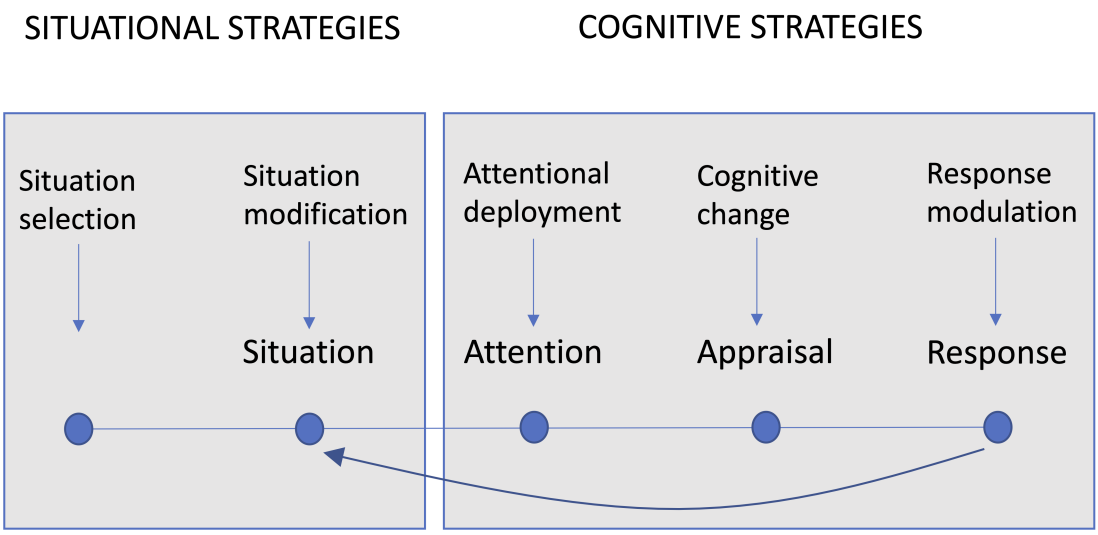

Figure 7.1: The process model of self-control (adapted from Duckworth, White, et al. (2016)). The framework focuses on how 'impulses' — responce tendencies to think, feel, or act — develop over time, and organises self-control strategies according to the stage of impulse generation at which they intervene.

selection of specific interventions among many, and for generating hypotheses about potential and limitations to be explored in future research.

There may be further room to explore conceptual frameworks popular in psychological research on self-control but rarely applied in HCI. Currently, one of the most influential frameworks of self-control in psychology is the 'process model' (Duckworth, Gendler, et al. 2014), adapted from James J. Gross' work on emotion regulation (Gross 2015). This framework focuses on how 'impulses' — response tendencies to think, feel, or act — develop over time, and organises people's self-control strategies according to the stage of impulse generation at which they intervene (see Figure 7.1). In this framework, self-control strategies work either by choosing what situations to expose oneself to (*situation selection*); changing the circumstances of the situation one is in (*situation modification*); changing what one pays attention to within a given situation (*attentional deployment*); re-adjusting how one values what one does pay attention to (*cognitive change*); or by directly inhibiting or enhancing impulses (*response modulation*). This model has been used by Duckworth, White, et al. (2016) to study self-control strategies among university

students, has been preliminary applied in HCI work on emotion regulation (Miri et al. 2018), and may prove useful in future digital self-control research.[4]

Other work from basic self-control research that may supply avenues of inspiration includes research on how people's assessment of the opportunity costs of their current task influences mindwandering, boredom, and mental effort (Forrin et al. 2019; Kurzban et al. 2013). This research may be useful for understanding effects of how digital devices, such as smartphones, introduce additional behavioural options to their users at each time step (cf. Dora et al. 2019; Lyngs 2017a), and has affinity with long-standing HCI research on 'information foraging' (Pirolli and Card 1995).

7.3.2 Understanding individual differences

Understanding what interventions work better for whom is key to generating usable evidence. The studies so far are beginning to paint a picture of substantial individual variation — with light-touch goal reminders sufficient to scaffold self-control for some, and high-friction distraction blocking needed by others — and of how such variation might be predicted by measures such as Big Five personality traits or susceptibility to social media distractions.

Psychological theory may be helpful to advance our understanding in this respect, in so far that it indicates how individual differences map to relative strengths and weaknesses in specific self-regulation mechanisms, which in turn may suggest particular types of interventions as more relevant. The dual systems framework may also be valuable for this purpose: for example, the sensitivity to delay that forms part of the Expected Value of Control (cf. 3.2.5) is closely related to measures of 'impulsivity' (Steel and König 2006). Therefore, design patterns focusing on this component (e.g., increasing loading times of distracting websites) may be more effective for individuals scoring high on impulsivity. Similarly, the dual systems framework suggests that measures of relative working memory capacity would predict individual differences in the effectiveness of interventions which reduce the

[4] My collaborator Kai Lukoff is currently exploring use of this framework to categorise self-control interventions for smartphone use.

amount of potentially distracting information the user is exposed to, or which use goal reminders to keep a focal task from being forgotten (cf. section 5.6.1).

Zooming out, our understanding of individual differences is also likely to be helped by drawing on theories that apply a wider socioeconomic lens (cf. section 2.3.5). Thus, sociological research has found that self-control ability predicts many valued life outcomes, including physical health, substance dependence, personal finances, and criminal offences (Cheung et al. 2014; Moffitt et al. 2011). Accordingly, interventions addressing self-control (e.g., improving the degree of control that people perceive they have over their own lives and their environment, Gillebaart and Ridder (2019)) have been suggested as central to reducing societal problems (Moffitt et al. 2011). We may therefore expect socioeconomic concerns to be relevant for digital self-control research (cf. Kaba and Meso 2019): first, baseline variation in self-control ability, which correlates with indicators of socioeconomic status, is likely to translate into similar variation in digital self-control struggles. Second, the technical knowledge and skills required to set up one's digital environments so as to reduce digital distraction are likely to be unevenly distributed (Hargittai 2002; Jenkin 2015). Hence, future research into individual differences in digital self-control should keep a wider socioeconomic perspective in mind, which could help identify study populations for whom research in this space may be particularly important (cf. Devito et al. 2019).

7.4 Revisiting what success looks like

We now return to the notion of 'success' for future digital self-control design patterns. Reflecting on the findings from existing studies and the present thesis, what might a desirable future look like?

The current state of research provides a rough picture of how a wide range of design patterns may support user self-control, with initial indicators of how main implementation details (e.g., how readily accessible and actionable usage visualisations are), and individual differences (e.g., distraction blocking may be

more effective for users who struggle more with managing distractions at the outset) influence their effectiveness. While this initial work offers suggestive findings, an additional wave of high-powered, confirmatory studies is required to establish their reliability — preferably in collaboration with industry researchers (cf. Orben, Dienlin, et al. 2019; Science and Technology Committee 2019) — before we can provide specific design guidelines that are rooted in robust research. What we *can* do at this point, however, is to use the initial body of evidence in conjunction with relevant theory and findings from general self-control research, to provide some guiding principles (cf. Shneiderman et al. 2018): in section 5.6.1, we used the dual systems framework and key findings from psychological research to generate clear predictions for the potential and limitations of two design patterns for self-control on Facebook. In the following, we extend this approach to provide a general guiding principle for design patterns aimed at assisting users in exerting self-control over digital device use.

7.4.1 From balancing screen time to empowering users to sculpt a balanced digital environment

As outlined in section 5.6.1, psychological research has shown that people who are better at self-control — perhaps somewhat paradoxically — use it less (Galla and Duckworth 2015). That is, people who are better at acting in accordance with their longer-term goals rely less on conscious in-the-moment self-control (System 2 control, cf. Chapter 3), and instead set up their environments to reduce exposure to distractions, and/or form habits that make their intended actions more reliant on automatic processes (System 1 control). As outlined in Chapter 3, a psychological explanation for this is that conscious self-control requires both (i) relevant longer-term goals to be present in working memory, and (ii) the expected value of control — which fluctuates over time with mood state and other influences — to be high enough to overcome the strength of competing impulses, which makes conscious self-control an unreliable strategy. It follows that, when designing to support digital self-control, it should be a main concern for us to empower users to adjust

their digital environments such that the amount and motivational pull of the information they are exposed to remain within a range which — given their working memory limitations, reward sensitivities, and other relevant traits — allows them to effectively navigate those environments in accordance with their long-term goals, without being 'overpowered' by distractions.

Thus, in many situations, design patterns for managing time spent on devices overall and within specific functionality — which is what most existing studies have focused on — fail to address the root problem: to take the example of Facebook, a key struggle reported by our participants in Chapter 5 was inability to stay on task during use, largely because an excessive amount of engaging information on the newsfeed made them forget their original goal. This is not unique to Facebook; Lukoff et al. (2018) found in an experience sampling study that people tend to drift off-task during app use on smartphones, and that such drift is associated with finding use less meaningful. Thus, finding the right fit between the affordances provided by the user interface, and the user's capabilities and goals, is key to digital self-control (cf. Cheng, Lo, et al. 2017): when the cause of self-control failure is that the amount, and/or the motivational pull of, the information users are exposed to overpower their ability to stay on task, time management tools are unlikely to be the most appropriate design solution. Rather, a better solution is to provide tools for scaling down information amount and engagement level so that the user is able to effectively remain directed by their longer-term usage goals.

To be clear, time management interventions are appropriate in some circumstances (cf. Chapter 4's finding that 'time' was the most frequent term in user reviews of DSCTs). For example, in the case of video games, if the user's goal is solely to enjoy being immersed in the game, supporting self-control may simply amount to helping the user spend only his intended amount of time in that environment. However, in the case of Facebook, users' goals are more likely to focus on accomplishing a specific task (e.g., messaging a friend, creating an event) rather than spending an allotted time on the site. In such cases, tools for time management (including those Facebook introduced in response to concerns over 'problematic use') are trying to

solve the wrong problem, if what users struggle with is staying on task in the face of an interface that provides an endless stream of highly engaging content.

Focusing on users' ability to sculpt their digital environment should naturally align with the goal of *universal usability*: as a profession, the goal of HCI is to address the needs of all users, across the diversity of human abilities, motivations, and personalities (Shneiderman et al. 2018). Similarly to usability principles of determining users' skill levels, I suggest the following guiding principle for digital self-control design patterns:

> Consider what level of information amount and attractiveness will be within a range that allows the user to exercise self-control and form their intended usage habits. Provide the user easily accessible means to adjust these factors to a level that suits them.

This level will vary between users, as well as for the same user over time – as particular habits for intended use are formed, the user may be able to handle a higher level of engaging information while remaining in control (cf. section 6.5.2).

Whereas design patterns such as usage visualisations, timers, and lockout mechanisms have dominated existing digital self-control studies (only one study, Lottridge et al. (2012), tested an intervention which made distractions less visually prominent), I therefore encourage future research to focus on design patterns which allow users to directly sculpt the amount and relative attractiveness of the information they are exposed to (cf. section 6.5.1). Such work may build on established usability principles of, e.g., using multi-layer approaches to handle multiple classes of users, with simpler 'training-wheels' interfaces being provided to novices (cf. Carroll and Carrithers 1984; Shneiderman et al. 2018). Specifically, such research efforts could study the effects of, e.g., by default hiding video recommendations on YouTube or Facebook's newsfeed (cf. Chapter 5) and enable users to opt-in to video recommendations, or newsfeed posts, at varying amounts and refresh frequencies. This could lay the groundwork for interfaces that allow users to experiment with different amounts and engagement levels to find a 'Goldilocks' level where they can effectively reap the benefits of algorithmically tailored content

without having their self-control ability overpowered. Such a line of work might benefit from engaging with the rich literature on attention management in aviation, which for decades have studied how to avoid distraction during navigation of complex information systems (e.g., Raby and Wickens 1994; Wickens 2002, 2007; Wickens and Alexander 2009), and has yet to be consulted in digital self-control research.

Ultimately, we may wish to work toward systems that are able to automatically detect the user's goal and adapt the interface accordingly. For context, Cheng, Lo, et al. (2017) found in a study of Pinterest that users reported roughly 50% of their use as being goal specific and 50% as goal non-specific, and that self-reported intent could be rapidly predicted from user behaviour. One exciting opportunity for future research therefore involves design patterns that would, for example, automatically make YouTube look different if the user goes to the site to find a cooking how-to video, compared to if the user visits the site to entertain themselves on the bus.

This approach readily connects with arguments to move from an 'attention' to an '*intention* economy' (Searls 2012), in which people are able to shape their relationship with vendors on their own terms, and express their personal preferences, make choices, and participate in relationships in ways that are aligned with their intentions (cf. Harris 2016). Similarly, I would argue that devising effective means with which users can sculpt the affordances of their user interfaces, so as to match their unique needs and abilities in relation to self-regulation, should be a key consideration in future research on digital self-control design patterns.

7.4.2 Conditions for success - markets and regulations

In this thesis, we scoped our investigations to individual self-regulation. However, as noted in section 2.1.3, wider dynamics of the internet economy are main drivers of the way many current design patterns are effectively aim to undermine, rather than support, digital self-control. Therefore, when considering what it would take to move towards a future where users' design needs are met, we need to look beyond individual users. Whereas any deeper investigation of the attention economy is

not the aim of this thesis, I will in the following provide some brief remarks on what I perceive to be the main practical considerations:

Because we find ourselves in a world where a small number of tech companies hold disproportionate influence over how billions of users of digital technology direct their attention on a daily basis, it is highly important how these individual companies decide to resolve questions over digital self-control. As of yet, the 'digital well-being' tools introduced by Facebook, Google, and Apple all focus on visualising and limiting time spent on digital devices. Meanwhile, design solutions that would empower users to adjust their exposure to engaging information within services are only potentially available if services can be accessed in a browser and users are sufficiently tech-savvy to discover and install a suitable browser extension. In the case of YouTube and Facebook, this may not be surprising, as providing users easy means to remove or limit the output of recommender engines would not only relinquish control over expensively-engineered drivers of engagement, but do so at risk of revenue decline. In so far that providing such controls to end-users is important to digital self-control, some form of regulatory intervention may therefore be required to align companies' incentives with users' interests.

However, even though the UK government have tentatively explored regulation of 'persuasive interfaces' in relation to children's use of technology (Wright and Sajid 2019), it is not clear what meaningful regulation might look like. Attempts to regulate design directly is challenging: regulation at the level of specific design features (prohibiting bottomless feeds?) is likely to be rapidly outdated by design innovations; and regulation at the level of more general principles ('users shall be provided controls to scale down information amount and attractiveness') may be too open to interpretation to be meaningful (cf. Turel 2019)

An alternative is to regulate in ways that incentivise market competition around desired parameters. For example, if users were in possession of their own personal data and companies competed over ways to interlink and interact with it (see Tim Berners-Lee's vision for a re-decentralised internet (2019)), users might be able to choose between many different user interfaces to similar functionality, and select the

product which best allows them to align their digital device use with their longer-term goals, given their cognitive abilities and personalities. This would contrast with the current situation in which users who wish to benefit from Facebook's social connectivity are stuck with a user interface engineered to optimise revenue through extraction of attention and personal data. To change the status quo, regulators might mandate platform interoperability to enable companies to compete over creating user interfaces to similar data (cf. 'adversarial interoperability', Doctorow (2019); in the US Congress, a recent bipartisan bill proposed to do just this, Mui (2019)). However, because opening up platforms also increases the risk that data are misused by third-parties, this road may contain obstacles, given recent privacy scandals associated with Facebook's past practices of allowing third-parties extensive access to personal data.

Alternatively, regulators may consider digital design as analogous to, e.g., organic farming. That is, regulators may consider creating incentive schemes that make alternative business models that do not rely on extracting users' attention and data more viable, and therefore make design goals aligned with digital self-control more likely. This might be achieved by, e.g., mandating that app stores prominently display badges disclosing companies' business models, which could make it more appealing for consumers to pay for a product in which the developers' design goals are aligned with their usage goals, as opposed to one which is optimised for extraction of their attention and personal data.

7.5 Next steps: Advancing digital self-control research through scalable action research

Much of this thesis invites follow-up research to, e.g., establish the robustness of findings and generate additional insights from explored methods. For example, as outlined in Chapter 4, additional insights might be extracted from the dataset of user reviews we collected from DSCTs in online stores, through additional thematic analyses of reviews sampled from tools implementing specific design features of

interest. Similarly, Chapter 5's study of interventions for self-control on Facebook was exploratory and should be followed by confirmatory studies, using effect sizes from the original study as a guide in power analyses for establishing a minimum sample size. In this section, however, we present a broader vision for advancing the state of digital self-control research, a vision that is centered around the Reducing Digital Distraction workshops (cf. Chapter 6).

Thus, just as it is instructive to be explicit about what we think digital self-control design patterns should achieve, it is useful to consider what research infrastructures would effectively advance research in this space. In this respect, two observations may be useful to keep in mind:

First, the challenge of supporting digital self-control is here to stay: as increasingly immersive digital technologies emerge — consider, for example, Facebook's massive investments in VR technologies (Stein and Sherr 2019) — understanding how to design in ways that safeguard people's ability to align device use with longer-term goals will only become more important. Therefore, our research efforts should be equipped to accumulate knowledge on user struggles and usage goals, as well as the effectiveness of design patterns for digital self-control, over time as digital technologies evolve.

Second, designing for digital self-control is an important and global challenge: as central activities — news consumption, entertainment, social communication — become digitally mediated, it is of real consequence that we discover effective design solutions and disseminate them effectively. Therefore, research efforts should consider practical impact, at scale.

However, with the exception of the Stanford HCI Group's *HabitLab*, which appears to reflect an enduringly maintained infrastructure, all existing studies of design patterns have been one-off investigations. Moreover — again with the exception of *HabitLab*, as well a couple of studies that deployed evaluations in the form of university campaigns — most investigations have been small-scale and conducted solely for research purposes.

Chapter 6's study of the Reducing Digital Distraction workshops represent an initial step toward a research infrastructure which aims to (i) accumulate high-quality data relevant to central digital self-control research questions over the course of years, (ii) create positive impact by disseminating promising interventions to key audiences, and (iii) be able to scale. More specifically, this envisioned infrastructure consist of two complementary pieces: a **workshop format, embedded within the student course offerings at the University of Oxford**, and scaled via collaborations with other researchers and universities (cf. the recent push for 'many labs' projects in psychology Klein et al. (2014)); and a **complementary online format** which builds on insights from the workshops and scales beyond student populations. Following the completion of this thesis, I will continue work with my collaborators on this infrastructure. Each element will be developed through a number of iterative steps:

ReDD workshops: refining, embedding, scaling First, we will continue iteration on the workshop format and materials into a stable, thoroughly field-tested version. Afterwards, we will work with key stakeholders at the University of Oxford to include the workshops in the catalogue of welfare and study skills offerings available to students. Finally, we will collaborate with researchers and stakeholders at other institutions to extend the workshops beyond Oxford.

ReDD online: testing tasks, online workshop, scaling First, we will conduct online studies of how key tasks from the workshops can be translated into an online format. Afterwards, we will develop an online-only version of the workshops, which walks the user through a process of reflection and intervention selection. Finally, we will widen the focus of the online offering beyond students, and incorporate intervention recommendations based on accumulating evidence from the workshops and online studies.

In other words, the initial key step is to embed the ReDD workshops within the infrastructure of an educational institution. This may not only allow the workshops

to reach a larger number of students, but also enable research data to be collected long-term within an institutional structure that is more resilient to the ebb and flow of research funding. Thus, by developing a format which helps address a student need, we hope to piggyback on existing infrastructure, establishing an enduring research tool, that may subsequently be exported to other institutions and beyond. Eventually, we will scale this effort to broader audiences via an online platform which distils evolving findings into a high quality tool for exploration and recommendation of targeted interventions, and for advancing digital self-control research.

Conclusion

In 2012, the Pew Research Center surveyed a large number of internet pundits on their predictions around the impact of digital technologies on young adults in 2020. Numerous respondents expected the key challenges to revolve around attention and self-control, with a new social divide likely to emerge in an addictive digital world: whereas large benefits would accrue to those able to adapt, safeguard their attention, and use technology positively to advance their goals, those without clear goals or desire to achieve something would get trapped in a downward spiral of distraction and fall further and further behind (Pew Research Center 2012; cf. Postman 1985).

Whereas such bleak scenarios may be exaggerated (Orben 2019), the evidence summarised in Chapter 2 does suggest that the functionality and convenience provided by smartphones and computers, combined with the design imperatives of the attention economy, cause many, if not most, users to struggle routinely with exercising self-control over their digital device use. This should not be surprising, as self-control researchers have long found that relying on conscious willpower is a poor strategy when temptations are permanently available. Therefore, as an ever-expanding range of activities becomes digitally mediated, devising effective design patterns to support user self-control, regardless of cognitive abilities, motivations, or personalities, must be a research priority.

In this thesis, we asked how existing digital self-control tools might help us identify effective design patterns for supporting self-control over digital device use. As an answer to this question, we showed how the hundreds of tools available in online stores, combined with a dual systems framework as interpretive lens, provide a powerful starting point for understanding common self-control struggles and identifying promising design patterns for mitigating them: we organised existing

tools based on their design features and on mapping those features to cognitive mechanisms involved in self-regulation, and analysed their user numbers, ratings, and reviews. We pointed out how this helps identify widely used or theoretically interesting features under-explored in current research, as well as feature gaps, which can guide subsequent targeted research. As a demonstration of this, we conducted a controlled study of two specific interventions for self-control on Facebook drawn from the Chrome Web store, both of which were found to potently influenced behaviour and reduced unintended use.

Effective interventions are not one-size-fits-all—specific self-control needs arise from many contextual and personal factors. In moving towards a better understanding of such factors and how existing interventions might be better applied, we ended our empirical investigations by embedding a broad sample of existing interventions in a workshop for addressing digital self-control struggles among university students. These workshops suggested that interventions which target specific distracting UI elements, or even which serve as 'training wheels' for self-discipline, may represent especially promising avenues for future work.

Looking forward, there is ample reason to be optimistic about this field of research. On the one hand, portable, powerful, and inter-connected digital devices do present an unprecedented self-regulation challenge: never before have so many behavioural options, information about nearly everything, engaging games, and communication with friends, family, and strangers, been instantly available. On the other hand, this very challenge presents a unique research opportunity. Precisely *because* digital devices afford so much functionality, they allow us to testinterventions with greater precision, flexibility, and dramatically lower effort than changes to the physical environment. Research on design patterns for digital self-control should therefore have every opportunity to make rapid progress and discover effective ways to rein in the Siren song of digital distraction.

The future to hope for is one in which people are able to develop beneficial habits of technology use and are resilient against predatory nudging by clickbait

advertisers and data harvesters. I sincerely hope that the work presented in this thesis will help us realise that future.

Appendices

A

Chrome extensions for self-control on Facebook

Table A.1: Browser extensions for self-control on Facebook, identified by searching the Chrome Web store in February 2018. Also available (with urls to the extensions) on the thesis' Open Science Framework repository: osf.io/ed3wh/

Title	Summary	Number of users	Rating	Number of reviews
F.B. (FluffBusting) Purity	Provides granular control, options to remove the news feed, restyle colours, hide suggested content, and more	198,708	4.83	1,804
News Feed Eradicator for Facebook	Removes the news feed and replace it with nothing or with motivational or customised quotes	138,781	4.62	919
Kill News Feed	Removes the news feed	51,233	4.62	584
QCLean	Removes ads, sponsored posts, and recommended games	36,629	1.54	1,927
Todobook	Replaces the newsfeed with a todo-list. Clearing the todo-list unlocks 5 minutes of news feed	4,549	4.74	172
Facebook Demetricator	Removes numerical metrics, such as number of friends and number of likes	3,211	4.36	25
Detox for Facebook	Replaces the newsfeed with content from other sources, e.g. mashable, the verge or github	3,112	3.15	41
Time's Up! - Facebook time limiter	Can prompt user to stop, or force close the tab, when a set time limit has passed. Browser toolbar button shows how much time is left	2,018	3.42	24
Facebook Chat Only	Hides everything except the chat sidebar	1,709	3.79	34
Focusbook	Promps the user for why they visit Facebook, then periodically reminds them of what they typed in until they leave the site.	1,424	4.08	38

Table A.1: Browser extensions for self-control on Facebook, identified by searching the Chrome Web store in February 2018. Also available (with urls to the extensions) on the thesis' Open Science Framework repository: osf.io/ed3wh/ *(continued)*

Title	Summary	Number of users	Rating	Number of reviews
Newsfeed Burner	Removes the news feed	1,021	4.73	11
Auto Logout	Automatically logs the user off after 10 minutes	382	4.20	5
Facebook Visit Stats	Adds counter to the browser tool bar showing number of visits made to Facebook	322	2.40	5
Hide News for Facebook with Timer	Hides the newsfeed and adds simple 'show feed' button to toggle it on again	319	4.80	5
Feminist News Feed Eradicator for Facebook	Replaces the news feed with inspirational feminist quotes	308	4.29	7
Focusbook (Facebook News Feed Remover)	Replaces the news feed with suggestions for alternative activites in the form 'you could be doing' + random activity 'instead'	248	4.17	6
Stop Scrolling Newsfeed for Facebook	Hides the newsfeed after a selected amount of time (15s, 1m, 5m)	219	4.57	21
Cat Feed	Replaces the news feed content with pictures of cats	202	4.57	7
FB Newsfeed Killer	Removes the newsfeed plus the prompt to make posts	162	4.50	2
Friction for Facebook	Replaces the newsfeed with self-control tips like 'go to messenger.com if you're on FB to send messages'; remove color from notifications	127	4.86	7
MinimalHero	Removes the news feed and limit number of browser tabs that can be simultaneously open	110	5.00	1
Distraction-free Facebook Chat UI	Adds button for hiding everything except the chat sidebar	108	4.88	8
Minimal Distraction Free Facebook	Removes everything from the Facebook homepage except the top nav bar and replaces it with a motivational quote	105	5.00	2
Timewaste Timer	Charges 1$ from a set deposit account when Facebook is used for more than a specific daily duration	95	5.00	3
Simply Facebook	Removes everything except the newsfeed and the chat sidebar	78	3.00	1
Turn Facebook Black & White	Turns the site black and white	70	1.00	4
Social Habit Disruption	Displays a 'There are better things to do' popup and prompts the user for a number of minutes they need access	69	4.33	3
Desktop Messenger - No Distractions	Adds button to the browser toolbar that takes the user to a messenger-only version of Facebook	55	5.00	1

Table A.1: Browser extensions for self-control on Facebook, identified by searching the Chrome Web store in February 2018. Also available (with urls to the extensions) on the thesis' Open Science Framework repository: osf.io/ed3wh/ *(continued)*

Title	Summary	Number of users	Rating	Number of reviews
Codeforces WA Questions FB News Feed	Replaces the news feed with pending questions on Codeforces (website for competitive programming)	43	4.78	9
I don't care about your likes	Hides likes and notifications	41	5.00	1
Facebook without photos	Removes pictures on Facebook	40	3.00	1
Social Relief - Relief from your social feed.	Adds button to browser toolbar which lets the user block access for 1 day, 1 week, or 1 month	37	5.00	3
Hide Facebook News Feed	Removes the newsfeed and adds button to browser toolbar for toggling it on	35	5.00	1
News Feed Hider	Removes the newsfeed during specific hours of the day	31	3.00	2
deface	Removes everything except the chat sidebar	30	4.75	4
facebook usage control	Blocks Facebook after a set daily time limit has been spent	30	4.00	2
Social Rehab	Blocks Facebook	29	3.00	2
Facebook NoStream	Removes the newsfeed plus the prompt to make posts	28	2.67	3
Focus for Facebook (Free)	Unfollows everyone in the user's newsfeed	28	0.00	0
No Feed	Removes the news feed	27	4.50	2
Rap News Feed for Facebook	Replaces the news feed with inspirational rap quotes	16	5.00	2
Clutter Free Facebook	Removes the news feed	11	5.00	1
Facebook Bliss	Removes the news feed	9	5.00	1
FBNoTrend	Removes trending topis	7	5.00	2
Facebook Filter	Removes sponsored and suggested posts, trending topics, and comments	5	0.00	0
FB Blinders	Removes names and images from posts	5	0.00	0
Neuter Facebook	Removes newsfeed, chat side bar, sponsored posts, and shortcuts	2	5.00	1
Quieter Facebook	Removes the news feed	2	0.00	0
99xfy	Removes chat sidebar and short cuts	1	0.00	0
Facebook Feed Relief	Adds option next to each news feed post for hiding it	1	0.00	0

B

Sample poster from recruitment for the ReDD workshops

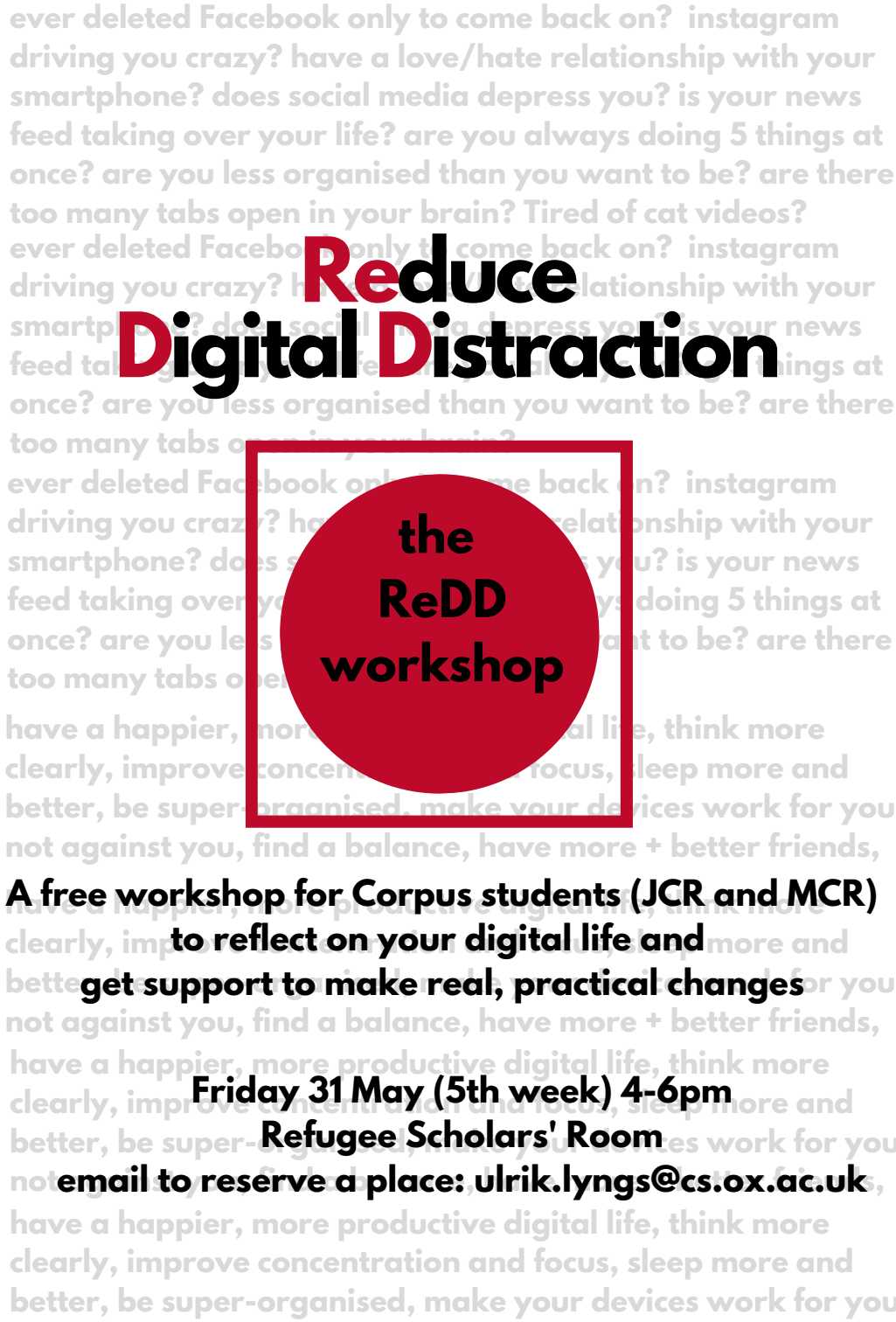

Figure B.1: Example of recruitment poster for the Reducing Digital Distraction workshop pilots.

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