Exploring smartphone overuse and meaningful use

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A thesis submitted for the degree of

Doctor of Philosophy

September 2024

I would like to dedicate this thesis to my father, mother, wife, and daughters. You all illuminated my life during this journey.

Declaration

I declare that the work presented in this thesis is, to the best of my knowledge and belief, original and my own work. Many of the ideas in this thesis were product of discussion with my supervisor Professor Corina Sas. The material has not been submitted, either in whole or in part, for a degree at this, or any other university. This thesis does not exceed the maximum permitted word length of 80,000 words including appendices and footnotes, but excluding the bibliography.

Sultan Saleh Almoallim

Acknowledgements

Following years of hard work and dedication contributing to my PhD dissertation, I am grateful to all who have supported me academically and professionally. I want to thank my supervisor, Professor Corina Sas, for her valuable encouragement, guidance and support. Throughout my dissertation, Professor Corina dedicated much time and effort. I truly appreciate her support, which enabled me to develop new concepts, explore my ideas, and continuously aim for perfection in everything I do. I will always be grateful for our lively discussions at every stage of the writing process.

I am incredibly thankful to my loving parents. They have supported me in prayers throughout my studies, and I would like to express my gratitude to them.

Thanks to my brothers for their moral support. Special thanks to my brother, Mohammed, for financially supporting my expenses abroad.

Importantly, I would like to thank my loving wife, Amal, for the love, support, and encouragement she always gave me. She took our family's responsibility, bearing the pressure of work and home throughout my studies.

As for my lovely daughters, Houri and Ladan, words cannot express my love for them. They have the softest spot in my heart and motivate me to achieve excellence. This would not have been possible without their love and support, for there were times that I felt like giving up.

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Abstract

Most HCI studies on digital overuse emphasize the negative impacts of technology, particularly smartphones and apps, which are intended to be addictive and habit-forming. Thus, the phenomenon of smartphone overuse needs to be thoroughly understood in order to design effective mitigation measures. Traditionally, technologies and apps are designed to have as little friction as possible, while this thesis seeks to explore the reverse mainstream innovation principles. The research commenced with an autoethnographic study, reviewing both commercial and academic digital well-being applications. This initial step was essential in identifying theoretical underpinnings and features of existing apps. To examine the smartphone usage patterns in terms of meaningful and meaningless use, and to understand the motivations behind such behaviors, a diary study was conducted with 20 participants aged between 19 and 40. Participants were asked to self-report their usage through an online form over a 14-day period, and to upload screenshots of automatically tracked data from their smartphones. Following this diary study, these participants engaged in co-design workshops where they were presented with examples of design frictions to limit meaningless use. They were then encouraged to generate ideas to shed light on novel design frictions to support meaningful use. To further explore the application of design frictions in real-world contexts and assess their impact on smartphone usage, an additional 20 participants were recruited for a user study. This study involved evaluating a bespoke Android mobile app in the wild. Participants were asked to install the application on their smartphones and use it for a few minutes over a two-week period. After each usage, participants completed an online form and at the end of each week they participated in a half-hour interview. This thesis contributes to the body of knowledge by informing designers about the functionalities offered by top-rated digital well-being applications and providing guidelines for the design of such apps. The thesis also contributes to exiting knowledge by highlighting the origins of meaningful and meaningless smartphone use. This has an important design implications mainly to support meaningful use rather than limiting meaningless use. A pivotal implication is the integration of a hedonic element into the design to potentially enhance meaningful use. Moreover, the thesis provides a nuanced understanding of the relative value of different design frictions, demonstrating how some can facilitate meaningful use and mitigate problematic use. Conversely, it also highlights that certain frictions may be inappropriate for application in specific types of apps.

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Chapter 1: Introduction

1.1 Research Background

Smartphones are key technologies weaved in the fabric of daily life for most people across the world (Atas and Çelik 2019; Busch et al. 2021; Radesky et al. 2020; Baumgartner et al. 2023). They are used for social purposes, such as staying in touch with family and friends, as well as for pragmatic purposes including as an alarm clock, to complete work-related tasks, personal banking, online shopping, and learning information and languages. Smartphones are also used for leisure activities such as gaming, reading, listening to music, and watching videos. Moreover, they have been framed as social objects (Nakamura 2015; Schwind et al. 2019): meaning that their use in public spaces and social settings is generally socially acceptable regardless of the purpose of the phone session.

Given their increasing popularity among all user groups, smartphones have been extensively researched both in academia and industry. Smartphone producers and app developers seek to improve the technology's performance, and perceived value to increase its uptake (Ayodele et al. 2020; Baishya and Samalia 2020; Gunduc 2021). Popular improvements include faster data processing, longer battery life, and more visually attractive interfaces. While such innovations improve functionality and accessibility (Carmien and Manzanares 2014; Díaz-Bossini and Moreno 2014), they also encourage habitual use. As a result, users struggle to stay 'off-device' due to a fear of missing out on new content (Brailovskaia et al. 2021; Casale et al. 2023; Pinder et al. 2019). Over time, habitual smartphone use can also lead to the development of phantom ringing syndrome (PRS) or phantom vibration syndrome (PVS). These conditions refer to instances where a user perceives ringing (PRS) or vibrations (PVS) indicating an incoming call, message, or notifications which are not actually present (Kruger and Djerf 2017; Y.-H. Lin et al. 2013; Rosenberger 2015).

Concerns over problematic smartphone use have been present for decades and continue to increase, especially regarding young people (Green 2011; Qiu 2017).

Smartphone overuse is discussed in various forms including technological 'dependency' or 'addiction' (Ding et al. 2016; Hiniker et al. 2016; S. H. Jeong et al. 2016). Despite the growing body of literature, the academic arguments concerning smartphone overuse are inconsistent and sometimes contradictory due to challenges in defining 'overuse'. Phone use is subjective; what counts as overuse is influenced by user's background and specific context of use, as well as broader social norms, beliefs, and cultural practices (Hong et al. 2019; Oulasvirta et al. 2012).

Candussi et al. (2023) draw together research in this area looking at patterns of problematic smartphone overuse in university students. They highlight Aljomaa et al. (2016) who concur that high usage does not equate to problematic use, because smartphone is often indispensable for some occupations, but rather overuse is more associated with increasing use of social media or communication features. Therefore when referring to smartphone overuse, while the assertation of overuse may be contextually and culturally rooted, it is possible to recognise and be more specific about particular features or elements of smartphone use which are predictors of (problematic) overuse.

Laurence et al. (2020a) performed research within Brazilian University students, discovering that a correlation exists between chat and social media usage, and problematic smartphone use; WhatsApp, Facebook, Snapchat and Instagram ranked of highest importance to users who registered problematic use (using SAS-BR, a Brazilian Version of Smartphone Addiction Scale (Laurence et al. 2020b)), as well as registering higher on measures of loneliness. Tamura et al. (2017) similarly investigated adolescents in Japan and noted a correlation with higher use of social media apps (120min+ per day) and increased incidence of depression, compared with those spending similar time on the smartphone but playing games, searching or watching videos. Alosaimi et al. (2016) similarly find an increased correlation between use of smartphones for more than 8 hours per day, primarily social networking and watching news and an increase in unhealthy lifestyle and adverse effect on academic performance.

Evidently there is an increasing body of evidence pinpointing overuse to be particularly linked with social media. Accepting that the reasons for and uses of

this category of application can be varied and nuanced leads to questions about the subjective validity and utility of smartphone use.

In recent years, human-computer interaction (HCI) research has studied technology use through various conceptual frameworks to more consistently explore its subjective nature. For instance, Mekler and Hornbæk (2019) proposed the Framework of Meaning as a practical tool to analyse meaning as an experience in HCI interaction with five core dimensions: connectedness, purpose, coherence, resonance, and significance. Overall, meaningful smartphone use is associated with positive emotions and fulfilling technology interactions; meaningless use – including overuse – is associated with negative emotions and unfulfilling interactions (K. Lukoff et al. 2018; Mekler and Hornbæk 2019).

Smartphone overuse has been also increasingly discussed in relation to digital wellbeing, which refers to 'the impact of digital technologies on what it means to live a life that is good for a human being' (Burr et al. 2020, 2313). Digital wellbeing has been also a growing concern in industry. For instance, Apple (Apple 2022, 21) introduced features to help users 'take action to improve their overall wellbeing'; Google (Google 2021) is 'committed to giving everyone the tools they need to develop their own sense of digital wellbeing. So that life, not the technology in it, stays front and center'.

Several mitigation measures have been also proposed to reduce and prevent smartphone overuse. Design friction is a popular approach which involves deliberately designing friction into technology to slow and ultimately reduce its use (Purohit et al. 2020). For existing technologies such as smartphones, this usually involves adding obstacles to otherwise smooth and quick processes, such as adding extra steps to unlock the screen. Design frictions can be more or less extensive and invasive depending on the intended level of inconvenience. A microboundary is an example of a small, weak obstacle designed to help users slow down, and reflect on their use of technology (Cox et al. 2016). By reflecting on their actions, users can distinguish habitual, mindless smartphone use from mindful use and reduce the former. Despite their high potential to reduce smartphone overuse, microboundary-level interventions are still rarely used for this purpose.

1.2 Research Rationale

The rationale behind this PhD project was to contribute new knowledge concerning the phenomenon of smartphone overuse as viewed from user's perspective. The research sought to provide new insight into patterns of smartphone use and what smartphone users consider to be meaningful and meaningless phone or app use. Building on these findings, the research sought to develop novel, user-centred solutions to prevent and reduce smartphone overuse. Among various design friction options, this PhD project research has focused on microboundaries because of their high potential to induce behavioural changes in phone use through micro-interventions, i.e. small, relatively unobtrusive interventions with potential for long-term impact on smartphone overuse.

1.3 Aims and Objectives

The overall aim of this PhD project is to explore users' phone and app meaningless and meaningful use, and these can be better addressed and supported respectively. This aim was translated into the following research questions:

1. What is digital wellbeing and what are users' smartphone/app use, both meaningless and meaningful?
2. How can we better design to limit meaningless smartphone overuse and to support more meaningful smartphone use?
3. What is users' perceived value of micro-interventions illustrating different type of cognitive frictions for use on everyday life?

From the research questions above, the following objectives were formulated:

1. What are users' experiences of phone/app meaningless and meaningful use?
2. How can we design novel technology-based micro-interventions to limit meaningless phone/app use, and support meaningful phone/app use?
3. What is users' perception of such micro-interventions when used in everyday life?

The study adopted the Framework of Meaning (Mekler and Hornbæk 2019) and the digital wellbeing perspective (Roffarello and De Russis 2019a) as main theoretical underpinnings, to maintain the focus on user experience rather than technology. The former helped to analyse the perceived purpose and significance of smartphone interactions; the latter helped to critically reflect on the explored micro-interventions from users' perspective.

Table below illustrates the mapping of thesis; research questions to the main chapters.

<table>
<tr><td>Research Questions</td><td>RQ1: Understanding digital wellbeing and smartphone/app use</td><td>RQ2: Designing to limit meaningless phone/app use and support meaningful phone/app use</td><td>RQ3: Evaluating novel micro-boundary interventions in everyday life</td></tr>
<tr><td rowspan="2">Studies/ Chapters</td><td>Scoping review</td><td>Study 1: Functionality review and autoethnography of top rated digital wellbeing apps</td><td rowspan="2">Study 4: Exploration of the Puzzle Block app in-the-wild</td></tr>
<tr><td>Study 2: Diary study</td><td>Study 3: Co-design workshops</td></tr>
</table>

Table 1: Overview of the research questions and the main studies chapters

1.4 Contribution to Knowledge

This PhD project contributes to knowledge in several ways. From a theoretical perspective, it advances current knowledge on how and why people use their smartphones, what constitutes meaningless and meaningful use. These insights add to current understandings of how to design smartphone interventions to encourage meaningful smartphone use and limit its meaningless use. Specifically, the insights highlight the need to design such interventions using a user-centred approach to ensure positive, long-lasting results.

From a design perspective, this research contributes updated design guidelines and novel conceptual designs for digital interventions to discourage meaningless use through the lens of five types of design frictions: cognitive, emotional, motivational, social and physical, and to support meaningful smartphone use through a focus on physical and emotional wellbeing, productivity, time management, and attention training.

Lastly, from a technological perspective, this research contributes by exploring Puzzle Block, a novel mobile phone application illustrating different types of cognitive frictions such as Math, Trivia, and Words puzzles, through a two week study in-the-wild.

1.5 Contributing Publications

- Almoallim, S., and C. Sas. "Functionalities review of digital wellbeing apps: towards research-informed design implications for interventions limiting smartphone use." JMIR Form Res 6 (2022): e31730.

- Almoallim, Sultan, and Corina Sas. "Patterns of Meaningful and Meaningless Smartphone Use: A Diary Study." In 36th International BCS Human-Computer Interaction Conference, pp. 251-261. BCS Learning & Development, 2023.

1.6 Thesis Structure

The thesis is structured as follows. Chapter 2 presents a scoping review of research on digital wellbeing, followed by an overview of recent HCI research on smartphone overuse in Chapter 3.

Chapter 4 presents thesis/ overall methodology including the overall research approach main research methods and their rationale.

Following the methodology, chapter 5 presents a functionality review of 39 most popular digital well-being apps available on the Google Play Store, as well as 17 apps discussed in academic literature. Functionality review was complemented by an autoethnography study of these apps.

The following three chapters describe the three main users studies. Chapter 6 presents Study 1: a two-week diary study focused on smartphone meaningless and meaningful use for which participants tracked and recorded their daily smartphone use. Chapter 7 presents Study 2: co-design workshops focused on five types of design frictions and five areas for meaningful smartphone use. Chapter 8 describes Study 3 which explored the use in-the-wild of Puzzle Block app illustrating cognitive frictions and their impact on phone/app use.

The findings from the three studies are critically discussed with reference to the literature in Chapter 9. The chapter also recommends directions for future research.

Chapter 2: Scoping Review of Research on Digital Wellbeing

The aim of this scoping review (Munn et al. 2018) was to map the body of work on digital wellbeing, both within the HCI literature, and beyond.

2.1 Paper Selection

To identify the papers, the search was conducted in summer 2021 on the ACM Digital Library (DL) using the keyword: "*digital wellbeing*", aiming to capture computer science and HCI relevant papers. Given the growing interest in digital wellbeing from medical research, and that JMIR journals also cover work in this space, a tailored search for these papers has been made on Google Scholar, using the search term: "*digital wellbeing"* AND "*JMIR"*. The selection of papers followed PRISMA methodology (Liberati et al. 2009; Page et al. 2021) (Figure 1).

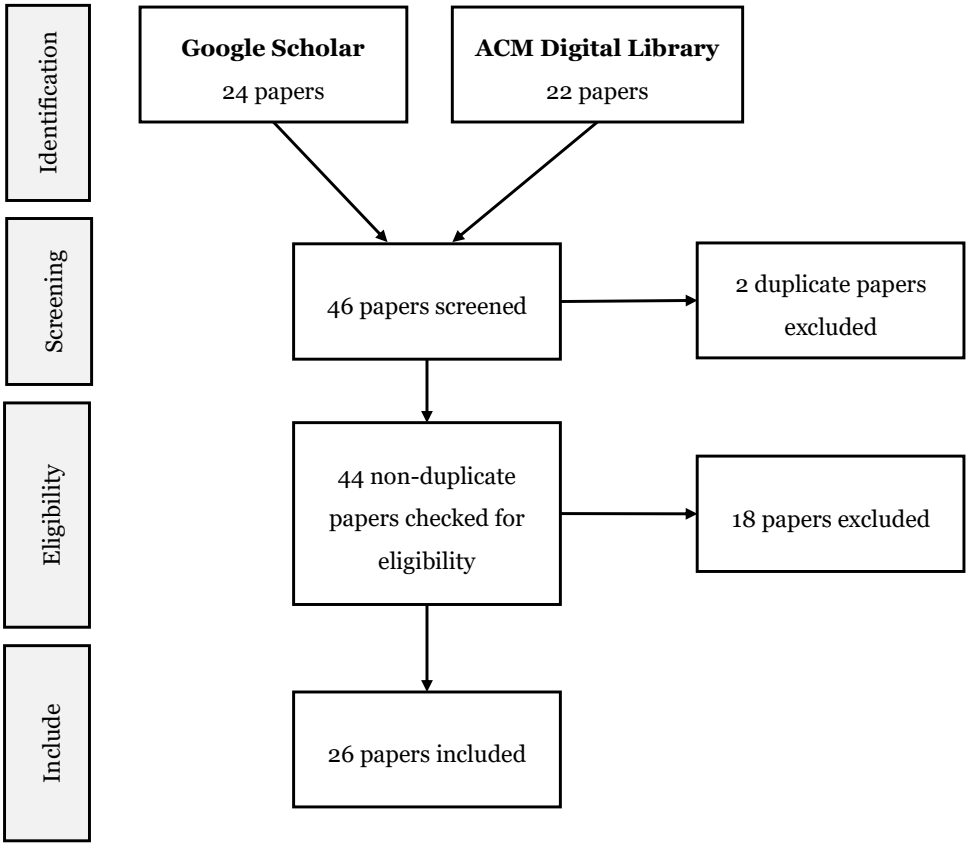


Figure 1: PRISMA Diagram of Search Process

At the screening stage, from the 44 identified papers, 2 duplicates were removed and then their abstract was read to explore their match the eligibility criteria which were publications on "behaviour change theories, tools and interventions for digital wellbeing." 18 papers were removed at this stage, including reports of work-in-progress, workshop or position papers and other literature review or meta-review papers. This led to a final set of 26 papers as marked with * in Reference list.

2.2 Analysis

For the scoping review, the adopted approach was thematic analysis which consisted of identifying recurrent themes and summarizing the findings under each theme. The themes were identified through an iterative process involving topics covered in other HCI reviews such as technology, interventions, user groups (Sanches, Janson, et al. 2019), to which the following themes were added as they emerged from the reviewed papers: types of interventions, their impact, research methods for exploring digital wellbeing, challenges of digital wellbeing and future research directions. The reflexive thematic analysis, (Terry and Hayfield 2020) was particularly useful for the development of such themes as informed by the content of papers.

The following sections described and analyse the data on a theme-by-theme basis.

Theme	**Sub-themes**
1. Definitions	Digital wellbeing
	Related concepts
2. Targeted aspects	Emotion
	Physical
	Behaviour
3. Interventions	Psychological
	Digital
4. . Technology	Smartphone applications
	Websites
	Frameworks

5. Theoretical underpinning	Other (Specify)
6. Users	Age group
	Gender (M/F)
	Place of study
	Type of participants (medical staff, students, etc)
	Health condition
7. Challenges	Problems encountered
	Suggesting future research to complete current studies
8. Evaluation Findings	Effectiveness
	User Groups
	Validity Issues
9. Topics for further research	Novel design of technology-based intervention for digital wellbeing
	Richer understanding of users' motives and the sociality of digital wellbeing interventions

Table 2: Categories for coding in analysis

2.3 Findings

This section describes the main findings from the scoping review of digital wellbeing starting with its meanings and aspects being targeted, technology-based interventions, their evaluation with different user groups, and validity concerns.

2.3.1 Meanings of Digital Wellbeing and Targeted Aspects

Findings indicate limited definitions of digital wellbeing with only 7 out of 26 papers. Interestingly, 16 papers provided implied definitions of digital wellbeing that fell short of a direct statement. The remaining 3 papers did not provide an identifiable definition, for example, one paper described a workshop to produce a definition of digital wellbeing but no conclusion was reported (Cecchinato et al. 2019).

There was limited consensus for a generally accepted definition of digital wellbeing, with three distinct meanings being proposed namely that of technology overuse, technology-based health services and interventions, and management of personal information against cyber threats. Each of these are further detailed.

Technology overuse, particularly (i.e. smartphones and online social networking sites). This was the most frequently used meaning in relation to digital wellbeing highlighted by 9 papers. Most of these papers emphasised the negative impact of digital technologies, and how these may be mitigated.

Descriptions of general negative impact featured in all of the 9 papers: problematic use of digital technologies and in particular the limited ability to regulate one's phone use (Harris et al. 2020; J. Kim et al. 2019), distractions, interruptions, and increased stress from notifications on mobile devices (Weber et al., 2018), and "*excessive phone checking, which interferes with everyday life when people experience unwanted impulses to check their devices"* (Pinder et al. 2019). For workers, such negative consequences may impact on employees' " ICT enabled availability" (Saternus 2019).

The remaining five papers (Roffarello and De Russis 2019a; Kitson et al. 2019; Devito et al. 2019; Tran et al. 2019; Wiese, Pohlmeyer, and Hekkert 2019) addressed addictive, 'excessive', or compulsive behaviour related specifically to the use of smartphones, internet, or social networking technology.

To address such challenges, scholars called for moderated technology use (Király et al. 2020; Widdicks and Pargman 2019), and in particular conscious use (Roffarello and De Russis, 2019a) or more meaningful use (Purohit, et al., 2020) for "the long term benefit" (Rofarello and De Russis, 2019b) of "meaningful purposes" (Király et al. 2020) and personal growth (Kitson et al. 2019) which goes beyond the "lock out mechanisms" aimed to limit meaningless use (Tran et al., 2019).

Three papers (Devito et al. 2019; Kitson et al. 2019; Tran et al. 2019) mentioned beneficial attributes , positive effects, or desirable behaviour related to digital wellbeing such as community building and social support, mindfulness and transformative experiences, and meaningful interaction. A fourth paper

mentions (Wiese, et al., 2019) activities related to long-term health that could be incorporated into product designs based on Positive Psychology, but not specifically digital products, such as 'learning', 'contributing to greater good', 'investing in social connection', 'managing stress, hardship, trauma' and 'joy of use'.

Technology-based health services and interventions capture the meaning of digital wellbeing as the technology mediated delivery of 'traditional' health (Sarah and Leonard 2019) and healthcare services (Bhatt et al. 2020; Burr et al. 2020; Craven et al. 2019), or health interventions (Holt-Quick et al. 2021) including those for wellness and wellbeing particularly for mindfulness (K. Lukoff et al. 2020), fitness (Fleck et al. 2020), or digital tools to support members of marginalised communities suffering from racism. (TO et al. 2020).

Findings indicate that 9 studies focused on technology-based treatment (Bhatt et al. 2020; Burr et al. 2020; Craven et al. 2019; Sarah and Leonard 2019; Bharmal, Hassenzahl, and Laschke 2020; TO et al. 2020; K. Lukoff et al. 2020; Fleck et al. 2020; Holt-Quick et al. 2021) to support new behaviours, meaning changes in ways of working or accessing treatment, either by supporting practitioners or individuals directly through self-management tools.

Management of personal information against cyber threats capture the meaning of digital wellbeing as protection against such threat by making well informed decisions over digital products (Forno 2019), in order to protect users' vulnerability to intentional aggressive cyberbullying acts (Arslan et al. 2019).

2.3.2 Technology-based Interventions for Digital Wellbeing

Findings indicate different interventions aimed to limit phone overuse or to support health and wellbeing, supported mostly through mobile app and web browser extension technologies.

Seven studies reviewed or used publicly available apps from Apple/Google app stores, including social media apps (Facebook, Instagram) as well as other 'Digital Wellbeing' related apps (Arslan *et al.*, 2019; Rofarello and De Russis, 2019a; Wiese, et al., 2019; Bharmal, et al., 2020; Bhatt *et al.*, 2020; Fleck *et al.*, 2020; Lukoff *et al.*, 2020).

Six new applications were developed; four mobile apps (Weber, et al., 2018; Kim *et al.*, 2019; Rofarello and De Russis, 2019b; Bharmal, et al., 2020), a cyber-bullying AI recognition algorithm (Arslan et al. 2019), a chatbot (Holt-Quick et al. 2021) and a web browser add-on (Purohit, et al., 2020).

Interventions aimed to limit phone overuse used mobile apps for self-monitoring, break habits or raise awareness of phone use (Roffarello and De Russis 2019c), also mobile apps integrated with Google Calendar and phone reminders or notification services for similar purposes (Bharmal, et al., 2020), lock-out apps to limit excessive, problematic and undesirable use by increasing the cost of interaction (J. Kim et al. 2019), browser extensions capturing use of social media browsing to support awareness and break habits (Purohit, et al., 2020), as well as cognitive bias modification techniques such as the approach avoidance task (AAT) to reduce bias toward smartphone use (Pinder et al. 2019; Wiers et al. 2011).

For heath interventions, findings indicate chatbot-based dialogic intervention for mental health (Holt-Quick et al. 2021)

The types of interventions are split between device-based interventions using features built into browsers/phone apps intended for long-term use, or those with a more dialogic approach , reinforcing the impression of the emerging 'digital wellbeing' therapeutic interventions where digital tools play a distinct part.

Theoretical underpinning of technology-based interventions

With respect of theoretical underpinning, findings indicate limited use of theories. Of the six apps developed across all the papers reviewed, four were referencing theories, each of them different:

- (Phone overuse) Habit forming and Social support theories (Roffarello and De Russis 2019c)
- (Phone overuse) Design Friction (J. Kim et al. 2019)
- (Health intervention) Positive Psychology, Cognitive Behaviour Therapy (Holt-Quick et al. 2021)
- (Health intervention) Mindfulness (K. Lukoff et al. 2020)

2.3.3 Evaluation of Technology-based Interventions for Digital Wellbeing

In the research paper that investigated using digital tools for the delivery of health care (Holt-Quick et al. 2021), the findings were overall positive. The dialogic intervention was delivered via chatbot for mental health treatments for individuals with alcohol use disorder and participants reported a significant reduction in the number of drinking days and the quantity of alcohol consumed compared to a control group.

Where the research investigated the area of a smartphone or digital technology overuse, or mitigating the effects of it, the findings were more mixed. All but one studies reported the desired effects of reducing the targeted activities or inciting the desired change in attitude, however also reported limitations in measurement frameworks for the intended effect and number of diversity of participants.

Pinder et al.(2019) used cognitive bias modification (CBM) techniques, Attention Bias Modification (ABM) and Approach-Avoidance Training (AAT) to reduce bias toward smartphones use, it was notable as they reported no noticeable effect following their intervention on smartphone bias.

CBM refers to a psychological intervention technique designed to change negative thought patterns and biases, such as identifying neutral or positive interpretations of ambiguous scenarios (MacLeod et al. 2009; Meissel et al. 2021). ABM (also known as Attention Bias Modification Treatment, ABMT) involves training exercises aimed to redirect focus from negative stimuli, this could include training exercises involving flashcards, where the participant has to recall the position of the neutral card, compared to the negative one (Hakamata et al. 2010). AAT is a therapeutic technique to modify automatic tendencies to approach or avoid stimuli, thereby influencing behaviour and emotional responses (Eder and Krishna 2024). Participants are trained to make avoidance gestures to build a habit of avoidance, for example turning over a mobile phone to ignore notifications (Wiers et al. 2011).

Fleck et al. (2020) used workshop based discussions on personal information informing decisions on collection, different types, sharing and risks. All but one

participant generated intentions to change their behaviour, which the majority acted on in the weeks following the workshops.

Purohit et al. (2020) used a web browser extension for intervention on social media browsing to break habits and raise awareness, though they reported that it increased reflection, they could not conclusively say it reduced time spent.

Bharmal, et al. (2020) used a mobile phone app, combined with Google Calendar and phone reminder/notification service to set intentions and break habits and change behaviour, in an evaluation with three participants all three engaged more in the activities chosen to fulfil the intention.

Kim et al. (2019) used a lock-out task app integrated into smartphone to reduce unwanted usage by increasing cost of interaction. Users had to enter a long code shown on the screen. The results showed that the lockout task discouraged nearly half of the app use intentions when the code was 30 digits long.

As well as reporting that designs of apps and particular interventions had the desired effect, in some papers the findings also began to question the overall premise. Devito *et al.* (2019) reaffirmed that social network applications and the use of smartphones have **many benefits**, especially for marginalised people such as building community, gaining social support, and even exploring identity.

Rofarello and De Russis (2019a) mentioned that while the tools are designed to successfully break habits of phone overuse, there has been however limited work on forming alternative habits, for example (Wiese et al. 2019; Király *et al.*2020) identify behaviours to promote but do not cover how to achieve this.

Bharmal, et al. (2020) started to explore this through interventions such as mobile apps aimed to support intention forming and implementation, however their findings were less conclusive with respect to intervention's efficacy.

With respect to *user groups*, findings indicate that sample sizes range from 10 to 67, with an average of 31, and about one third of the papers (9 out of 26) involved participants mostly young adults (18 to 30 years) (Table 3). Their demographics align with HCI bias towards Western, Educated, Industrialized, Rich or Democratic context of study (Linxen et al. 2021). In particular, most of these papers included participants as young people such as students or graduates,

people from professional groups (office workers, mindfulness teachers, "experts", experienced counsellors, researchers, and developers) or otherwise simply "patients", or "internet users" and "actual users". These included people interviewed, or otherwise involved in research, not exclusively interventions.

Study	Total Participants	Age group	Gender	Intervention Type / Study Type	Duration
(Roffarello and De Russis 2019a)	38	Mean: 22.5 years, Standard Deviation 4.46	24M, 14F	Overuse / In the wild	3 weeks
(Saternus 2019)	67	20 – 60 years Average 39	37M, 30F	Health / Lab (Interview)	N/A
(Tran et al. 2019)	39	"early adolescence to older adulthood"	Not stated	Overuse / Lab	N/A
(J. Kim et al. 2019)	10	Mean: 28.75, SD=4.67	8M, 2F	Overuse / In the wild	3-week
(Pinder et al. 2019)	40	Mean 26.9	28M, 12F	Overuse / Lab	N/A
(Fleck et al. 2020)	18	23 – 33	4M, 14F	Health / Lab	5 weeks
(TO et al. 2020)	14	18 – 45	4M, 14F	Health / Lab	N/A
(Wiese, et al., 2019)	12	18 – 36, Median 31	4M, 8F	Health / Lab	N/A

Table 3: Participants Included in 8 Studies and types of interventions

Regarding gender, substantially more males were involved in the studies compared to females, except for two papers where the participants were mostly female (14F/4M) (Fleck et al. 2020; TO et al. 2020). Ethnicity was limitedly reported but one study was aimed exclusively at non-white individuals, so the participants identified as Black, Asian or Hispanic.

The location of participants was mostly Western Europe (UK/Germany/Switzerland/Italy) and the USA. One study (Bhatt et al. 2020) was based in India and looked at social media posts. Two studies (Cecchinato *et al.*, 2019; Purohit, et al., 2020) recruited locally (Switzerland) and also via social media, which may have extended their recruitment to remote participants worldwide, although still limited to English speakers. The final two aspects to mention were educational/professional background and health conditions. One study (Bhatt et al. 2020) looked at the provision of digital technologies for healthcare services, therefore all participants had some health condition, but no specific conditions were mentioned and were not a specific part of the selection criteria.

The other two thirds (17 out of 26 papers) do not involve study participants, as they focus mostly on theoretical perspectives, or design without user input (methods are reported in 4.3).

Validity Issues

An important finding is the commonly mentioned factors when reporting the outcomes of technology-based interventions which could impact their validity, both for health and for limiting phone overuse.

These factors concerned participant samples in terms of limited size, as indicated in Table 3 and mentioned by (Kim Inyeop et al. 2017; J. Kim et al. 2019; Tran et al. 2019) and representativeness to include for instance marginalized groups beyond the WEIRD (Western, Educated, Industrialized, Rich, and Democratic) contexts (Devito et al. 2019) , as well as the limited duration of evaluation**,** with suggestions being made for larger, more representative samples, and longer evaluation to study long-term effect (Craven et al. 2019; Fleck et al. 2020; Király et al. 2020; Bharmal, Hassenzahl, and Laschke 2020).

Additional validity concerns were raised regarding the measurement of phone overuse or problematic use and the need for better frameworks to evaluate it (Purohit, Barclay, and Holzer 2020; Tran et al. 2019; Roffarello and De Russis 2019c), where even clinical measures such as the Smartphone Addiction Scale have had limited evaluation (Hamamura et al. 2023).

2.3.4 Future Research Directions

This section describes three main research direction that the state-of-the-art has pointed towards. The above themes have already indicated how the body of work so far has been limited, as well as initial success regarding technology-based interventions and how this may be extended.

Supporting meaningful technology use rather than merely limiting overuse

This is one of the most important findings , highlighted by several papers (Roffarello and De Russis 2019b; Devito et al. 2019; TO et al. 2020) and marking a new paradigm in thinking about digital wellbeing, from the current common focus on the negative impact of 'overuse' to the positive experiences related to meaningful (Cecchinato *et al.,* 2019) or transformative interactions (Kitson et al., 2019), increased user experience (Purohit, et al., 2020). delivering on wellbeing factors (K. Lukoff et al. 2020; Wiese, Pohlmeyer, and Hekkert 2019), thus moving "beyond lock out mechanisms" (Tran et al. 2019).

Novel design of technology-based intervention for digital wellbeing

Future research directions have been also suggested to address the limitations of current interventions, for instance by exploring the value of habit detection approach (Roffarello & De Russis, 2019c), off-device anti-smartphone training (Pinder et al. 2019), or novel design of different lockout mechanics to limit problematic phone overuse, and how lockout tasks can be designed to address such problems. (J. Kim et al. 2019).

Richer understanding of users' motives and the sociality of digital wellbeing interventions

This recommendation relates to the fundamental understanding of users' motives and behaviours related to digital wellbeing for instance through co-design studies to uncover the balance between moderate use and users' freedom of choice, and how some users' internet use affect others such as family members (Widdicks and Pargman 2019).

This theme also focuses on leveraging social support for digital wellbeing interventions for instance by leveraging social support theory for limiting phone overuse (Roffarello and De Russis 2019a), or the support of peers in social networking sites for wellbeing (TO et al. 2020).

2.4 Summary

To conclude, this scoping review focused on 26 papers on digital wellbeing selected from Google Scholar and ACM DL.

Technology overuse is the primary meaning of digital wellbeing research, albeit additional, less common meanings have been identified related to technology for health and wellbeing, or for limiting the impact of cyber threats.

The meaning of technology overuse is predicated by the premise that technologies such as smartphones, mobile apps, or social networking sites can be overused, and that such user behavior should be limited. Many digital wellbeing interventions aim indeed to restrict usage given that "*excessive phone checking […] interferes with everyday life*" (Pinder et al. 2019).

This thesis adopts the working definition of digital wellbeing as concerned both with problematic phone overuse, also habitual or meaningless use, and how it can be limited, as well as with meaningful phone use and how it can be supported.

Chapter 3: Literature Review

3.1 Smartphone Overuse

This section provides an overview of the state-of-the-art of smartphone overuse, its negative impact, approaches to exploring it, and main interventions developed to limit problematic smartphone use. It expends the scooping review with a review of more recent HCI work on meaningless and meaningful phone overuse.

Phone over use is a complex phenomenon with rich antecedents contributing to it, and significant physical, cognitive and emotional negative consequences for users. Modern technologies, particularly smartphones and apps, are intended to be addictive and habit-forming. They are designed with precise colour palettes, shape combinations, and vibration patterns to elicit specific chemical reactions in the brain which encourage the prolonged use of smartphones (Hynes 2021). Even pragmatic technological innovations such as accessibility and usability improvements to increase usefulness tend to stimulate the habitual, compulsive use of smartphones.

As smartphone use is strongly subjective (Hong et al. 2019; Oulasvirta et al. 2012), there is also considerable ambiguity about the concept of its 'overuse'. For example, Roffarello and De Russis (2021) (Monge Roffarello and De Russis 2021) investigated digital wellbeing in relation to multiple devices and found that the most problematic user behaviours derived from the simultaneous use of multiple devices. This suggests that problematic use is affected by multiple factors and extends beyond a single technology, making HCI research on smartphones overuse even more complex.

With respect to its negative impact, smartphone overuse affects all user groups in multiple ways. Smartphones are typically held below eye level (İNal et al. 2015) and operated with one or two hands. From a physical health perspective, this forces the user into an unnatural, uncomfortable posture which can cause musculoskeletal discomfort and pain in multiple areas of the body including the neck, shoulders, wrists, and fingers (Derakhshanrad et al. 2020; İNal et al. 2015). All these health issues, particularly discomfort in the neck due to the forward

head tilt and in the hands and fingers from using the phone, become worse with longer, more frequent phone sessions.

Smartphone overuse has also been associated with cognitive dysfunction, leading to lower work productivity, impaired attention, and reduced task engagement (Duke and Montag 2017; Harris et al. 2020). Moreover, phone overuse has been linked to multiple mental health issues, notably anxiety and stress (Hynes 2021; Weber et al. 2018; Roffarello and De Russis 2019a). These negative impacts on wellbeing also negatively affect the users' emotional intelligence and social skills as the users struggle to 'disconnect' from technology (Aranda and Baig 2018; Russo, Ollier-Malaterre, and Morandin 2019).

The adverse effects of smartphone overuse, often also referred to as smartphone addiction or problematic smartphone use, have fallen under the emerging umbrella term of digital well-being. Vanden Abeele and Nguyen (2022) describe how academic references to the term digital well-being have risen dramatically since 2016 and have been referenced in diverse fields such as cultural studies, human-computer interaction, philosophy, communication sciences, sociology and psychology. While being used across many fields has resulted in multiple interpretations, they draw attention to the common factor, which is that digital well-being has emerged as a response to an 'always-connected' lifestyle with a negative connotation to wellbeing and contrasted with 'digital disconnection' having a positive effect (Syvertsen, 2020).

While identifying social media as a key indicator of smartphone overuse and negatively impacting digital well-being, research has also sought to identify particular characteristics and mechanisms that impact well-being. Gomez et al. (2022) focus on online "Upward Social Comparison" (when an individual compares themselves to others who they believe are faring better than they are). They observe the trends in social media to focus on positive self presentation (Sas et al. 2009) and minimize negative events, and identify a correlation between participants with a high level of online upward comparison with higher levels of depressive symptoms, negative self-perceptions, and a greater number of maladaptive social media behaviors. Referring to "Social Media Disorder" and its psychosocial consequences (e.g., anxiety, depression, social problems). Thorell et al. (2024) also highlight the strongest correlation of negative effects with using a

smartphone and social media for the purposes of social compensation, escape and self-status.

Dutt (2023) conceptualises digital well-being slightly differently and studies the effects of online risks on the concept: "*feeling safe and equipped to manage risks in all areas including physical, psychological, financial, and social, within the digital environment*". They reference that participants feel threatened and exposed, especially via participatory media practices, and whilst mentioning physical and psychological impacts, they also mention threats such as cyber stalking/bullying/harassment, and exposure to fraud and other cybercrime.

Dutt mentions the expectations that government and regulation offer protection from online threats, it has also been clear that media companies (content producers or platform operators) often do not act in the interests of users' well-being. Roffarello and De Russis (2022) point toward the domain of 'dark patterns' meaning user interface and design techniques optimized to increase time spent and daily visits with characteristics to distract a user from their intended goal, experience a lost sense of time and control and feel a sense of regret in hindsight about the time spent. They highlight key techniques of these attention-capture patterns; recommendations, autoplay, pull-to-refresh, infinite scrolling, and social investment and establish usage in key social media apps Facebook and YouTube. This highlights that smartphone overuse increasingly encompasses the impact of significant social media usage and the need for users to have awareness and management of their own digital well-being.

3.1.1 Research Approaches to Studying Smartphone Overuse

The phenomenon of smartphone overuse needs to be thoroughly understood in order to design effective mitigating interventions. However, this is challenging as smartphone overuse is highly subjective, dynamic, and context-dependent. As a result, the phenomenon has been investigated using widely different theoretical approaches, practical techniques, and target user groups. Collecting data from study participants is a popular option to investigate overuse at the point of origin, however, the high reliance on user-reported data has repeatedly been highlighted as a quality concern. Lee et al. (2021) (P. H. Lee et al. 2021) found large

discrepancies between self-reported data on smartphone use and the data automatically collected by smartphone trackers. Similarly, Boase and Ling (2013) highlighted several discrepancies between user-reported smartphone data and automatically logged data, noting that self-reported data suffers from 'low criterion validity'. They also suggested more comprehensive methods to collect data on smartphone use, although asking participants to manually check usage logs on their phones may result in 'frustration and additional time to complete surveys' (Boase and Ling 2013, 518). Alternatively, dedicated data collection apps may be employed to automatically, regularly collect information directly from the participants' smartphones.

A large body of HCI research has investigated smartphone overuse at the smartphone level, often from an interdisciplinary perspective which draws from behavioural, health, psychological, and even philosophical research. Such high-level research typically seeks to understand the users' reasons to use their smartphones and the psychological implications of the phone sessions.

Rooted in Greek philosophy, the concepts of *hedonia* and *eudaimonia* have been repeatedly used to investigate the quality of HCIs (Huta and Ryan 2010; Li et al. 2021; Mekler and Hornbæk 2016). This approach frames hedonic smartphone use as non-instrumental and fundamentally 'for pleasure', while eudaimonic use is instrumental and directed towards a clear goal (Mekler and Hornbæk 2019). Huta and Ryan (2010) (Huta and Ryan 2010) developed the Hedonic and Eudaimonic Motives for Activities (HEMA) scale to measure user wellbeing based on their hedonic and eudemonic motives. Using this scale, Li et al. (2021) found that pursuing hedonic aims is positively related to smartphone addiction; pursuing eudaimonic aims is positively related to higher wellbeing and negatively related to phone addiction. In other words, seeking momentary hedonic satisfaction through technology encourages addiction, while seeking meaningful, purposeful eudaimonic goals through technology increases wellbeing without encouraging addiction.

Other researchers have used a narrower, app-level approach to investigate smartphone overuse. Measuring phone use directly with tracking apps has become increasingly common as it simultaneously speeds up the data collection process and reduces the likelihood of data validity issues. For example, Ding et

al. (2016) (Ding et al. 2016) used app-logged data combined with surveys and interviews to gain 'deeper insights into smartphone overuse'. Their study highlighted significant differences between app types, with communication and social apps being the most addictive ones. Roffarello & De Russis (2023) note that self-tracking involves monitoring user behavior and offering feedback, such as through visualisations of the collected data, timers, and countdowns.

This thesis takes a combined approach to understanding smartphone overuse, inspired by Mekler and Hornbæk (Mekler and Hornbæk 2016; 2019) the research explores the concept of meaningful and meaningless interaction and their intersection with hedonic and eudemonic goals (Huta and Ryan 2010). While existing approaches have strived to characterize smartphone overuse in terms of app logs and tracking, then assign meaning from exiting research, it takes a novel user-centered design approach to enable users themselves to define, visualize and explore their own concepts of meaning and meaningless rather than overlay an external judgmental framework.

3.2 Technology-based Interventions for Smartphone Overuse

This section examines previous interventions to affect smartphone overuse. They are described on the basis of their strategic approach (method of intervention, theoretical basis), identifies the direction of research (areas of interest, success), and any research gaps or needs.

Just as tracking smartphone use can occur at the smartphone or app level, so do potential solutions to mitigate its overuse. HCI research has investigated a broad range of options with various theoretical underpinnings and design techniques applied across intervention levels, although app-level interventions are increasingly preferred (Ding et al. 2016; Roffarello and De Russis 2019a).

Phone-level interventions tend to lock the entire smartphone, which is unhelpful as the users quickly learn to bypass the block when seeking to use the phone for pragmatic purposes (Ko, Choi, et al. 2015). This learned behaviour – automatically bypassing the block – is then applied to all smartphone use, both

eudaimonic and hedonic, thereby turning the intervention into another mindless step to access the phone (Kovacs, Wu, and Bernstein 2021). By contrast, app-level interventions can be personalised and therefore effective as they allow users to block selected apps, such as addictive social media apps, and for specified periods (J. Kim et al., 2019). Haliburton et al. (2024) found that the brief design frictions introduced by app blocking significantly decrease the frequency of users' attempts to open targeted apps, promoting more meaningful app use.

3.2.1 Mindful Versus Mindless Use Approach

Most interventions aim to encourage mindful use, or discourage mindless use. Mindful phone use refers to the intentional and less automatic engagement with mobile phones, characterized by reduced multitasking, lower attachment, decreased online vigilance, and increased wellbeing (Woodlief et al. 2024). Mekler and Hornbæk (2019) highlight that mindful interaction fosters meaningful experiences. Mindless use is characterized by automatic, habitual behaviour, often leading to negative outcomes like reduced satisfaction and increased stress.

Riva et al. (2019) proposed Positive Technology as a framework for designing interactive e-experiences that foster positive change and empowerment, focusing on three key experiential variables: “Emotional Quality (affect regulation), Engagement/Actualisation (presence and flow), and Connectedness (collective intentions and networked flow)”.

Other researchers proposed similar design principles, such as encouraging reflective practice (Fleck and Fitzpatrick 2010), and meaningful experiences rather than lock-out mechanisms to hinder meaningless use (Tran et al. 2019).

Several studies have reviewed digital wellbeing apps to evaluate their effectiveness and identify areas for improvement. For instance, Almoallim & Sas (2022) conducted a functionality review of the 39 most popular digital well-being apps on the Google Play Store. Their findings reveal that these apps primarily focus on limiting screen time, while also fostering a more nuanced discussion about such tools by distinguishing between monitoring usage, tracking it against set limits, and offering targeted interventions to support reduced usage. They

argued that a broader design focus centred around digital wellbeing is needed to design effective intervention apps. Specifically, future HCI research should focus on 'supporting meaningful use rather than limiting meaningless use' (Almoallim and Sas 2022, 11).

While efforts to extend the current research focused on limiting problematic or mindless phone use to meaningful use have been increasingly made, most research has yet to explore different interventions for limiting use, leveraging timeboxing, frictions, and microboundaries.

Timeboxing is a time management technique that allocates fixed periods to specific activities and stop when the fixed periods reach its end, whether or not the task is completed (Miranda 2011).. Duke and Montag (2017) also noted that timeboxing mitigates smartphone addiction's negative impacts on productivity and mental health. By consciously limiting smartphone time, users can better manage attention and reduce stress, fostering a healthier digital balance.

3.2.2 Design Friction

Design frictions are 'points of difficulty occurring during interaction with technology' (Cox et al. 2016a, 1390). Effectively, the approach seeks to reverse mainstream innovation principles since most technologies and apps are traditionally designed to have as little friction as possible. Rather than helping users to painlessly achieve their goals, design frictions intentionally slow users down to encourage them to reflect on their actions (Mejtoft, Hale, and Söderström 2019).

Design friction can be implemented in many forms, to many extents, and at different levels to deliver the desired amount of inconvenience to the user. Various interventions aim to create inconvenience by placing additional, mandatory interactions before the user can use their device as planned. Such interventions force the user to spend more time and effort on uninteresting, non-target tasks before they can access the target technology or app (J. Park et al. 2018; Cox et al. 2016). According to Almoallim & Sas (2022), these interventions promote awareness of app usage limits through real-time notifications. These include explicit alerts, like push notifications on locked and unlocked screens,

either in the status bar or as pop-ups. Some notifications are large and cover much of the screen. Implicit reminders, such as screen dimming, also support awareness of time limits. Additionally, daily reminders to review tracked data enhance long-term awareness, focusing on overall usage patterns throughout the day rather than specific moments of app use. These findings suggest that design friction interventions which require more time and effort to be overcome are more effective in preventing smartphone overuse.

Another method to create inconvenience for the user is to generate irritative audio or tactile signals. Like all smartphone functions, sounds and vibrations are specifically designed to attract and maintain the user's attention (Hynes 2021). Both sounds and vibrations can be used to keep the user's focus on a smartphone game or announce notifications such as new messages and incoming calls. On average, smartphone users are estimated to receive over 60 notifications a day (Pielot, Church, and De Oliveira 2014). While such vibration patterns are designed to be useful (notifications) or pleasant (games), phone vibrations can also be deliberately designed to be irritative to reduce smartphone use. Drawing from negative reinforcement and nudge theory, Okeke et al. (2018) designed a novel Android app which triggers repeating vibrations whenever the user exceeds the daily usage limit set for an app. The intervention was designed to be subtle and nudge the user into choosing to end the app session. While this was effective and reduced the use of the target app (Facebook), the number of app sessions remained unchanged since the intervention occurred after, not before, opening the app (Okeke et al. 2018). The results suggest that additional, more preventive interventions such as visual prompts before opening problematic apps may be needed to prevent undesirable app sessions (Okeke et al. 2018). This view is supported by Stawarz et al. (2015) (Stawarz, Cox, and Blandford 2015), who proposed novel design guidelines to develop smartphone apps that support the formation of desirable habits.

One example of a preventive design friction intervention for smartphone overuse is the Let's FOCUS app developed by Kim et al. (Kim Inyeop et al. 2017; I. Kim et al. 2017). Designed for college students in a learning context, the app proactively filters and blocks specific apps to help students self-regulate their smartphone use and remain focused on their studies. The success of the virtual intervention

was closely linked to the voluntary participation of the users in the live trial (Kim Inyeop et al. 2017), suggesting that similar interventions are more likely to be effective if they are voluntarily adopted.

Design friction has also been applied to other technologies. Echoing Okeke et al. (2018) work on vibration-based digital nudging, Schneider et al. (2018) highlight the importance of choice architecture in reducing meaningless app use. By defining clear goals and understanding user behavior, designers can implement targeted nudges that promote more intentional interactions with technology. For instance, using default settings to prioritize beneficial features or providing reminders about usage limits can direct users towards more meaningful engagement. Techniques like setting visual reminders, displaying usage statistics, or emphasizing social norms encourage users to reflect on their app habits. By leveraging these design strategies, nudging helps users make more conscious choices, ultimately reducing aimless app use and fostering healthier digital habits.

These examples indicate the potential for design friction as an effective intervention method for smartphone-based activities, particularly overuse. While the least effective measures (audio and vibration-based cues) did not attract much attention the evidence indicated that more direct interruption-based tasks combined with higher-difficulty cognitive tasks have been more effective and hold greater potential (Cox et al. 2016a; Park et al. 2018; J. Kim et al. 2019). It can be seen in the included research in this area, that it has to date lacked a thorough exploration of the types of tasks that users would find both effective and motivating toward their behaviour change. This research direction and gap in knowledge contribute toward the aims of this thesis and will be taken forward in later sections.

3.2.3 Slow Use and Non-use

Design friction is a natural facilitator of slow thinking and, by extension, slow design (Mejtoft, Hale, and Söderström 2019). The slow design philosophy promotes wellbeing by encouraging users to 'do things at the right time and at the right speed which helps them to understand and reflect on their actions' (Grosse-Hering et al. 2013, 3431). Consistent with this philosophy, Hallnäs & Redström

(2001) proposed a series of design guidelines to develop 'slow technology' which encourages its users to reflect on their experiences and thoughts.

A practical example of slow design is The Slow App by Neelesh Misra, the founder of the Slow Movement in India (Misra 2023). On the Apple and Google stores, it is presented as a wellbeing app to help users slow down and celebrate slow experiences to achieve better mental and physical health. Moving beyond the app level, some users choose to replace their smartphones either temporarily or permanently with 'dumb' phones which lack most of the advanced functionalities of modern phones, such as internet access and apps (Ward et al. 2017). These minimalist devices increase the interaction cost (Almoallim and Sas 2022) and help users to slow down, thereby encouraging reflection on the use of technology and deterring its overuse (Hallnäs and Redström 2001).

Another body of HCI work has focused on interventions supporting targeted smartphone non-use, that is, 'the reduction only of usage behaviors that users wish to limit' (Hiniker et al. 2016, 4746). Human decision-making is based on producing the greatest outcome value from the available options, so smartphone non-use can be achieved by increasing the value of non-use or making use an unviable option (J. Kim et al. 2019). In practice, the former approach involves promoting eudemonic motives such as mindfulness and self-improvement; removing smartphone use as an option means preventing mindless hedonic use by limiting or removing the user's access to technology. For example, the MyTime app was developed as 'an intervention to support people in achieving goals related to smartphone non-use' (Hiniker et al. 2016, 4746). MyTime tracks in-app use for specific apps to help users monitor their smartphone use as well as identify problematic app-level use. In turn, this prompts the users to reflect on their current phone use and encourages them to plan and enact changes to limit problematic, app-specific use.

The research indicates a clear interest in reducing phone usage and the principle of reflection and mindfulness as a means by which to undertake self-improvement. Reflection has been promoted not only by time away from a device but also through the presentation of usage patterns back to the user for their consideration. The examples contribute to the aims of this thesis to explore mindful and mindless smartphone interaction, where the principle of reflection,

and time for reflection play a large part in forming an understanding of and practice of mindfulness (Blanke et al. 2020) .

3.2.4 Microboundaries

A microboundary is a type of design friction intervention which provides 'a small obstacle prior to an interaction that prevents us rushing from one context to another' (Cox et al. 2016a, 1390). It is a concept for which various definitions have been proposed. For example, Cecchinato, et al. (2015, p.3997) (Cecchinato, Cox, and Bird 2015, 3997) defined a microboundary as 'a strategy to limit the impact of micro-role transitions caused by cross-domain technology mediated interruptions'. The small obstacle is intended to stop users for a short moment and encourage them to reflect on their actions and intentions. Specifically, a microboundary seeks to shift user behaviour from System 1 (fast, automatic thinking) to System 2 (slow, mindful thinking). The argument for microboundaries is that despite being 'uncomfortable' interactions, they can be worthwhile and ultimately enrich the user experience (Cox et al. 2016).

Microboundaries are increasingly present in HCI research, yet they still have relatively limited application in practice. They have been designed into 'launcher' apps, such as LessPhone Launcher, to reduce the functionality of home screens to discourage smartphone overuse (Lyngs et al. 2022). Other microboundary interventions include tailored notifications and the activation of screen dimming when a phone session exceeds a pre-set time limit (Almoallim and Sas 2022).

Kim et al. (2019) proposed stronger microboundaries with embedded workloads: each task created a 'gulf of execution on gratification seeking' to increase the cost of smartphone gratification and encourage the switch from fast, system 1 thinking to slow, system 2 thinking (J. Kim et al. 2019, 3). This example highlights the challenges in quantifying the 'right' amount of intervention that should be delivered by a microboundary. It seems reasonable to classify short, relatively unobtrusive interventions like smart notifications or dismissible reminders as microboundaries (Cecchinato, Cox, and Bird 2015; Cox et al. 2016). Conversely, a lengthened unlock process with more workload is an additional, compulsory task which outright obstructs smartphone use, so it may be perceived as more than a weak, 'micro' intervention.

The concept of microboundaries effectively captures the key elements of slowness, mindfulness and reflection, and specifics of design friction that were seen as most promising in the earlier sections. The term is adopted as the preferred reference within the thesis for this reason and will be used going forward on the grounds of accuracy and specificity.

This chapter reviews interventions aimed at mitigating smartphone overuse, categorizing them by strategic approach, theoretical basis, and effectiveness. It highlights that phone-level interventions are less effective in contrast to app-level interventions which can be more personalized to block specific apps for set periods, which users prefer for promoting mindful use and wellbeing.

The chapter also explores mindful use; reflective engagement that enhances wellbeing, and mindless use; automatic and habitual, often leading to negative outcomes. Design principles such as timeboxing, design frictions, and microboundaries are introduced.

Despite progress, several research gaps and opportunities for further work are identified. Current interventions often fail to balance effectiveness with user motivation, leading to limited long-term behaviour change. There is a need for interventions that support meaningful and reflective engagement with technology, promoting digital wellbeing by encouraging mindful use rather than merely restricting access.

Existing interventions provide a foundation, more nuanced and user-centred approaches are needed. This thesis therefore aims to guide interventions that are both effective and motivating, supporting users in achieving a healthier balance with their smartphone use using a microboundary approach. This direction will significantly contribute to the field of Human-Computer Interaction (HCI) and the broader goal of enhancing digital wellbeing.

Chapter 4: Methodology

4.1 Overall Approach

The PhD thesis employed a user-centered design approach involving mostly qualitative research methods, with the aim to explore and understand user behaviour related to digital wellbeing. The thesis comprised three main studies: a two-week diary study, co-design workshops, and a user study for evaluating in the wild a digital wellbeing app.

The research was carried out remotely. The questionnaires during the diary study were completed online; the interview sessions and the workshops took place via Microsoft Teams and Miro, an online visual platform for collaborative work.

Beside user studies, the PhD thesis also involved a scoping review of 26 papers on digital wellbeing, and a review of 39 top rated commercial apps for digital wellbeing analysed through two complementary methods. First, their functionalities were reviewed based on their descriptions from Google Play. Second, through an autoethnography study, these apps were used by at least 2 weeks, to directly interact with them in order to viscerally understand how these functionalities work and may be experienced by potential users in their daily lives.

This chapter provides an overview of the methods used, and briefly reflects on the choice of the methods and the effectiveness of their application in the PhD project. More broadly, this includes the overall approach of user-centred design and qualitative research, followed by a description of the specific methods of diary studies, co-design workshops, user studies, functionality review, and autoethnography.

4.2 User-Centered Design

User-Centred design (UCD) is an approach commonly used in the HCI field to hold paramount the user perspective and experience throughout the research process. Where other design approaches focus on fulfilling tasks (activity-centred design) or system integration (system design), UCD focuses on identifying and satisfying the needs, wants, and values of users (Chammas et al., 2015). This is often achieved by involving users in all stages of the design process, which is typically iterative (Wood and Romero, 2010). The UCD approach can help to understand user behaviour and user-technology interactions (Polanco-Diges et al., 2022). It is particularly suitable to satisfy user needs using mature technologies, such as smartphones, rather than emerging technologies (Velloso et al. 2018). This research approach taken within the PhD project involved the users in the research throughout the entire design cycle, from understanding needs to evaluating prototypes in the wild. This approach leveraged various methods, best suited for specific aims, and also complementing each other in specific studies.

The diary study was a longitudinal reflective approach to enable users to share information, given time for consideration and opportunity to answer accordingly (Flaherty, 2024). The workshops were collaborative, leveraging the presence of other participants to elicit more instantaneous and consensus-based data. Finally, interviews were used to allow the researcher to discuss issues and probe the participants on a one-to-one basis.

4.3 Qualitative Research

This thesis uses predominantly qualitative methods, and before describing them in depth, here it is a brief overview of qualitative research, its benefits and limitations. Qualitative research investigates the meaning people associate with a phenomenon, while quantitative research is preferred to test objective theories and examine relationships between variables (Creswell and Creswell, 2017). Qualitative methods are widely used in HCI to investigate topics where the answers are more complex than a true-or-false dichotomy (Blandford et al.,

2016). Qualitative research usually involves small sample sizes (Dencombes, 2010) and use open-ended questions to allow participants to provide insightful responses using their own words rather than predetermined answers.

Qualitative research is typically emergent and cannot be tightly prescribed. As such, it may entail a longer data collection process, data consistency issues, or invalid results (Queirós et al., 2017). The disadvantages of qualitative research can be mitigated by automating and standardising the data collection process via online forms, surveys, or dedicated data-gathering apps. Nevertheless, it is often challenging to identify cause-effect connections between qualitative data points and draw meaningful conclusions, so qualitative research findings should not be viewed as generalisable outside a study's sample (Neale et al., 2014).Simply put, qualitative research seeks more to answer the why and how of a topic than to uncover empirical certainties. In this PhD thesis, they were preferred to unpack users' behaviors of smartphone use, their feelings and motives, to gather their thoughts on conceptual design ideas for different types of frictions, and their feedback on the evaluated apps.

4.4 Research Methods

4.4.1 Diary Study

The diary study is a flexible, participant-driven data collection process in which the study participants keep a log of their experiences and thoughts. A structured diary study may require participants to regularly record information using structured forms or dedicated smartphone apps, while other studies may allow participants to record their thoughts with minimal structure via audio or video diaries (Blandford et al., 2016).

The diary study is an effective method to investigate participant behaviour since the participants record information as it occurs, thereby minimising the influence of the researcher on the process (Carter and Mankoff, 2005). A diary study has also a high ecological value as the collection of data usually occurs in the participants' natural environment (Jarrahi et al., 2021). This means that, compared to more prescriptive methods such as surveys or interviews, a diary

study can offer substantial insight into the participants' unique habits and situational decision-making processes (Bolger et al., 2003; Czerwinski et al., 2004).

In this PhD thesis, the aim of the diary study (Chapter 6) was to explore the patterns, motivations, and goals that underpin habitual and meaningful smartphone use. The researcher sought to identify design implications for creating novel interactions that better support meaningful smartphone usage while discouraging behaviours associated with meaningless use.

4.4.2 Semi-structured Interviews

Interviews are one of the most common data collection methods in qualitative studies due to their adaptability to different research fields, contexts (e.g. remote research), and sample sizes. Interviews can be structured, semi-structured, or unstructured. Semi-structured and unstructured interviews are more common in qualitative studies to facilitate the collection of subjective data which can provide a deeper understanding of the phenomenon under investigation (Gill et al., 2008). However, unstructured interviews can lead to excessively varied or inconsistent responses which are difficult to analyse. By contrast, semi-structured interviews blend closed-ended and open-ended questions, providing enough structure to address core topics as well as some flexibility to further investigate relevant points (W. C. Adams 2015; Ruslin et al. 2022).

In this PhD thesis, participants took part in three semi-structured interviews: the first after the diary study (Chapter 6), the second after the co-design workshops (Chapter 7), and the final one during the evaluation study at the end of weeks 1 and 2 (Chapter 8). The interviews following the diary study aimed to investigate participants' phone usage patterns, particularly the meaning associated with their phone sessions. The interviews after the co-design workshops aimed at the perceived benefits, challenges, and potential of cognitive, emotional, social, motivational, and physical frictions in supporting meaningful smartphone use and reducing meaningless interactions, based on users' goals and experiences. Finally, the semi-structured interviews during the evaluation study aimed on investigating users' perceptions and the effectiveness of voluntary lockout frictions in influencing their specific app usage on smartphones.

4.4.3 Co-design Workshops

A co-design workshop is a collaborative, iterative design approach which encourages the participation of users in the design process to ensure the output meets their needs and wants (Bødker and Kyng 2018). Compared to more researcher-driven design methods, this approach democratises innovation by shifting the decision-making power from the researcher to the participants (Harrington et al., 2019).

In this PhD thesis, the co-design workshops were used (Chapter 7) to explore friction-based design solutions aimed at promoting meaningful smartphone use while reducing meaningless interactions. The aim was to identify effective microboundary-based friction measures that support user well-being by encouraging meaningful smartphone engagement and discouraging behaviours associated with dissatisfaction.

4.4.4 User Studies for Technology Evaluation

A user study is a collaborative, user-centred process which encourages the participation of users in evaluating whether a solution meets their needs. It can be used throughout the design process to regularly collect constructive feedback and guidance for follow-up design (Zhou and Guo, 2018). For example, user studies may involve the assessment of low-tech design mock-ups during early design stages and high-tech applications or prototypes during later stages. Compared to more researcher-driven evaluation methods, user studies allow the researcher to directly observe and assess user behaviour in a controlled or semi-controlled environment.

4.4.5 Apps' Functionality Review

App reviews are a rich source of user opinions (Dąbrowski et al. 2022). These functionality reviews are based on a comprehensive theory of decision-making, ensuring that sufficient foresight is applied to evaluate and anticipate future outcomes. The app functionality reviews involve assessing the app's features, usability, and overall performance to determine how effectively it meets user needs and aligns with its intended purpose.

In this PhD thesis, 39 commercial apps were reviewed to explore their key functionalities and design implications in the context of digital wellbeing. The aim was to identify and articulate the key functionalities of top-rated well-being apps, informed by their theoretical underpinnings, to inspire the design of more effective technologies for promoting user wellbeing.

4.4.6 Autoethnography

Autoethnography is a qualitative research practice whereby the researcher reports from their direct personal experience to describe and critique cultural beliefs, practices and experiences (Adams and Manning, 2015). Autoethnography can be conducted in two ways, one way is to use reflective writing as a way for the researcher to introspect their feelings and interpretations of events 'evocative or emotional autoethnography', or two 'analytical autoethnography' where the researcher is a clear participant in the research and committed to understanding a broader social phenomena (Anderson, 2006).

In this PhD project, the objective was for the researcher to examine the use of, and impact of different digital wellbeing apps, with a view to understanding the features and functionality, performance and stated theoretical basis. This places the method in the category of analytical autoethnography, with the researcher, gathering both observational evidence in terms of the features and functionality present in the apps as well as subjective analysis of the usability, quality and potential effectiveness (quality of technical design as well as potential effectiveness toward its stated aims).

The research is performed from the standpoint of the researcher as a well-informed HCI expert, evaluating all 39 digital wellbeing apps. The authors iteratively generated and revised the coding scheme over several months. The process followed a hybrid approach integrating inductive and deductive codes, informed by prior work on functionalities (Roffarello and De Russis 2019b) such as tracking, data presentation, and interventions.

4.5 Quantitative Methods

Within this predominant qualitative approach, a few quantitative methods were also used such as validated scales measuring emotional states and motives for phone use, as part of the diary study, as well as logs of phone and app use captured with the SPACE app, a digital wellbeing app. These were intended to triangulate the qualitative methods and provide complementary data supporting the understanding of users' behaviors, motives and emotions.

4.6 Limitations and disadvantages

A key limitation of the diary study and semi-structured interviews is in self-reported information. Responses influenced by participants' own perspectives, limitations and biases – for example, recall bias or forgetfulness. Semi-structured interviews are heavily dependent on the proficiency of the interviewer in questioning and being able to remain neutral (Creswell and Poth, 2018). Both can be affected by the Hawthorne effect (Silverman, 2016); participants' tendency to provide socially acceptable answers, particularly when it comes to a sensitive topic, or answers that would 'please' the interviewer. Finally, a diary study is also dependent on the duration and response rate, or effort put into it by the participants, a too-short duration may fail to capture end trends or longitudinal effect, and too detailed or burdensome tasks may result in poor or lack of responses (Creswell and Poth, 2018).

Autoethnography can also be subjective based on the researcher's own viewpoint and therefore lack generalisability; in this case, the researcher's interpretation of the quality and design features of the applications reviewed may not be represented in the wider population. Similarly, the Hathorne effect can still apply, based on the researcher's concern for their own agenda and pressure on objectivity (Ellis et al., 2011).

While co-design workshops offer the opportunity for creativity and expanding the design space, they come at a cost of the time and effort required to organise them, and can be highly influenced by the range of diversity of participants, leading to possibly conflicting ideas and making consensus difficult, or skew based on

particularly dominant personalities or strongly held viewpoints in the group (Sanders and Stappers 2008).

Mitigations toward these limiting factors is outlined in greater detail in the following sections of the thesis concerning each method. To broadly outline, the approach consisted of a combination of methods complementing each other.

The diary study uses self-reporting, prompted by and in combination with log data such as application screentime statistics. The semi-structured interviews also reference the logs, and responses submitted during the diary study. With autoethnography, the coding is reviewed by more than one researcher to challenge and offer alternative interpretations. In terms of design generalisability, co-design workshops are conducted to design an application used within the same user group or at least the same demographic / recruitment pool.

4.7 Conclusion

In this chapter the overall research approach and research methods have been introduced and briefly discussed in the context of how appropriate they were for the PhD project. The intention was to justify the choices, while demonstrating an awareness of their pros and cons. The next chapter presents the functionalities review of digital wellbeing apps for monitoring, tracking, and limiting use, involving also an autoethnographic approach.

Chapter 5: Functionalities review of digital wellbeing apps

5.1 Introduction

Given the limited research on the theoretical and evidence based aspects of digital wellbeing apps (Parry et al. 2020; van Velthoven, Powell, and Powell 2018), we argue that unpacking the functionalities of most used commercial apps is an important initial step towards better designing them. The exploration of functionalities and features of mobile apps is an emerging research area, with initial HCI work focusing on digital interventions and especially development of apps for specific conditions such as depressions (Bowie-DaBreo et al. 2020; Qu et al. 2020), or for supporting for instance mindfulness (Claudia Daudén Roquet and Sas 2018; Claudia DaudénC Roquet and Sas 2020) or physical activity (McCallum, Rooksby, and Gray 2018). In contrast, the functionalities of digital wellbeing apps have been less investigated. A noticeable exception is Roffarello and De Russis' (Roffarello and De Russis 2019b) exploration of 42 digital wellbeing apps and their descriptions on Google Play whose findings indicate as key features (i) tracking user behavior through phone unlocks, phone/app time, app checking, (ii) data presentation through phone/app summary, charts, daily/widget recap, social comparison, (iii) phone interventions through timers, blockers, (iv) app interventions through timers, blockers, notification blockers, and (v) extra features such as motivational quotes or rewards. However, given the brevity of apps' descriptions available on marketplaces, a richer source to identify their key functionalities is the actual use of the apps while authors, as HCI experts adopt the role of the user by directly interacting with the apps; a method previously used for app reviews (Qu et al. 2020; O'Kane, Rogers, and Blandford 2014; Jake-Schoffman et al. 2017).

Specific functionalities of digital wellbeing applications have been also explored through research prototypes usually implementing tracking and notifications (Kim Inyeop et al. 2017; Ko, Yang, et al. 2015), while others included also specific

interventions for limiting use (Hiniker et al. 2016; J. Kim, Cho, and Lee 2017). For instance, Socialize (Roffarello, De, and De Russis 2021; Roffarello and De Russis 2019b) app integrates most common functionalities of tracking, data presentation, real-time notifications, and blocking use which were evaluated in the wild with 38 young people over 3 weeks. Findings indicate improvements in terms of problematic use, measured through phone addiction scale, and self-regulation measured through general self-efficacy scale. While this is one of the few studies involving measures to explore the effectiveness of digital wellbeing app, the Socialize app itself does not appear to be novel, borrowing common functionalities of commercial apps, whose theoretical grounding is limitedly unpacked. Focus app (Potapova, Cetinkaya, and Liebchen 2020) is another research prototype that leverages Nielsen's heuristic to support tracking phone use and the blocking of any app, indeterminately or for a limited time set by user, with the option to unblock them at any time, and provision of educational content on digital addiction. To mitigate overuse from a broader perspective, another research prototype, FeelHabits app (Bravo 2020) tracks and notifies users about their usage of specific apps albeit rather than on smartphone alone, this apps tracks use across devices and blocks them if limits set by the user are exceeded.

Other strand of scholarly work with richer theoretical underpinning has focused on restrictive and coercive interventions intended to be stronger than persuasive interventions by supporting users to commit to self-impose limits of use while the phone is blocked (J. Kim, of Korea HAYOUNG JUNG, and of Korea 2019). The framework for influencing behavior change (Tromp, Hekkert, and Verbeek 2011) suggests 4 types of influence: persuasive (explicit, weak), coercive (explicit, strong), seductive (implicit, weak) and decisive (implicit, strong) based on influencing force (strong, weak) and salience (explicit, implicit). Inspired by this framework, Kim and colleagues designed and evaluated GoalKeeper (J. Kim, of Korea HAYOUNG JUNG, and of Korea 2019), a smartphone app featuring both a *weak lockout*, i.e., the phone is locked increasingly longer: 1, 5, 15, 30 and 60 minutes each time the user exceeds the time they have previously set for use, with each lockout being mitigated by a temporary 15 min allowance time; and a *strong lockout*, i.e., the phone is locked until midnight without any allowance. Their findings indicate that both mechanisms were more effective than mere notifications of use, with the strong lockout being the most effective as users set

longer limits for not using their phones. While in the latter case users experienced also more frustration, this was mitigated by the flexibility of setting their own limits and one-time opportunity to modify it.

Despite this growing academic interest in digital wellbeing, the commercial apps far outweigh the research prototypes in in terms of uptake. Thus, the increased adoption of commercial wellbeing apps offers an opportunity to explore their potentially richer set of functionalities and the aim of this paper is to articulate these functionalities as well as the novel design implications informed by them in order to better inspire the design of technologies for wellbeing. To address this aim, we focused on the following research questions:

1. Which are the key functionalities of the top rated digital wellbeing apps?
2. What theoretical underpinning support these functionalities?
3. What design guidelines for digital wellbeing apps can be informed by these functionalities?

Our contributions are three-fold. First, we unpacked richer insights about tracking and monitoring functionalities in terms of user profiling, and understanding of monitoring as a *complete, location-based, and flexible practice* that can benefit from tailored, time-based visualisations. Second, we identified four interventions for limiting use including richer understanding of different types of obstacles for limiting use, as well as of specific features for less explored functionalities such as supporting awareness for reaching use limits, focused attention and motivation to keep within set use limits. Third, grounded in our findings, we generated six design implications for digital wellbeing apps.

5.2 Method

To identify the digital wellbeing apps, in winter 2019 we searched for free apps in Google Play Store using the following search terms: digital wellbeing, digital detox, detox apps, unplugging, and distraction, which is a new direction given that extensive previous work on such apps has prioritized addiction and screen time (Roffarello and De Russis 2019b). We have focused on Google Play since Android apps represent the largest global market share, over 2.5 greater than iOS apps (StatCounter 2021), while the latter is also more restrictive in terms of

available information (Roffarello and De Russis 2019b). However, future work could extend this exploration to other platforms.

For each search term, the top 250 most relevant apps returned on Google Play were retained, totaling 1250 apps, with 37 duplicates. At the screening stage, after reading their titles, summary descriptions and main screenshots, we excluded 931 less relevant apps such as fitness, activity planner, or non-digital detox apps. The eligibility of the remaining 282 apps was assesses based on their full descriptions, with further 147 apps being excluded such as utility apps, games, and general wellbeing and meditation practice apps. From the remaining 135 apps, we further excluded those with less than 1000 raters, and with average rating score less than 4, leading to 39 apps to be included in our review. PRISMA diagram for searching and screening process for digital wellbeing apps is shown in Figure 1. We also note that 12 of our 39 apps are also available on Apple store, 7 of them with user rating above 4.2.

Our final set consisted of 39 digital wellbeing apps (Table 4 in Appendices) which were analysed through two complementary methods. First, a review of their functionalities based on their descriptions from Google Play. Second, an autoethnography with the authors, as HCI experts directly interacting with them in order to viscerally understand how these functionalities work and are experienced by potentially users in their daily lives. Such interactions were iterated, involving at least 2 sessions for each app, lasting for at least 30 minutes. For the autoethnography, we used Samsung Galaxy Note9 phone with Android mobile operating system.

Autoethnography can be conducted in two ways, in one way a practitioner participates in an activity, experience or reflective practice and can either report on their emotional response, and reflect on it through writing, to understand a broader social phenomenon (Anderson 2006; Ellis et al. 2011). This is often known as ‘evocative or emotional autoethnography’, or as ‘analytical autoethnography.’ Alternatively, autoethnography can be a form of research that aims to capture direct personal experience to describe particular cultural beliefs, practices and experiences (T. E. Adams and Manning 2015).

The first author evaluated all 39 digital wellbeing apps, while 20% (8/39) of the apps were evaluated also by the second author. Through the use of both methods, the authors iteratively revised the coding scheme over several months, a process which has followed a hybrid approach. This integrated deductive codes, informed by prior work on functionalities (Roffarello and De Russis 2019b) such as tracking, data presentation, and interventions (Table 5). The inductive coding was informed the distinction between tracking and monitoring, the revision of interventions functionalities as tracking phone or app use by setting limits, and of data presentation or visualisation and its subcategories such as numerical and diagrammatic format through charts, round diagrams, metaphors, heat maps or reports. Particularly important are the new functionalities capturing four interventions for limiting use.

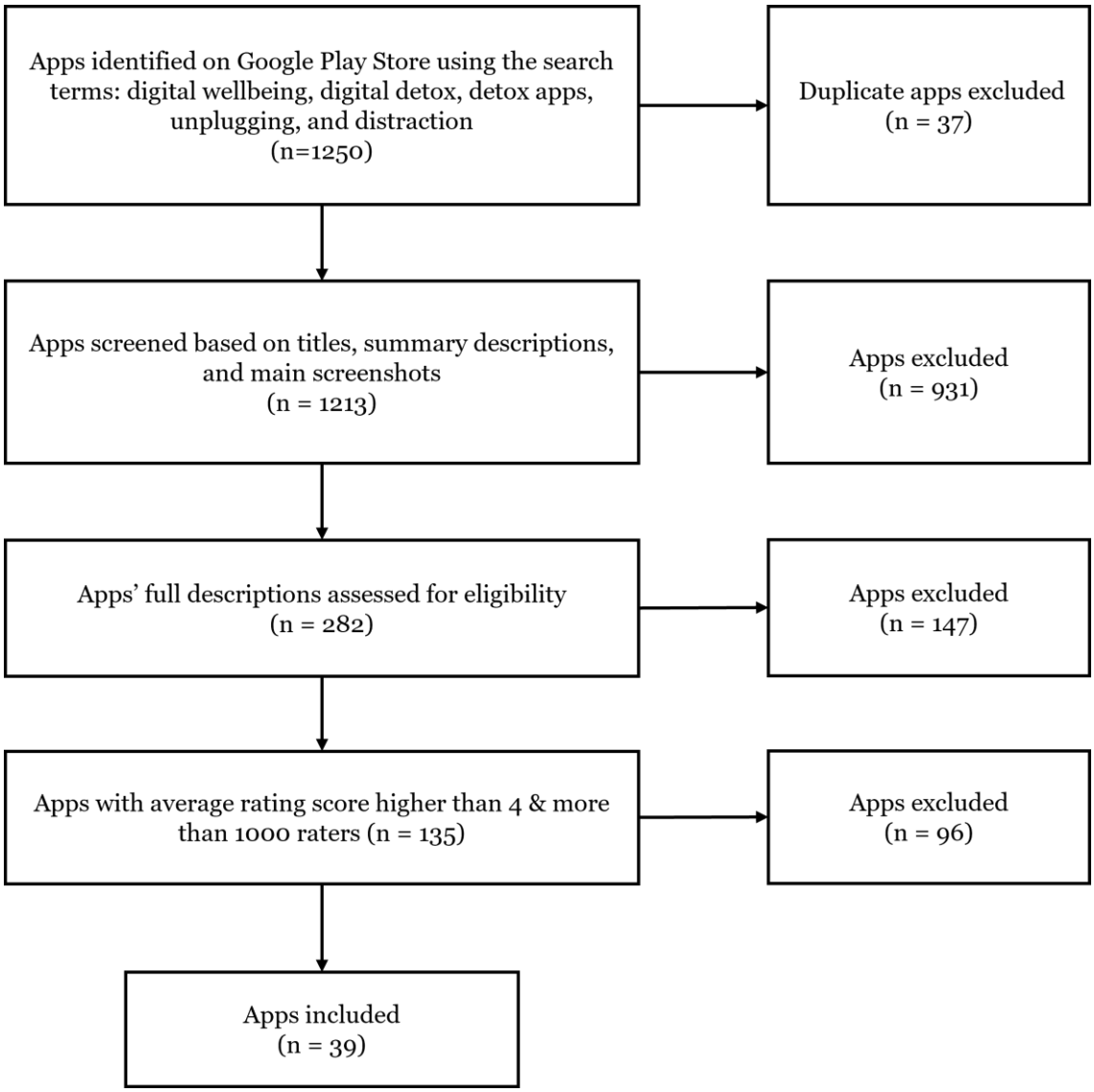


Figure 2: PRISMA diagram for searching and screening of digital wellbeing apps

Functionalities codes and subcodes	Definitions
Tracking	
Recording phone or app use	The tracking functionality supports the recording of phone or app uses
Visualizing tracked use data	The tracking functionality supports the visualisation of tracked data
Profiling users	The tracking functionality supports profiling users based on tracked data
Monitoring	
Setting time limits of phone/apps use, their scope and place	The monitoring functionality provides use time limits or support users to customize them in terms of scope and place
Visualizing monitored data	The monitoring functionality supports the visualisation of monitored data against set time limits of use
Providing flexibility for limiting monitoring	The monitoring functionality supports flexibility for liming monitoring through allowances to extend use beyond the set time limit, excluding apps from being monitored, or discontinue the monitoring
Interventions for limiting use	
Creating obstacles to limit phone/apps use	This intervention supports creating different types of obstacles to limit phone or apps overuse
Supporting awareness of reaching the set use limits of phone/apps use	This intervention supports users' awareness of reaching the set use limits through different types of notifications varying in content and form
Supporting focused attention away from phone/apps	This intervention supports users' focused attention on main task and away from habitual phone/apps use through training or white noise
Supporting motivation to keep within limited use	This intervention supports motivation to keep within limited phone/apps use through rewards/penalties, motivational quotes/education, and social motivation

Table 5: The main codes and subcodes from apps analysis

To better contextualize our review in scholarly work, we subsequently extended the list of apps with 17 digital wellbeing apps designed in academia which we found through search on Google Scholar using the keywords: "digital wellbeing application" or "digital wellbeing app". This search returned 42 papers which after reading their abstracts, led to 17 papers describing such apps (marked with an asterisk in Reference list). The remaining 25 papers do not included digital wellbeing apps and for this reason they were excluded. We have explored the functionalities of the apps described in the 17 papers by applying the above coding system to their description, as not all of them were available to download from apps marketplaces. All the tables provided in appendices include information on both commercial and academic apps.

5.3 Results

This section starts with a brief overview of the descriptive characteristics and ethical aspects of the 39 apps, continues with identified main functionalities of top rated digital wellbeing applications, and how they compare to the applications developed in academia.

5.3.1 Descriptive Characteristics of Digital Wellbeing Apps: Ethics

The descriptive characteristics captured by our analysis include app category, target users, scientific underpinning and evidence base, and cost. Findings indicate that the top rated digital wellbeing apps belong to 6 categories albeit feature predominantly in Productivity category (27 apps), followed by fewer apps in Tools (4), Personalisation (3), Health and fitness (2), Parenting (2), and Lifestyle category (1). Together with their main aim of limiting phone overuse, this is an interesting outcome that can be linked to the ethical principal *of non maleficence* (Sanches, Janson, et al. 2019) in order to protect users from the negative impact of phone overuse. These can also be aligned to the ethical principle of *beneficence*, in particular, the predominant instrumental value of digital wellbeing apps supporting increased productivity rather than their

eudemonic value for supporting meaningful goals (McMahan and Estes 2011). Arguably, the latter would further strengthen their beneficence potential.

Another important outcome, which can potentially hinder their beneficence is the limited science-base of digital wellbeing app, with 38 out of 39 apps not specifying if they are backed up by research, the only exception being the Focus To-Do app described as "science-based app". This indicates the importance of these app unpacking in their descriptions the scientific underpinnings informing their design and any available outcomes from evaluation studies. In turn, this will support users make more informed choice regarding their beneficence.

The target users of digital wellbeing apps appear to be unrestricted, with most of them available to users of all age, which reflects the principle of *justice*. Indeed, all but 4 apps are rated on Google Play as PGEI 3, which stands for Pan European Game Information. The remaining 4 apps: Brain Focus Productivity Timer, Lock Me Out, SleepTown, and Sma-Phospital do not specify any age. Interestingly, the design of the apps does not vary with age, as we see the same functionalities for both children and adults. We also looked if the target users include clinical population. Findings indicate that 38 out of 39 do not specify clinical user groups while 1 app: AppBlock mentions its suitability for ADHD children or adults. This suggests that digital wellbeing apps predominantly target users without specific conditions or health concerns. However, given their value for supporting attention, some of these apps may be beneficial for users with attention deficit. Future work should further explore this.

Also related to justice, the cost of the digital wellbeing apps is an important aspect which can increase or limit diverse users accessing them. Regarding cost, an important outcome is that while all 39 apps are free to download, only 11 are entirely free to use, while 28 apps offer in-app purchase mostly for removing adds, unlocking premium features, or subscribing to premium versions of the apps. This is an important outcome indicating that most functionalities of these apps are freely available, making their use particularly inclusive.

Digital wellbeing apps have an interesting relationship with the ethical principle of autonomy. On the one hand, these apps tend to limit one's use of phone or apps, while on the other hand, consistent findings have shown that autonomy is

already impaired (Levy 2016) when people live with some form of addiction such as phone overuse.

5.3.2 Functionalities of Digital Wellbeing Apps

We now turn our attention to the key functionalities of digital wellbeing apps. The iterative analysis led to specific functionalities which can be broadly grouped into 6 main functionalities: tracking use of phone or apps, monitoring use against set limits, together with four functionalities that highlight interventions for limiting use namely: creating obstacles for the phone or apps use, supporting awareness of reaching the set use limits, supporting focused attention, and support motivation to keep within limits of use. Each of these functionalities is further detailed.

5.3.2.1 Tracking Overall Phone and Apps Use, User Profiling

Findings indicate that 28 digital wellbeing apps automatically track or record overall phone use, use of specific apps or both (Table 6 in Appendices). In particular, (i) the overall use of the time spent on phone was captured by 3 apps through overall screen time across all apps measured per minute, hour, day, or week, or number of time the phone unlocks per hour or day; (ii) the use of specific apps that provide users the choice to select them in order to capture only their screen time was captured by 15 apps, while (iii) 6 apps tracked both the overall use of the phone and the use of specific apps. Other digital wellbeing apps provide users the choice to select the time when the tracking can take place, for instance between 9am and 5pm but not outside of the specified time window. Tracking can also be contextualized, with 3 apps (AppBlock, Instant-Quantified Self, Lock Me Out) allowing its coupling with physical locations specified by users.

With regard to visualisation, the tracked use data tends to be provided in numerical and diagrammatic format through reports (27), charts (21), round diagrams (9), metaphors (4), or heat maps (1) (Table 6 in Appendices). The 4 apps providing metaphoric visualisations are Forest: Stay focused, Focus To-Do: Pomodoro Timer & To Do List, SPACE, and SleepTown, with the latter ‘s visualisation consisting of raising virtual towns when maintaining regular sleep hours. In addition, from the 27 of apps including reports, 20 apps provided daily and weekly reports of screen time and 7 apps provided only daily such reports.

Findings also indicate that 10 of the 39 apps extend tracking functionality to also inform user profiling. Out of these 10 apps, 4 apps use either the tracked data of app usage (App Usage, Screen Time) to generate categories of used app for broader purposes such as productivity and social, or ask users to identify these categories (SaveMyTime, Boosted). In addition, 3 apps provide users the option of creating different profiles for different settings which could be used to support different levels of limited use of phone or apps, both with payment (HelpMeFocus) or without payment (Stay Focused). For instance, by allowing them to specify location or specific WIFI network where set limits are activated (AppBlock). This is important indicating flexibility of the interventions for limited used to the situatedness of users' different contexts such as homes or work. Finally, YourHour app also aims to identify levels of phone addiction based on tracked data, while Digital Detox app offers predefined levels of limited use that users can chose from. These two apps are interesting as they attempt diagnosis of smartphone addiction and prediction of the intervention intensity. While smartphone addiction is not yet a clinical condition featuring in the Diagnostic and Statistical Manual of Mental Disorders (DMS), its problematic behaviors as diagnostic criteria have started to be explored (Y. H. Lin et al. 2016). In addition, several scales have been developed for measuring phone addiction (Kwon et al. 2013; De-Sola et al. 2017) that meet the psychometric properties of validity and reliability. If digital wellbeing apps aim to identify user's level of addiction which will allow for a better tailored intervention, these scales are useful to consider.

Interestingly, the remaining 11 apps which do not provide tracking functionalities include 8 apps supporting focused attention usually on offline activities (Forest, Boosted, Pomodoro smart timer, Brain focus timer, Sleeptown, Engross, Visual timer, Hold), 2 launchers apps minimizing the number of apps being displayed (LessPhone Launcher an Before Launcher), and 1 app for turning off email notifications (Quite for Gmail).

5.3.2.2 Monitoring Phone/App Use against Set Use Limits or Set Time Limits for Focused Attention

Apart from tracking, most digital wellbeing apps also allow setting use limits to track phone or apps usage against them (25/39). The distinction between

tracking and monitoring is that monitoring is based on user intentions to self-limit their use, while tracking merely captures the time spent on apps/phone without any such limits. Thus, tracking becomes a prerequisite activity, performed first in order to explore one's use patterns, and based on this information, use limits can be set. Indeed, all apps supporting monitoring also support tracking, but 13 of the apps, while supporting tracking, they however do not support monitoring. This is an important outcome as arguably, monitoring is better positioned to support behavior change towards limiting use than mere tracking; yet about 35% of the top rated app do not support monitoring.

While most apps (25/39) support setting limits for using the phone or its apps, the remaining 14 apps include 8 apps that allow people to focus attention by setting time for offline activities, and therefore away from phone and apps, 3 apps providing only tracking Smarter Time, Sma-Phospital, Usage analyzer), 2 launchers apps minimizing the number of apps being displayed, and 1 apps for turning off email notifications (Quite for Gmail).The prevalence of apps for focus attention on offline activities is an interesting and less explored monitoring aspect of digital wellbeing apps.

Monitoring functionality allows users setting the scope and place of limited use, visualisation of monitored content, and interestingly, options for limiting monitoring. With respect to the scope of the limited use, more than half of our reviewed apps offer options to reduce the use of some of installed apps (13 apps). This means that while using these digital wellbeing apps, some apps' use remains unmonitored. In contrast, the remaining digital wellbeing apps extend this option to monitor use to all apps on user's phone (6), or to the phone itself (7). Setting use limits can also be activated at specific location, either specified through the phone GPS or WIFI network, although only a few apps offer these options: 3 and 1 app, respectively.

Findings also indicate that 22 digital wellbeing apps support a more forgiving or *flexible monitoring* by allowing users to limit their monitoring in three ways. This include allowances to extend use beyond the set time limit (9 apps), and option to exclude specific apps from being monitored (19 apps). Allowances are breaks during the set nonuse time limit so that users can continue to use the phone or the apps despite being during their set nonuse time limit, with or without

(financial) penalties, while the number of breaks and/or their duration is either capped or uncapped. This can also include terminating the non use time limit earlier than it is actually due (4 apps). 19 digital wellbeing apps also offer the option of excluding specific apps from being monitored against time limits, especially apps such as App Usage Manage/Track Usage, AntiSocial, and My Phone Time. In addition, 14 apps allow users to discontinue monitoring when they reached the set use limit.

With regard to visualisations, monitoring function engulfs tracking one, so that it supports the visualisation of tracked data. However, visualisations specific to monitoring functionality are offered by less than half of the digital wellbeing apps. (19/39). This is an important outcome suggesting the value of considerably extending such visualisations within monitoring functionality. These 19 apps provide monitoring specific visualisations of (i) time unspent out of the use time limit, i.e., count down (12 apps), (ii) time spent out of the use time limit (6 apps), or (ii) even time overspent as percentage of time limit (1 app). These are provided in either text form (12 apps) and/or diagrammatic one as circles or progress bars (un)filled gradually with colors until the set time limit is reached, 4 and 3 apps, respectively. Interestingly, the monitoring of focused attention, usually during offline activities, can also be visualized, usually through time unspent out of the focus time (or time for not using the phone/apps), through countdown timers (3 apps), or circle progressively unfilled with color (1 app).

5.3.2.3 Interventions for Limiting Use of Phone and Apps

Findings indicate four interventions for limiting the overall use of the phone or its installed apps which include creating obstacles to limit use, supporting awareness of reaching the set limits, supporting focused attention, and supporting motivation for limiting use, which are further detailed.

5.3.2.4 Creating obstacles to limit phone and apps use

The first intervention consists of creating obstacles for excessive phone or app use (21 apps). Obstacles can be classified according to their force (strong or weak), saliency (explicit or implicit), temporal aspects such as being activated before, during or after excessive use, and social aspects such as parental control or social commitment (Table 8 in Appendices). Obstacles also differ with respect

to their source (being generated by the digital wellbeing app or by users) and could be tailored to user profiles.

The identified strong obstacles features predominantly in commercial apps (18 apps). These obstacles cannot be circumvented include lockout of phone/apps beyond the set time limit of use (14 apps), interrupting use while the set use time has been reached (12 apps), and unchangeable time limits of phone/app use (6 apps). In contrast, weak obstacles have features in much fewer apps (5 apps), with only one app providing both strong and weak obstacles, i.e., StayFree. Weak obstacles do not directly restrict use but make it more difficult through notifications from phone or apps after overuse (4 apps), notifications inside the digital wellbeing app when reaching time limit (4 apps), micro boundary interactions that make it more difficult for users to access their apps targeted by limited use (2 apps). Microboundary interactions are particularly interesting as although theoretically explored in academic research, they have been limited implemented through design. Such interactions feature in 2 apps (LessPhone Launcher, and Before Launcher) and consist of "launchers" as substitute home screens for user's phone which display only a reduced number of apps, so that accessing other apps requires additional clicks for navigating from the launcher to them.

According to their saliency, most obstacles are explicit such as lockout (8 apps), set time limits for phone/apps use (14 apps), and textual or visual notifications (4 apps), while others are implicit such as launchers (2 apps) or activation of dimming mode of phone's screen when set time limit was reached (1 app). This much lower number of implicit obstacles is interesting, suggesting a less explored design space and their potential value of complementing explicit obstacles.

With respect to temporal aspect, most obstacles are created before the use of phone/app and activated during the set limited time for using the phone or apps. The exception is flexible time limits which can be changed not only during but also after the set time limit for use has ended.

The obstacles also have a social dimension, albeit only 5 apps implemented them, in two forms: parental control (4 apps) or social commitment (1 app). Regarding

the latter, Forest app leverages feeling of failure to social commitment is a type of obstacle in order to prevent users from accessing apps while with friends.

With regard to source, the obstacles can be created by the digital wellbeing app or by the user. The former leads to automatically generated obstacles usually through user profiling (11 apps), while the latter leads to customized obstacles (13 apps). Apps allowing users to set use limits usually restrict this option to specific apps rather than all apps. Examples of automatic setting of use limits feature in YourHour app which provides short users 'quizzes to identify if the app is used for work or entertainment. Another example is SPACE app supporting limited phone use through automatically suggested limits. Interestingly, 2 apps allow users to create multiple profiles, each profile with particular setting to be assigned to different tasks (HelpMeFocus, Stay Focused). This is an interesting option, allowing users different modes of engaging with specific apps, which could for instance help with the context setting such as work or leisure, and different phone usage for each.

Not at least, different types of obstacles may be tailored to different user profiles for matching for instance level of addition (1 app) or users' preference for a specific level of digital detox: easy, medium, and hard detox (Digital Detox) that are proposed to users to choose from (Digital Detox app). Interestingly, no apps attempt to recommend interventions at different level (weak or strong) based on tracked data. This is a less explored feature with potential to provide adaptive interventions better tailored to users' needs.

5.3.2.4.1 Supporting awareness of reaching the set use limits of phone/apps use

The second intervention is supporting awareness of reaching the set limits of use and is provided by 13 apps (Table 9 in Appendices). Such awareness is predominantly supported through explicit notifications of reaching the set time limits (12 apps) usually in textual or diagrammatic form, with both push notifications which appear when the screen is both locked or unlocked usually at the top in the status bar) (4 apps) or pull notifications which appear suddenly in the middle of the screen as a small window alerting the user of something, sometimes these are big, covering most of the screen) (7 apps). Notifications can be provided in both the digital wellbeing apps about the use of the phone or its installed apps (13 apps), and as embedded within a specific app when the time

limit relates to that app (11 apps). In contrast to explicit notifications, implicit ways to support awareness of reaching time limit include screen dimming. While less common (1 app), these are interesting, more subtle ways to notify users of reaching their use limits for specific apps or phone, and to persuade disengagement. While both notifications and screen dimming are provided in real time, daily reminders to review tracked data support higher level of awareness beyond a specific instance of "in the moment" use and more about the historic user over the day (7 apps).

5.3.2.4.2 Supporting focused attention on primary tasks and away from habitual phone/app use

The third intervention supports focused attention, and features in over 70% of digital wellbeing apps (29/39) (Table 10 in Appendices). These include all apps that support monitoring (25) and 4 additional ones: Boosted, Pomodoro Smart Timers, Engross, and Hold. By aiming to limit phone and apps overuse, digital wellbeing apps implementing monitoring functionality implicitly support focused attention on the main task since they prevent user's attention being hijacked by habitual phone/apps use.

Findings also indicate that 8 apps (4 which support monitoring and 4 which do not: Boosted, Pomodoro Smart Timers, Engross) explicitly target the training of focused attention. These apps encourage users to stay away from phone in order to focus on specific offline tasks for a set time. This is a different use of time limit, that the one in monitoring functionality, as people are supported to practice the adaptive behavior of maintaining attention for a set time away from phone, rather than resisting for a set time the temptation to use the phone.

In addition, 5 out of these 8 apps for training focused attention also provide users with white noise to better facilitate concentration. This is an interesting outcome, and although these apps provide limited evidence for its value, scholarly work indicates that white noise defined as "task-irrelevant auditory input containing many frequencies of equal intensities" [3,p.1] has potential to improve cognitive performance in both healthy adults (Herweg and Bunzeck 2015) and those with attention deficit (Söderlund, Sikström, and Smart 2007). Mechanisms that could explain the benefits of white noise include its ability to moderate brain arousal by

inducing neural noise which at specific dopamine-based thresholds could stimulate cognitive performance (Baum and Chaddha 2021).

5.3.2.4.3 Supporting motivation to keep within limited use of phone or apps

The fourth intervention supports motivation for limiting phone and apps use (12 apps). Findings indicate three mechanisms for supporting motivation. First is the reward/penalty feedback usually implemented by those apps that support monitoring (7 apps), with rewards being provided when users successfully kept within their set use limits of their phones and apps. Main types of rewards leverage gamification principles and consist of badges at different levels (2 apps), points (2 apps), virtual coins (1 app), building virtual trees (Forest) or town (SleepTown), or motivational quotes (4 apps). Main categories of penalty content are metaphoric and consist of virtual tree withers (Forest) or town building collapses (SleepTown). Interestingly however, most of monitoring apps (20/29) do not support such motivation through rewards and penalties.

Second, beside the reward/penalty feedback provided on the basis of successful or unsuccessful keeping within set limits of phone or apps use, other type of motivation is provided to support behavior regulation of limiting use, both during or even before the actual behavior of limiting use. This less common type of motivation consists of motivational quotes, either provided by the app (2 apps: Stay Focused, HelpMeFocus) number and names) or generated by the user (2 apps): StayFree, App Usage - Manage/Track Usage), or educational content about phone/life balance (1 app): SPACE, or motivational stories written by other users (1 app): YourHour.

Third, social support is another form of motivation, whose role in facilitating behavior change has been much acknowledged (Kelly, Zyzanski, and Alemagno 1991). An important outcome is the limited number of apps that encourage social support to limit use phone or apps use, either through competition (5 apps), collaboration (5 apps) or both (3 apps). This is distinct from the identified emphasis on competition (Matthews et al. 2016). For instance, the SPACE app allows comparing such progress of limited use. In contrast to this competition social motivator, our findings also show 5 apps leveraging collaboration, where family members, friends, or broader social networks are used. For instance, SleepTown app allows sharing sleep time goals with friends and setting similar

sleep goals with them. Another example is the Hold app that provides different ways to share focus time through finding nearby Bluetooth enabled-devices to encourage focused attention in group. The app Hold also integrates collaborative and competitive aspects, for instance by ranking users according to the points they gained from their time spent on focusing tasks, most often offline ones. Apps leveraging competition can also integrate social recognition. For example, Hold app rewards the top ranked user according to their points with a crown icon next to their username, and Focus app rewards the first 3 users with a trophy icon next to their usernames: gold, silver and bronze.

5.3.2.5 Comparison of commercial digital wellbeing apps with academic ones

This section focuses on the comparison of the functionalities of the apps developed in academia with those of commercial apps, with a specific focus on how they differ. It is not surprising that most of the academic apps share the tracking and monitoring functionalities available in commercial apps. For example, the lockout mechanism that blocks the phone until midnight when reaching use limit (J. Kim, of Korea HAYOUNG JUNG, and of Korea 2019) is similar to blocking apps/phone when the user exceed the defined time limit in some commercial apps (e.g. UBhind). Similarly, blocking and scheduling blocking in academic app Forest (Potapova, Cetinkaya, and Liebchen 2020) is comparable to commercial app AppBlock. One interesting distinction concerning tracking and monitoring is the new form of visualisation of tracked data in academic apps namely timelines.

In terms of interventions for limiting use, findings indicate additional key distinctions between commercial and academic apps for digital wellbeing. With regard to creating obstacles to limit phone or apps use, important distinctions concern the force and saliency of the created obstacles, their temporal aspect and source. With respect to force, commercial apps employ predominantly strong obstacles such as phone or app block (14/39 apps, 35%) instead of weak obstacles such as notifications or micro boundary interactions (5/39 apps, 13%), with only one app providing both strong and weak obstacles. In contrast, academic apps take a more balance approach, employing equally both strong (10/17, 59%) and weak (11/17, 65%) obstacles, with 5 apps employing both strong and weak. Given

the nascent research exploring the effectiveness of digital wellbeing apps, academic work is more likely to employ both types of obstacles in order to compare their effectiveness.

With respect to the saliency of obstacles, almost half of commercial apps (17/39, 44%) specify saliency, with all but one featuring explicit obstacles (which also tend to be strong), while SPACE app features implicit obstacles. In contrast, almost all academic apps (16/17, 94%) involve explicit obstacles, i.e., mostly notifications. Interesting here is the innovative use in academic apps of new type of obstacles for restricting use through design frictions. These could involve mandatory cognitive tasks such as entering a number of digits as users attempt to start interacting with apps targeted for limited use (J. Park et al. 2018), or entering 30 or 10-digitstry (J. Kim et al. 2019), which, when compared to merely pressing OK, indicate that the more complex the cognitive task, the more likely that users will restrain from engaging with those apps. Commercial apps present limited such cognitive task, one exception being MMGuardian app which requires entering a password by parents in order to prevent the child from removing the app or modifying the set time limit of use.

Findings also indicate differences regarding the temporal aspects of obstacles to use. While commercial apps employ these obstacles predominantly after use of the targeted apps (15/39 apps, 38%) as opposed to during use (4/39 apps, 10%), academic apps take a more balanced approach employing such obstacles equally during (8/17, 47%) and after the use of targeted apps (8/17, 47%), with 2 apps employing them both during and after use. This suggests the value of providing flexibility and users' choice, but also the importance of real time obstacles in limiting phone or apps overuse in real time.

With regard to obstacles' source, commercial apps use mostly obstacles set and customized by users (15/39, 38%) rather than obstacles set automatically (6/39, 15%), while in contrast, academic apps feature more automatically set obstacles (10/17, 59%) than those set by users (6/17, 35%).

Scholarly work on digital wellbeing apps has also focused on the types of apps that users are more willing to limit use. In this respect, empirical findings indicate that users were willing to restrict the use of specific apps such as messaging ones

(Löchtefeld, Böhmer, and Ganev 2013) , as well as social media or games apps (Hiniker et al. 2016). Academic work has also explored limited use beyond individual devices such as phones, but also across multi-devices and their context of use (Bravo 2020; J. Kim, Cho, and Lee 2017). Similar work has looked for instance at chatbots in order to notify users of their smartphone usage (Abreu 2021), or video platforms supporting pre-schoolers to self-manage their phone and app consumption (Hiniker et al. 2018).

The second intervention intended to increase users' awareness of reaching their limits of phone or apps use, also shows differences. While both sets of apps employ mostly explicit notifications to support such awareness, academic apps do so more (8/17, 47%) than commercial apps (11/39, 28%). Interestingly, both sets of apps also used implicit notifications such as screen dimming featuring in SPACE app, and vibrations for notifying users when they exceeded their set time limit for phone use featuring in Good Vibrations app (Okeke et al. 2018).

Intervention targeting focused attention has been supported by both sets of apps through training for focused attention, with 8/39, 21% of commercial apps and 5/17, 29% of academic apps providing such training. Interestingly, commercial apps also feature white noise, as a specific mechanisms for supporting focused attention, whose effectiveness as part of digital wellbeing apps has been less explored, although a body of scholarly work has shown its value for relaxation (Herweg and Bunzeck 2015; Söderlund, Sikström, and Smart 2007).

Finally, the fourth intervention for supporting motivation to keep within set limits, shows similar findings for the two sets of apps, with emphasis on rewarding user behavior when the goal of keeping within limits has been reached (9/39, 23% of commercial apps, and 3/17, 18% of academic apps), albeit commercial apps show more diverse forms of rewarding content, usually leveraging gamification principles, as opposed to academic apps which use merely points. In contrast, findings show much fewer apps leveraging punitive feedback when users fail to keep within set use limits, for both commercial apps (4/39, 10%) and academics apps (1/17, 6%). In terms of social support, a small number of apps provide it in order to support cooperation (5/39, 13% commercial apps, 2/17. 12% academic apps), competition and recognition ((5/39, 13% commercial apps, 3/17. 18% academic apps).

Also unique to research on academic apps for digital wellbeing is the extended focus of their audience to include not only individual users as commercial apps, but also groups of users. For example, such academic apps focused on enhancing self-regulation through groups of users collaborating or competing towards limiting their collective use of phone and apps (Ko, Yang, et al. 2015; Ko et al. 2016), limiting use as a family activity (Ko, Yang, et al. 2015), or through providing virtual app spaces for college students to restrict their phone use during class time (Kim Inyeop et al. 2017).

5.4 Discussion

The review of top rated digital wellbeing apps indicate 6 main functionalities: tracking use, monitoring use against set limits, together with four interventions for limiting use such as creating use obstacles, supporting awareness of reaching the set use limit, supporting focus of attention, and provision of social support. In this section, we theoretically position these functionalities, and leverage them to articulate new implications for better designing digital wellbeing applications.

5.4.1 Theoretically positioning of identified functionalities

The theoretical underpinning of digital wellbeing apps has received limited attention. In this respect, most work has looked at their adoption (Parry et al. 2020) leveraging for instance technology acceptance theories (Davis 1986; Venkatesh et al. 2003), including the more recent technology acceptance lifecycle model (Nadal, Sas, and Doherty 2020) although these models are rather generic, so leveraged for many personal or domestic technologies. Scholars such Lukoff and colleagues (K. Lukoff et al. 2018), Lyngs and colleagues (Colombo et al. 2020) or Colombo and colleagues (Colombo et al. 2020) have also identified other theories more relevant to digital wellbeing applications such as the uses and **gratification theory** (J. Kim, of Korea HAYOUNG JUNG, and of Korea 2019), **theory of planned behavior** (Ajzen 2011), **dual system theory** (Wason and Evans 1975), **nudge theory** (Okeke et al. 2018) or theories for regulation (Gross 2013). However, it is less explored how such theories have been actually

informing the developing of commercial wellbeing apps. The mentioned theories will be briefly introduced below, before further discussion.

Gratification Theory posits that individuals actively seek out media to satisfy specific needs and desires, such as entertainment, information, personal identity, and social integration (Katz et al., 1973; Kim et al. 2019). This theory emphasises the role of the audience in selecting media that fulfils their psychological and social needs, suggesting a user-centric approach to media consumption.

The Theory of Planned Behavior (TPB) asserts that an individual's intention to engage in a behavior is the primary predictor of that behavior (Ajzen 2011)(Ajzen, 2011). Intentions are influenced by attitudes toward the behavior, subjective norms, and perceived behavioral control. TPB has been widely applied in various fields, including health psychology, to understand and predict behaviors such as smoking cessation, exercise, and dietary habits.

Dual System Theory suggests that human cognition operates through two distinct systems: System 1, which cosidered to be fast and automatic, and System 2, which considered to be slow and analytical (Kahneman 2011; Wason and Evans 1975). This theory helps explain why people often rely on heuristics and biases in decision-making, as System 1 processes are more efficient but prone to errors compared to the more rational System 2.

Nudge Theory (Thaler and Sunstein 2009; Okeke et al. 2018) proposes that subtle changes in the environment can significantly influence behavior without restricting freedom of choice. Policymakers can improve public health and welfare outcomes by designing choice architectures that guide people towards better decisions, such as placing healthier foods at eye level.

Self-Regulation Theory explores how individuals control their thoughts, emotions, and behaviors to achieve personal goals (Baumeister and Heatherton, 1996; Baumeister and Vohs, 2007). It involves goal setting, self-monitoring, and self-evaluation, which are crucial for maintaining motivation and achieving long-term objectives. Effective self-regulation is linked to better academic performance, healthier lifestyles, and improved emotional well-being.

Prior work has shown that tracking is a key functionality of digital wellbeing applications that captures the use of the phone and its apps (Roffarello and De

Russis 2019b). This however does not make the important distinction between the digital wellbeing application running in the background to collect such information, and the user's active effort to **minimize** phone use. The former is usually important in the early stage of digital detox when people want to understand their consumption patterns, while the latter follows with setting up limits to phone or apps use. For this, we called the former tracking, and latter monitoring which is a better term for capturing or tracking data against a specific target. Most behavior changing application use monitoring towards specific goals such as exercising ones (McCallum, Rooksby, and Gray 2018) so the link between monitoring and goal setting is crucial. We note the important alignment of monitoring functionality to the three ingredients of self-regulation as reflected in **self regulation theories**: setting target standards, monitoring current state against these targets, and activating processes to reduce any identified distance between the current state and the targets (Baumeister and Heatherton 1996). Thus, we argue the designing for monitoring functionality can benefit from theoretical grounding in self-regulation theories.

With respect to monitoring, our findings also highlight value of **overruling the set use limits**. This is important for both instrumental reasons allowing the completion of some immediate tasks, but also for maintaining motivation in case of setbacks in meeting the set limits. In turn, this could more flexibly support the acknowledged high demands of self-regulation (Gross 2013) Future work is needed to explore effective ways for managing the negative emotions associated by setbacks.

In terms of data visualisation, findings indicate a richer range of formats available for the monitoring of phone/app use against set limits compared to their mere tracking. This makes sense since tracking aims primarily to support users' exploration and understanding, while monitoring aims mostly to support behavior change towards set goals (Klasnja, Consolvo, and Pratt 2011; Hyunsoo Lee et al. 2021). Hence, while more ambiguous representations are useful to motivate and engage users during tracking, for the monitoring functionality, more specific formats and particularly those including timelines are more useful. The latter allow people to easier match on the timeline their behavior with the recorded data to not only understand the data but use it for reaching the goals.

These outcomes align with previous work where we have seen the value of ambiguity of different type of captured data (Sanches, Höök, et al. 2019) to support users' engagement in understanding it, particularly relevant in tracking stage.

We now reflect on the key findings regarding the interventions for limited use. Our findings highlight the functionality of creating barriers for phone or apps overuse, which has received limited attention in previous research on digital wellbeing applications.

Roffarello and De Russis (2019) suggested the value of grounding the design of wellbeing apps to support behavior change, habit formation and self regulation, especially through social support.

The authors iteratively revised the coding scheme over several months, a process which has followed a hybrid approach. This integrated deductive codes informed by prior work on functionalities (Roffarello and De Russis 2019b) such as tracking, data presentation, and interventions. The inductive coding informed the distinction between tracking and monitoring, the revision of interventions functionalities as tracking phone or app use by setting limits, and of data presentation or visualisation and its subcategories such as numerical and diagrammatic format through charts, round diagrams, metaphors, heat maps or reports. Particularly important are the new functionalities capturing four interventions for limiting use.

Findings indicate that these differ in terms of source, force, saliency, temporality, sociality and user profile.

Weak obstacles and particularly implicit ones are illustrations of nudges which nudge theory describes as persuasive attempts for behavior change which do not limit users' choices (Thaler and Sunstein 2009; Kankane, DiRusso, and Buckley 2018)

5.4.2 Implications for designing digital wellbeing applications

We also articulate four implications for designing digital wellbeing apps including the call to move beyond screen time and support the broader focus of digital

wellbeing, supporting meaningful use rather than limiting meaningless use, leveraging (digital) navigation in design for friction and supporting collaborative interaction phone overuse.

5.4.2.1 Beyond Screen Time: Broader Focus of Digital Wellbeing

While most of these functionalities focus on limiting screen time, echoing previous findings on addiction and phone overuse (Roffarello and De Russis 2019b), an important outcome is that about a third of our apps support focus of attention either by limiting distractions or by training attention. We argue that this bias towards screen time fails to reflect the larger body of HCI research on wellbeing that can inspire novel apps that may better support users' skills for more mindful use of technologies. We call for stronger engagement of HCI research in the design of digital wellbeing apps that addresses this limitation. Indeed, our findings could mark a shift away from addressing a problematic behavior by explicitly limiting it, but rather by supporting a high level function which can arguably better address the root of the problematic behavior. There is an extensive body of work on mitigating the impact of interruptions (Czerwinski, Horvitz, and Wilhite 2004; Dabbish, Mark, and González 2011) and a growing interest in mindfulness technologies (Claudia Daudén Roquet and Sas 2018; Claudia DaudénC Roquet and Sas 2020; Daudén Roquet and Sas 2020; Häuslschmid, Hussmann, and Terzimehić 2019) that can support the design of these apps for digital wellbeing aiming to support focus of attention.

5.4.2.2 Supporting Meaningful Use vs Limiting Meaningless Use

Findings also indicate an important limitation of digital wellbeing apps reviewed in this work and in particular their rather narrow view of limiting use. We argue that this overlooks the broader goals for using technology in the first place, and users' different avoidance or approach motivations. For this, we can leverage goal theories and the distinction between hedonic and eudemonic or meaningful goals (McMahan and Estes 2011) and how the latter can be purposefully designed for. Emphasizing meaningful use of technology (Mekler and Hornbæk 2019) may be a better approach to avoid meaningless or habitual use leading to phone overuse, while accounting also for the scarcity of attention (Shirky 2020).

5.4.2.3 Leveraging (Digital) Navigation in Design for Friction

Findings highlight obstacles for preventing app use which can inform the design for friction (Mejtoft, Hale, and Söderström 2019) as mechanism for slowing down interaction (such as information session at the start of using a mediation app), which we know little about. Our findings suggest harnessing digital distance and navigation to the target application. This is supported by findings showing that virtual navigation in folder hierarchy and in real world share the same neural correlates (Benn et al. 2015). One can imagine that information architecture imposing additional digital navigation cost for reaching apps located deeper in the phone's information hierarchy whose use is to be limited, may mitigate against their overuse. We can also think of leveraging physical navigation for instance by allowing access to some apps only in physical locations which the user has to purposefully travel to, supporting thus fitness goals.

Kim and colleagues (J. Kim, of Korea HAYOUNG JUNG, and of Korea 2019) positioned their app and this family of restrictive and coercive interventions within the HCI work on uncomfortable interactions aimed to help people towards important goals while tolerating discomfort (Benford et al. 2012) and on design frictions through microboundaries consisting of small barriers enforced before an interaction in order to prevent habitual phone use (J. Park et al. 2018; Cox et al. 2016).

5.4.2.4 Supporting collaborative interaction for limiting phone overuse

Much work has shown the value of social support for behavior change and our findings confirm that this is also an important intervention for digital wellbeing apps. Our outcomes echo previous ones showing the benefit of social support for limiting smartphone use, albeit by leveraging competition. We argue that the value of cooperation can be better harnessed in the design of digital wellbeing apps, both for limiting overuse, and for training focus of attention. Our findings indicate that only 9 apps in our app review implements social support as a built in feature. This supports the argument presented in [12] that social support is a feature needed in digital wellbeing apps as current apps seem do not seem to leverage social support as a mechanism to enhance self-regulation.

5.4.3 Limitations and Future Work

We have focused on Google Play which limited our review of iOS apps not available on Google Play. Future work could extend this exploration to the other platforms. Future work can also aim to further strengthen the scientific underpinning of design principles of digital wellbeing apps both in terms of their theoretical framing and evidence based evaluation studies. Our findings indicate that despite the growing number of digital wellbeing apps, parts of their design space have been less explored, such as supporting awareness for reaching use limits, and motivation to keep within set use limits, implicit obstacles rather than explicit ones, recommended interventions to determine the right type of obstacles according the tracked data, and mechanisms for supporting focused attention. We encourage researchers and developers to focus on these aspects and together with the key features identified above, they can significantly improve the design of digital wellbeing apps.

5.5 Conclusion

We report on a functionality review of 39 commercial and 17 academic digital wellbeing apps. Findings provide richer understanding of tracking and particularly monitoring functionalities, together with four interventions for limiting use. These provide new understanding of different types of obstacles for limiting use, as well as of specific features for less explored functionalities such as supporting awareness for reaching use limits, focused attention and motivation to keep within set use limits. We conclude with six design implications for digital wellbeing apps including the call to move beyond screen time and support the broader focus of digital wellbeing, supporting meaningful use rather than limiting meaningless use, leveraging (digital) navigation in design for friction, supporting collaborative interaction to limit phone overuse, supporting explicit, time-based visualisations for monitoring functionality, and ethical design of digital wellbeing apps.

Chapter 6: Diary Study

6.1 Rationale and Aim

This study investigates users' perceptions of meaningful versus meaningless smartphone use. It aims to understand how meaningful usage might be supported while habitual, potentially harmful usage is discouraged by analyzing users' feelings, motives, and goals linked to smartphone use. This study closes a critical gap in the existing literature, which focuses mostly on the hedonic and eudaimonic elements of smartphone use while ignoring the importance of meaningfulness. The chapter presents findings from a wider study, focused on a two-week diary study in which participants' smartphone usage patterns, motivations, and perceived value are clarified.

Smartphones allow users to maintain social connections and complete various pragmatic tasks such as working and personal banking. However, most smartphones and apps are designed to be visually appealing and addictive, thereby encouraging frequent, habitual use. Habitual use refers to automatic smartphone behavior triggered by internal cravings or external stimuli, such as notifications or screen alerts (Wickord and Quaiser-Pohl 2022). Meaningless use results from these habitual, automatic actions that lack significance or purpose, such as passively browsing social media or engaging in entertainment solely to pass the time (K. Lukoff et al. 2018). In contrast, meaningful use can be defined as intentional or aware smartphone use (Stepanovic, Boer, and Jenkins 2022; Sela, Rozenboim, and Ben-Gal 2022), where the user engages actively with a clear goal or purpose in mind, resulting in the completion of a productive task (Roffarello and De Russis 2019a). Friction refers to any obstacle that hinders the creation of an optimal user experience (K. H. Lukoff 2022). It can discourage meaningless use by introducing barriers, while promoting meaningful use. Phone users, particularly avid users such as Gen Zs and Millennials (Curtis et al. 2019), may therefore struggle to control their usage and develop a smartphone ‘addiction’ (Ding et al. 2016). Smartphone addiction can have negative impacts on psychological and physiological health (Derakhshanrad et al. 2020; Wacks

and Weinstein 2021) and on the quality of in-person interactions (H.-J. Kim et al. 2017). Users who frequently access social networks, games, and other forms of entertainment are more likely to develop a smartphone addiction (S. H. Jeong et al. 2016). Smartphone addiction is a behavioral addiction characterized by compulsive and excessive smartphone use, resulting in an inability to regulate usage and leading to negative consequences in daily life (Wickord and Quaiser-Pohl 2022).

Several studies have investigated smartphone overuse through the dualistic lens of hedonic versus eudemonic use (Halfmann and Rieger 2019; Kong and Tan 2023; Li et al. 2021), where hedonic use is defined as non-instrumental and pleasure-driven while eudemonic use is instrumental and goal-driven (Mekler and Hornbæk 2016). However, there is still relatively little research into smartphone overuse through the lens of meaningfulness, which is a key component of the concept of eudemonic well-being (K. Lukoff et al. 2018; Mekler and Hornbæk 2019). To address these gaps, this study explored both the meaningful and meaningless use of smartphone, and how these can be better supported and discouraged, respectively, through novel interactions. It reports a two-week diary study focused on participants' feelings and motivations related to smartphone use, through the following research questions:

- What users' feelings, motivations, and goals underpin habitual and meaningful smartphone use?
- Are there different smartphone usage patterns that underpin habitual, versus meaningful smartphone use?

6.2 Method

This section describes study participants, procedure and data analysis.

6.2.1 Participants

The research involved a convenience sample of 20 participants recruited using university flyers and mailing lists through convenience sampling. The recruitment process did not specifically target individuals aiming to reduce their smartphone use but instead sought to engage a general university-affiliated

population. Participants ranged in age from 19 to 40 years (median age = 25), with 70% identifying as male and 30% as female. The group comprised slightly more Gen Z members (14 participants, 70%) than Millennials (6 participants, 30%).

The rationale for this user group is three-fold. First, smartphone use is widespread across all age groups and societal contexts but particularly extensive among teenagers and young adults (Csibi et al. 2021; Lemola et al. 2015; Marciano et al. 2022; Wacks and Weinstein 2021; Abi-Jaoude, Naylor, and Pignatiello 2020; Ricoy, Martínez-Carrera, and Martínez-Carrera 2022; Sohn et al. 2019), namely Generation Z (young adults born in or after 1995) and Millennials (those born between 1981 and 1995). Gen Z is 'digitally native' as it did not experience the world without mobile phones and social media (Pichler, Kohli, and Granitz 2021; Chang and Chang 2023): around 94% of Gen Z users own a social media account compared to 82% of Millennials (Curtis et al. 2019).

The participants were undergraduate and postgraduate students, academic staff, and early-career researchers. Educational attainment was generally high: 65% of participants either held or were pursuing a master's or PhD degree, while the remaining 35% included individuals currently enrolled in undergraduate or diploma programmes or holding high school-level qualifications. In terms of occupation, the group included PhD students (n=8), undergraduate students (n=5), researchers or postdoctoral fellows (n=5), a teaching assistant (n=1), and a part-time social media community manager (n=1). Device ownership was split between iPhone users (n=12, 60%) and Android users (n=8, 40%). All participants were regular smartphone users, reflecting on their motivations, emotions, and experiences with smartphone apps. One invited participant, a secondary school student, could not continue with the study because it was later determined that he was still a secondary school student and was not enrolled in any diploma or undergraduate programme.

An ethics application was submitted to the Faculty of Science and Technology Research Ethics Committee for formal review and approval before conducting the study. The application outlined the study's recruitment strategy, including details about the target population, anticipated age range, and the nature of data collection. It also included information about the commercial app that would be

used to collect data for 2 weeks from the participants' mobile smartphones. The submission explained how the app functioned, what types of data it would collect, and the measures to protect participant privacy and confidentiality. The study started after the ethics application was approved. Before participation, individuals were presented with information regarding the study's objectives, their right to withdraw at any time without consequences, and the requirement for informed consent for research participation. All data were anonymised and identified only through a randomly assigned participant ID to protect privacy and confidentiality. Only the research team had access to the raw data, and all data handling complied with the UK General Data Protection Regulation.

6.2.2 Procedure

The two-week diary study investigated smartphone use and included three parts (Figure 3). The first part was an onboarding session where participants were introduced to study aim, and the SPACE app. This is top rated free mobile app (Almoallim and Sas 2022) for digital wellbeing which tracks daily phone usage including total screen time, daily screen unlocks, and the most frequently used apps and their screen time. This app was selected to support participants monitor their smartphone and app use.

The second part was the actual diary study over the two weeks, when participants were asked to record each day in more details their interaction with one of the apps they used that day, while ensuring that the broad range of their commonly used apps are being captured throughout the two weeks, i.e., each day, they may focus on capturing interaction with an app, which they have not captured in previous days, unless their most commonly used apps are less than 14 (the duration of diary study). These detailed interactions were captured using a Qualtrics form to be completed as soon as possible after the interaction with the app that they decided to capture. The Qualtrics form included: three validated scales for emotional states and motives of using the app, and open questions on automatic or deliberate use of the app, learning achieved from the use of the respective app (i.e., Did you discover something new from this experience? What?), and perceived meaning of app use.

Validated Scales: Emotions and Motives

For emotions, we used two valid questionnaires measuring emotional states namely (i) the Positive and Negative Affect Schedule (PANAS) scale (Watson, Clark, and Tellegen 1988) consisting of two subscales, each with 10 items for positive (i.e., excited) and negative (i.e., upset) emotions respectively, which used a 5 point Likert scale; and (ii) the experiential components of boredom scale consisting of seven items such as "*How much did the feeling make you want to do something more meaningful*?" (van Tilburg and Igou 2012) captured in a 5 point Likert scale. This scale was included because boredom is an emotion often associated with meaningless, habitual use (K. Lukoff et al. 2018).

In addition to emotional states, a third scale was used to capture motives for using specific apps, namely the nine item Hedonic and Eudaimonic Motives for Activities (HEMA) scale capturing hedonic or pleasure related motives (i.e., "*Seeking to take it easy?")* and eudemonic motives such as those for growth or authenticity or meaning (i.e., *Seeking to pursue excellence or a personal ideal*?") for using the phone, through a seven point Likert scale (Huta and Ryan 2010).

Open questions on meaningful app use

The open questions on perceived meaning were informed by the five components of meaning from Mekler and Hornbæk's Framework of Meaning (Mekler & Hornbæk, 2019) namely (i) connectedness or the experience of being connected to one's self or to the world,, (i.e., Do you feel that this use of this app made you feel connected to the self and the world? How? If not, why?) (ii) purpose or sense of direction towards clear ends and future events (i.e., Do you feel that this use of this app made you feel a sense of core goals, aims, and directions?), (iii) coherence as the extent to which one's experiences make sense or fails to (i.e., Do you feel that this use of this app helped you make sense of your experiences? How? If not, why?), (iv) resonance as the immediate, unreflected experience of something making sense, without the need to reflect on (i.e., Do you feel that this use of this app did it feel right to you or helped you "click with something"? How? If not, why?), and (v) significance as aspects perceived as important and enduring (i.e., Do you feel that this use of this app will have any enduring value and importance for you? Why? If no, why not?).

The Qualtrics form also asked participants to upload at the end of the day the three screenshots from the SPACE app which includes time on phone, time on apps, and number of phone unlocks, and reflection on whether the SPACE data was surprising or will affect their phone use. Daily reminders were also provided to support users with the timely completion of the Qualtrics form.

In the second week, we introduced a micro-intervention aimed to prompt reflection on meaningful use, through four questions asked *before using the apps*. These questions focused on the trigger for interaction with the app, activity performed before interaction with app, and in particular, their intention and expectations from app use: "How do you expect to feel after using the app? Why?" and "What do you think you will accomplish by using this app?". These two latter questions aim to prompt users to reflect on the expected emotional and motivational value for that situated app use.

The diary study concluded with the third part: semi-structured interviews aimed gain deeper insights into participants' smartphone use , particularly the meaning associated with specific app use (or lack thereof).

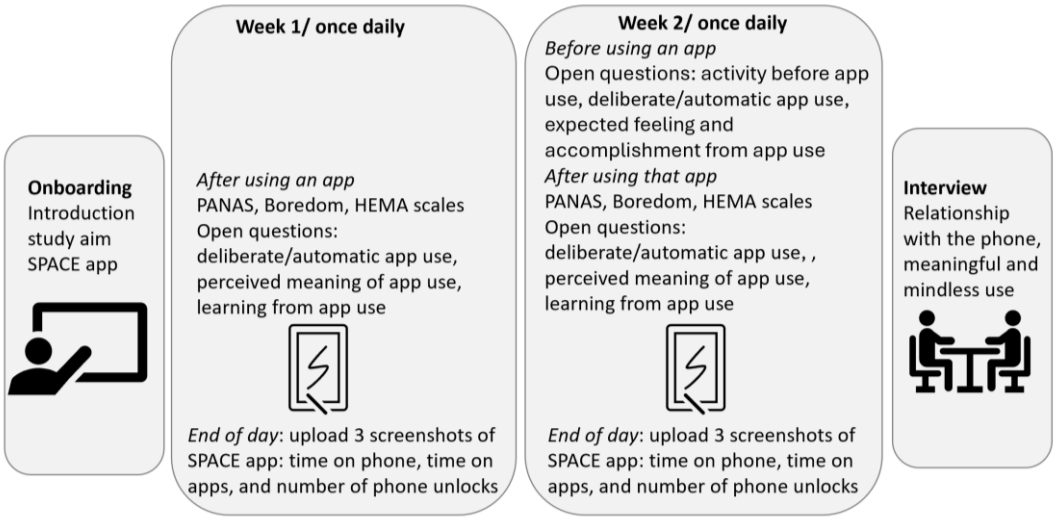


Figure 3: Two-week study protocol to assess smartphone use, integrating daily app interactions, psychological scales, and an in-depth interview

6.2.3 Data analysis

The research collected a mixture of qualitative and quantitative data. The quantitative data from the diary study was analysed in Excel to generate

descriptive statistics. Thematic analysis was used for analysing qualitative data. Thematic analysis requires systematically organising extensive collected data (Dawadi 2020) where the researcher is immersed through such data to connect fine details that were not instantly clear (Blandford, Furniss, and Makri 2016)

6.3 Findings

This section presents and discusses the findings from the diary study. This includes the analysis of quantitative data such as the SPACE data using descriptive statistics, and the thematic analysis of qualitative data such as the participants' answers to open-ended questions.

6.3.1.1 SPACE App Data: Phone and App Use

According to the SPACE screenshots, the most frequently used apps in Week 1 were messaging and social media apps: TikTok, Instagram, YouTube, Safari, and WhatsApp. The most used apps (3 to 4 hours) were Raid [P17], TikTok [P12], and Google Maps [P17]. Across participants, the average use times for the first, second, and third most used apps were respectively 1 hour and 24 minutes, 45 minutes, and 30 minutes.

In week 2, the most frequently used apps were the same as in week 1 (e.g. TikTok, YouTube), while the most used apps (over 6 hours) were TikTok [P12], YouTube [P5], and WEBTOON [P3]. The average use times for the first, second, and third most used apps were respectively 1 hour and 30 minutes, 44 minutes, and 30 minutes.

Most used apps according to the SPACE data (Figure 4) including Instagram, Snapchat, and WhatsApp, were also identified as frequently used apps from the self-reported data (Figure 6). Conversely, other apps such as Safari and Chrome were rarely recorded by the participants even though the SPACE data suggests they were frequently used – especially Safari, which was the most used app in week 1 and the second most used app in week 2.

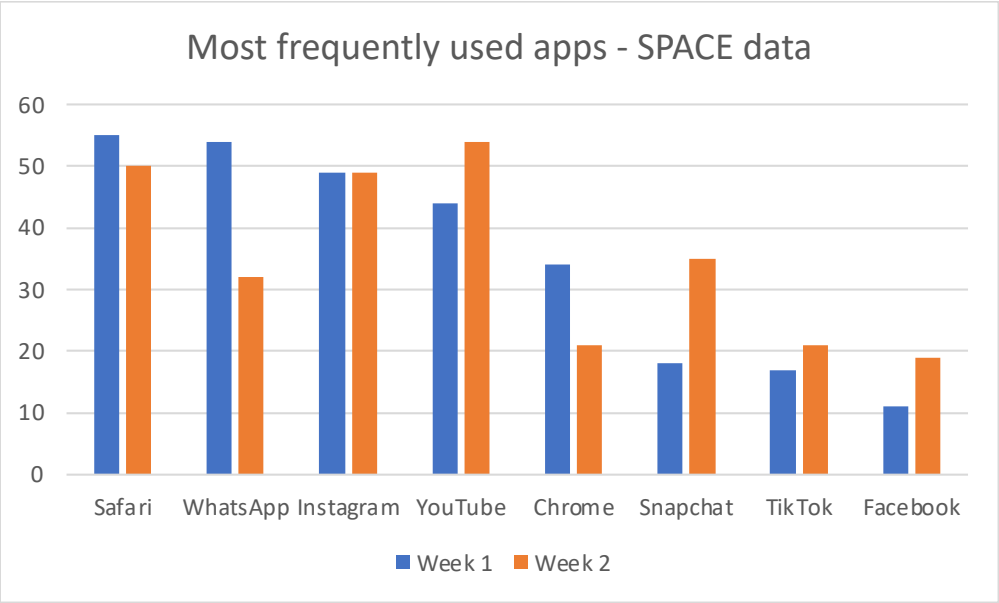


Figure 4: Most frequently logged apps by week - Space data (3 most used apps per participant)

At the phone level, the median daily use in week 1 was 3 hours and 28 minutes; the average use was 3 hours and 35 minutes (SD: 1 hour and 24 minutes). The maximum number of daily unlocks was 402 [P2], while the average was 99 (SD: 79). In week 2, the median phone-level use was 3 hours and 51 minutes, while the average use was 3 hours and 49 minutes (SD: 1 hour and 34 minutes). P3 recorded the most daily screen unlocks in week 2 at 391; the average among participants was 105 unlocks (SD: 76).

Figure 5 shows the minimum, maximum, and average use times for the eight most frequently used apps across both weeks identified in Figure 4. TikTok and YouTube had the highest average use times at 1 hour and 31 minutes and 1 hour and 3 minutes, respectively, while WhatsApp had the lowest average use time at just 34 minutes despite being the second most frequently used app in week 1 (Figure 4). This suggests that the WhatsApp app, while opened frequently, was only used for short periods compared to other frequently used apps such as YouTube.

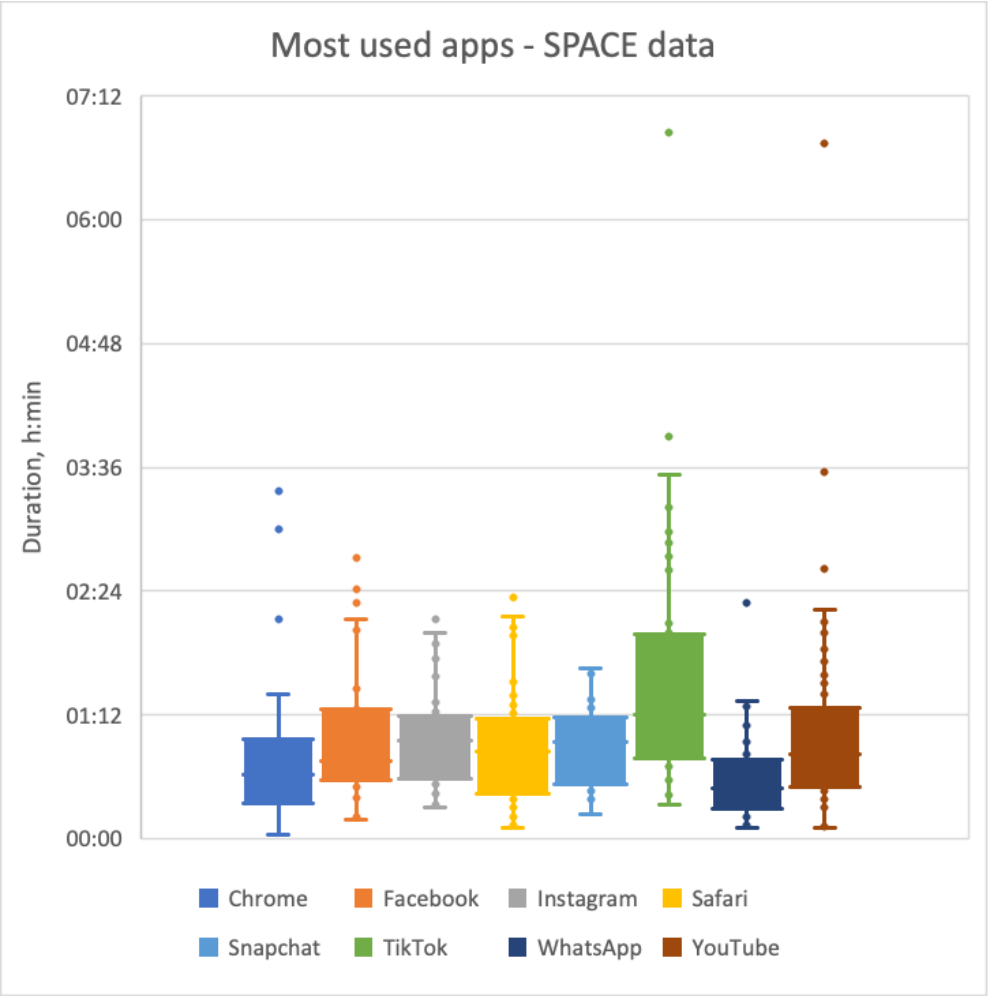


Figure 5: Most used apps across weeks – SPACE data

Reflection on SPACE App Logged Data

When asked to reflect on the week 1 SPACE app logged data, 43% of participants reported being surprised by it and 48% believed it will impact their future phone use. In week 2, significantly fewer participants were surprised (27%) while roughly the same percentage believed it will impact their phone use (41%). These findings suggest that participants already became aware of their smartphone use habits in weeks 1, albeit the perceived value of this information on future phone use appears to decrease over time (from 48% to 41%), especially since the phone and app use appears to have increased from week 1 to week 2, both in terms of screen time and number of unlocks. Moreover, the slight decrease in participants who believed this knowledge will impact their phone use suggests that a small

percentage of participants may have changed, or at least attempted to change, their overuse habits between weeks 1 and 2.

6.3.1.2 Self-reported Data on Qualtrics Forms

The 20 participants who took part in the two-week diary study recorded a total of 265 interactions: 165 in week 1 and 130 in Week 2. These numbers mean that, on average, the participants submitted 7.7 entries each day, range 3-17 in week 1, and slightly less in week 2: 6.3 daily entries, range 3-10.

Deliberate vs Automatic Phone/App Interaction

During Week 1, participants recorded 121 **deliberately** started app interactions (73%) and 44 automatically (i.e. mindlessly) started interactions (27%). The app sessions ranged from a few seconds, such as quickly checking emails [P17, P20], to over 10 hours on Spotify [P4]. The median duration was 11 minutes; the average duration was 26 minutes (SD: 1 hour and 2 minutes). During Week 2, participants recorded 99 deliberate app interactions (77%) and 30 automatic interactions (23%). The app sessions lasted from a few seconds to over 5 hours [P4, Instagram]. The median duration was 10 minutes; the average duration was 22 minutes (SD: 39 minutes). These are important findings, indicating increase in the intentional interaction and decrease in the automatic interactions, as well as shorter average duration of interactions from week 1 to week 2.

Triggers for Phone/App Interaction

In week 1, 18 out of 20 participants cited a specific intention to check new *notifications*, especially from messaging and social media apps, as their main reason for using specific apps. Most participants recorded these interactions as deliberate, whereas only a few recognized that these were largely automatic, mindless actions. The second most common trigger was a specific, *deliberate intention* to check other content, notably travelling information [P3, P5, P6]. Moreover, several participants cited *boredom* as a trigger for deliberate interactions: "*I was bored and decided to check Facebook for any news*" [P10].

Several of these trends continued in week 2. Checking specific notifications remained the main trigger for 12 out of 20 participants, and several other interactions were triggered by specific needs such as checking work-related or

travel information. Boredom was also frequently cited as a trigger, however, slightly more participants seemed to be aware that these sessions were largely habitual: "*Habit I guess. There was no reason actually*" [P20].

Figure 6 shows the most frequently logged apps by week. Overall, the most frequently used apps were messaging and social media apps: WhatsApp (21 counts), Instagram (20 counts), Facebook (19 counts), and Instagram (11 counts). During week 1, the most frequently used apps both automatically and deliberately were Facebook (17 counts each), Instagram (13 counts each), and Snapchat (11 counts each). An interesting finding is that the average use time was slightly lower for automatic sessions, 20 minutes, than for deliberate sessions, 28 minutes. During week 2, the most frequently used apps automatically were Facebook (17 counts), Instagram (13 counts), and WhatsApp (10 counts); the most frequently used apps deliberately were Facebook (17 counts), Instagram (13 counts), and Snapchat (11 counts). Also interesting, is that the average use times were lower than in week 1: 15 minutes (automatic) and 24 minutes (deliberate).

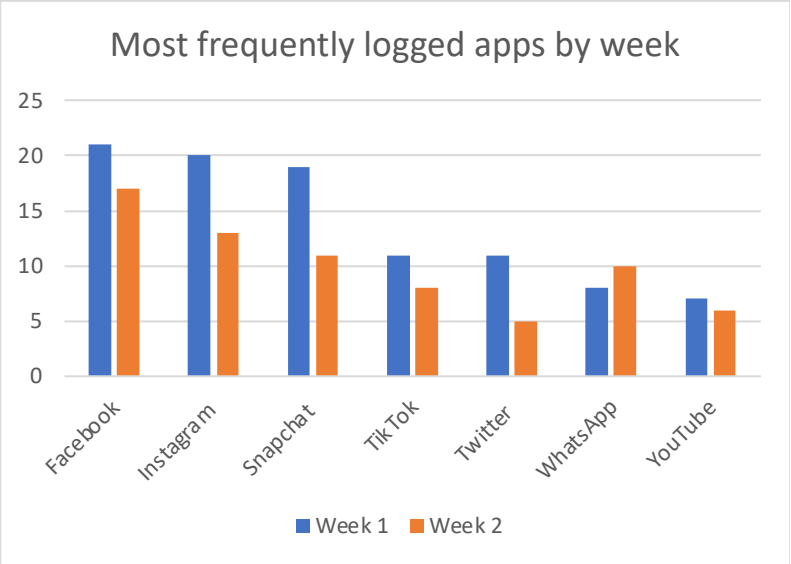


Figure 6: Most frequently logged apps by week among all participants

Motives for Phone/App Use

Concerning the motives behind using the apps, 4 eudemonic motives and 7 hedonic motives were assessed using a Likert scale ranging between '1 (not at all)' and '7 (completely)' to evaluate the items on Huta and Ryan's hedonic and eudemonic scales [36]'. Findings indicate that about one third of participants

(~30%) have limited motives of engaging with their apps, both eudemonic such as pursuing excellence, and hedonic ones such as seeking to pass time. On average, only 14% of participants were 'completely' driven by eudemonic or hedonic motives (score 7 (completely)).

The high percentage of participants who answered '1 (not at all)' did not fully aligned with the qualitative data from open questions, as some participants indicated clear, specific hedonic or eudemonic motives for using their phones. For example, P3 was seeking relaxation: "Wanted to watch some videos to entertain me after my exam"; P11 used the phone "Deliberately by a specific intention to check the marketplace". One possible explanation is that the participants viewed mitigating boredom as a separate reason from hedonic motives and answered '1 (not at all)' to indicate this. Participant answers that support this explanation include "Automatically, without particular reason" [P5], "I was bored and decided to scroll through my apps" [P10], and "Bored on a car ride" [P19]".

This discrepancy suggests that certain motivations, particularly those linked to habitual or boredom-driven behaviours, may not have been consciously recognised as hedonic. Smartphone use during periods of low stimulation, such as exam breaks or commuting, was frequently described in the diary entries as reactive or automatic. Participants appeared aware that these behaviours were not entirely purposeless, yet they often dismissed them as lacking meaningful intent. This indicates a potential conflict between their retrospective rationalisation and their digital experiences. While users may use apps to manage boredom or stress, they may not label such motives as hedonic, especially if the activity disrupts tasks, such as studying. This gap highlights the challenge of capturing complexity in self-reported motivational data, particularly where usage patterns resemble compulsive or addictive behaviours rather than deliberate entertainment.

Concerning the participants' motives for using the apps in week 2, most participants answered 'not at all' for both eudemonic motives (average: 30%) and hedonic motives (average: 23%), while all other answers were roughly equally distributed between '2' and '7 (completely)'. The findings closely mirror the results from week 1, suggesting that the participants still viewed mitigating

boredom as separate from hedonic motives and answered ‘not at all’ to indicate this. These findings support that boredom alleviation is a complex emotional driver that often blurs the line between meaningful and meaningless engagement. While some participants did acknowledge the soothing or social benefits of app use during downtime, they were less likely to report these experiences as intentional or goal-driven despite evident outcomes like reduced stress or social interaction.

Feelings, Thoughts, and Goals for App Use

The study also investigated the feelings and thoughts that triggered the use of specific apps measured with the same Likert scale from ‘1 (not at all)’ to ‘5 (very much)’ used by Van Tilburg and Igou (van Tilburg and Igou 2012). Across categories, most participants answered ‘not at all’ (32–45%) while only 3–9% answered ‘very much’ in week 1 (Figure 7). These findings indicate that over one third of participants were not driven by clear feelings, thoughts, action tendencies, actions, or emotivational goals such as wanting to do something meaningful or being challenged when they started the phone interactions. By contrast, only around 5% of participants were driven by clear factors. These findings are also not fully consistent with participants’ other answers as some participants gave clear reasons for using the phone. The participant answers to “How much did you feel bored?”, which was asked in the online form after Van Tilburg and Igou’s original questions, had similar percentages: nearly half (45%) were ‘not at all’ bored while only 4% were ‘very much’ bored. These values suggest that most phone interactions were not triggered by boredom, either. Again, this is inconsistent with participants’ answers to open-ended questions, where boredom was frequently mentioned as a trigger of phone interactions. Overall, these results suggest that awareness and identification of boredom is not trivial. All these findings were confirmed in week 2 (Figure 8). For example, only around

5% (2–11% range) of participants were 'very much' driven by clear factors.

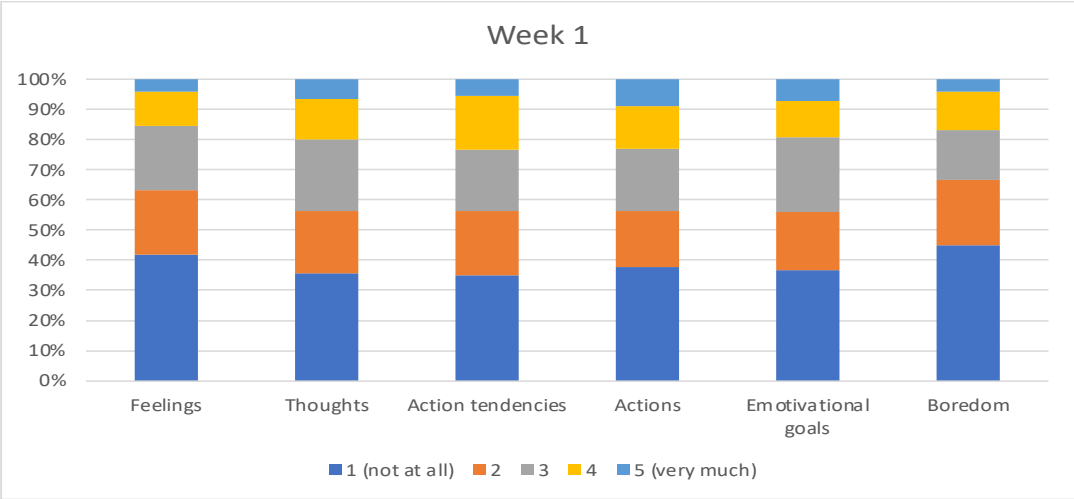


Figure 7: Participants' feelings, thoughts, and goals just before using the app in Week 1

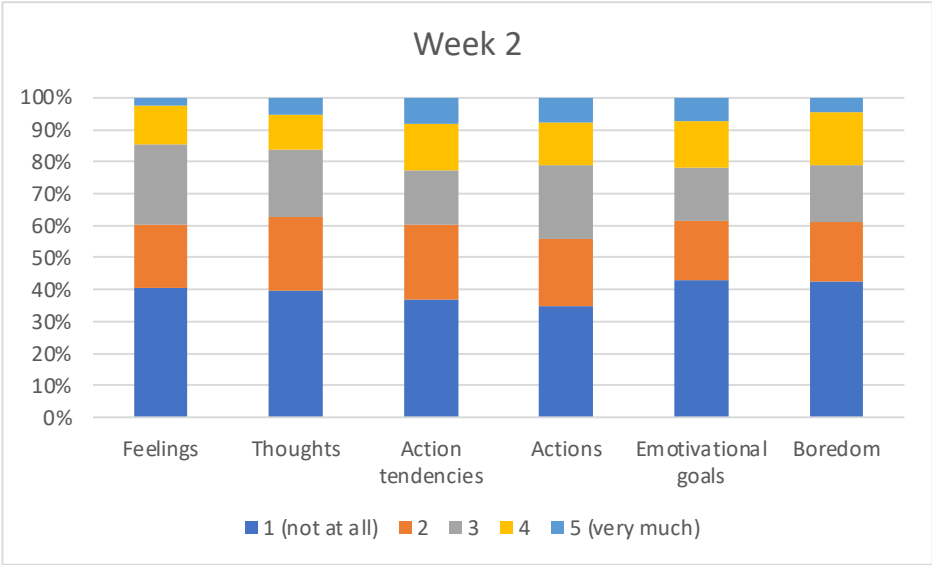


Figure 8: Participants' feelings, thoughts, and goals just before using the app in week 2

Positive and Negative Affect

Participants' affect after (but not before) each app session was measured using a Likert scale from '1 – very slightly or not at all' to '5 – extremely' to assess the 10 positive affect and 10 negative affect items on the PANAS scale (Watson, Clark, and Tellegen 1988). In week 1, most participants felt negligible positive affect as well as negative affect: only 2–3% felt extremely inspired and proud (positive affect) and 0% felt extremely afraid, hostile, irritable, scared, and upset (negative

affect). Similar results were obtained in week 2: most participants reported feeling negligible positive and negative affect. Qualitative reflections suggest that participants frequently used their phones as a micro escape—short, often passive interactions meant to ease discomfort or cope with emotional fatigue. These interactions were not necessarily associated with strong affective responses but served as a way to disengage from internal and external stressors. For example, participants reported reaching for their phones when they felt overwhelmed, socially exhausted, or bored—situations characterised by low emotional valence and varying arousal levels. In these moments, smartphone use offered a socially acceptable or contextually convenient method of emotional self-regulation.

The most common use patterns during these micro escapes included passive scrolling, browsing social media, and watching videos—activities described as purposeless or without long-term value. Yet, for many, this kind of use helped to manage emotional discomfort in the moment, even if it did not improve their mood long-term. These findings help to explain why participants may have reported low affect scores post-usage: the phone provided relief without necessarily sparking high-arousal emotional shifts. Thus, affect in this context may be more about stabilising than elevating or depleting emotional states.

An important finding concerning affect is that emotional states as interaction triggers tend to be mostly low-intensity negative or higher-intensity positive emotions. The relatively neutral affective responses support the interpretation that much smartphone use may be affectively flat or emotionally disengaged, raising questions about the true hedonic or emotional value derived from such interactions.

Perceived Learning and Meaning from Interaction with the App

The online form included several open-ended questions to encourage the participants to reflect on their use of specific apps. Their written answers revealed that in week 1, 71% of participants felt they had gained enduring value from the interaction while 71% felt more connected to the self and the world. While the former is surprising, the latter is less so, given the prevalence of social apps. Conversely, most participants did not feel a sense of core goals (58%) or make

sense of their experiences (59%). Overall, only around 48% of participants felt right or like they "clicked" with something by using the recorded app.

These results indicate that around 70% of participants felt that they gained value and/or higher social connectedness from the app interactions, yet only around 50% viewed these gains as being aligned to their goals. The self-reflection answers from week 2 were somewhat similar to those from week 1. Slightly fewer participants (64%) gained enduring value from the app interaction, while virtually the same percentage (70%) felt more connected to the self and the world. However, only 34–37% felt a sense of core goals, made sense of their experiences, and "clicked" with something compared to around 50% in week 1.

6.3.1.3 Self-report Bias of Phone/App Use

Comparing the self-reported data to the automatically recorded SPACE app data indicated that participants generally underestimated their smartphone use. For example, several participants recorded their app interactions as starting and ending at the same time. This may be reasonably accurate in some cases, such as P18's use of Google Authenticator. However, it is likely an underestimation in other cases, such as P17 checking their emails after receiving "too many unattended notifications" or P19 using their phone due to an "incoming message on snapchat". Similarly, the SPACE data from both weeks showed that several apps were used frequently and for long periods of time even though they were rarely featured in the self-reported data submitted by the participants. Remarkably, Safari was the most used app in week 1 and the second most used app in week 2 according to the SPACE app data, yet it was never recorded by the participants throughout week 1 and only recorded twice in week 2 [P3, P9]. Another example of self-report bias is the discrepancy between the average lengths of app interactions calculated using participants' self-reported data and the SPACE app data. According to the self-reported data, the average app interaction lasted 26 minutes in week 1 and 22 minutes in week 2. By contrast, the SPACE data for the six most used apps by each participant indicated that app interactions lasted around 33 minutes in week 1 and 35 minutes in week 2. This means that, in average, app interactions were in fact, around 10 minutes longer than suggested by the self-reported data.

6.3.1.4 Drivers of Smartphone Use

The finding that over 70% of recorded app interactions were deliberate during both weeks (Figure 9) is consistent with the thematic analysis of participants' motives for using specific apps. The main recurring themes were Need to Belong (NTP), Fear Of Missing Out (FOMO), and boredom: during both weeks, many participants turned to messaging and social media apps to satisfy NTB, reduce FOMO, and mitigate boredom.

Participant answers indicated that these interactions were overwhelmingly viewed as deliberate and worthwhile, especially those intended to mitigate negative states (notably, boredom) by seeking positive experiences (notably, social connectedness), thereby contributing to the 73–77% values reported in Figure 9. Furthermore, the thematic analysis revealed a small increase in self-awareness as several week 2 responses were more specific, insightful, and reflexive than those submitted in week 1, possibly as a result of the reflexive questions concerning the SPACE data. Notably, three participants associated their smartphone use with meaningful and purposeful activities. For example, P4 described their use as deliberate, stating that they used an app to "*gives me a good feeling in that moment, or even helps me improve myself by inspiring me*". Similarly, P5 contextualised their meaningful smartphone use around "*looking up something on the internet*" reinforcing the idea that their interactions were purposeful. P7 highlighted the value of leisure, explaining that their use of a smartphone was meaningful "*when it comes to leisure, it doesn't necessarily seem like a bad thing to spend too much time doing it because you're at least enjoying yourself*".

This increase in self-awareness may explain the increase in deliberate interactions in week 2 as the participants tried to avoid automatic interactions. This change also echoes the participants' week 1 reflections, where 48% claimed their phone use may change in response to the SPACE app data. This finding is consistent with those from previous work which showed that users often seek to reduce their smartphone use, especially for addictive social media apps which encourage mindless use (Kim Inyeop et al. 2017; K. Lukoff et al. 2018).

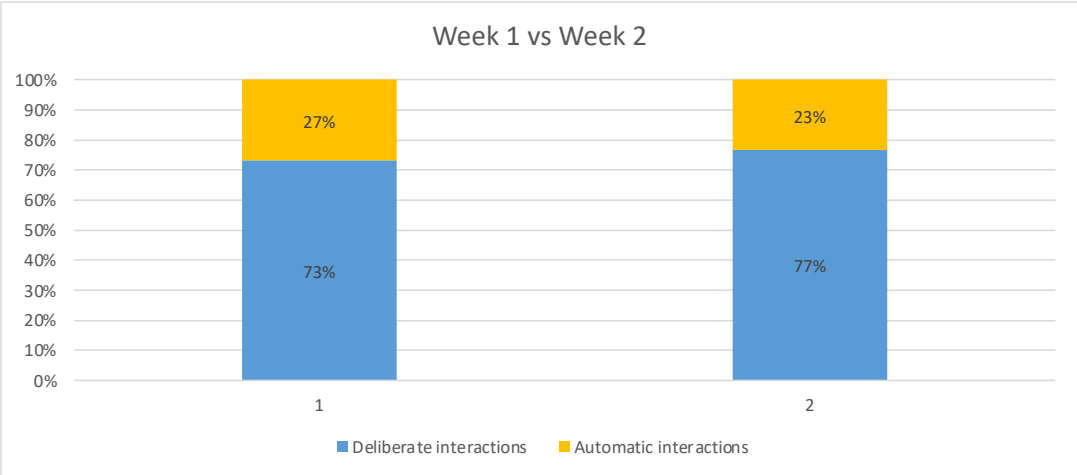


Figure 9: Interaction types by week

The gap between the moderate percentage of participants wishing to change their phone overuse habits and the minor increase in deliberate interactions can be explained by two factors. Firstly, the diary study was relatively short, so the week 2 data only offers a first glance into participants' behavioral changes. Secondly, smartphone users can experience a feeling of "wanting to quit but not doing so just yet" [10, p.3264] and may also struggle to find an effective strategy to reduce their smartphone use (Ko, Yang, et al. 2015). By contrast, the deliberate and automatic use data is largely inconsistent with the participants' responses concerning their eudemonic and hedonic motives for using specific apps, which only showed minor variations over time.

The diary study did not capture users explicit interest in reducing their phone or app use. Future work may account for this, by using for instance the transtheoretical model of change (Prochaska and Velicer 1997).

Most participants (around 28%) claimed to be not at all driven by clear eudemonic or hedonic motives throughout the study, while only around 14% reported being completely driven by them. However, the thematic analysis of participants' written answers indicated that several recurring themes – notably boredom, FOMO, and NTB – were strongly associated with clear motives and actions that led to app interactions. Throughout the study, most participants indicated that feeling bored and habitual use were common triggers to turn to specific apps, including 9 participants (45%) who explicitly cited boredom or specific habits such as wake-up and bedtime habits. Participants typically attempted to address boredom, FOMO, and NTB by "just checking" emails and

instant messages on Facebook or WhatsApp or by "just scrolling" content on social media apps such as TikTok and Twitter. Despite these being clear goal-driven actions, many participants did not associate them with equally clear eudemonic or hedonic motives. These findings suggest that many participants were not fully aware of how their emotions impacted on phone checking. This interpretation is supported by participants' answers concerning their feelings, thoughts, and goals before using specific apps. Around 40% of participants reported being 'not at all' driven by clear feelings, thoughts, action tendencies, actions, emotivational goals, or boredom during both weeks, compared to only 6% who were 'very much' driven by them. Furthermore, the thematic analysis of the deliberate and automatic use data highlighted that many participants were driven by clear feelings and goal-driven actions, such as "*a deliberate action to relax*" [P13]. Overall, these results suggest participants' limited awareness of their emotional states, motives and goals.

Although 'not at all' was the most common response for all the items measured via Likert scales, the diary study revealed a difference in responses between the assessed categories. Participants' eudemonic and hedonic motives remained virtually unchanged throughout the study; this may be explained by a conscious or subconscious hesitation to change their habits (Baumer et al. 2013), which in turn can be caused by NTB and FOMO (Sun et al. 2022). By contrast, participants' feelings immediately before using the apps changed moderately between week1 and week 2 (Figure 10). Week 2 saw a distinct increase in participants feeling like doing something more purposeful ('action tendencies' category) and a decrease in participants feeling restless and unchallenged ('feelings' category), yet more participants felt moderately to very bored.

Action tendencies are the second highest level of emotional awareness after the awareness of physical sensations (Lane and Smith 2021), so the marked increase in this category suggests the participants became more self-aware in Week 2, possibly due to the open-ended reflection questions. In turn, this may explain why some participants were able to recognize they felt bored rather than restless or unchallenged.

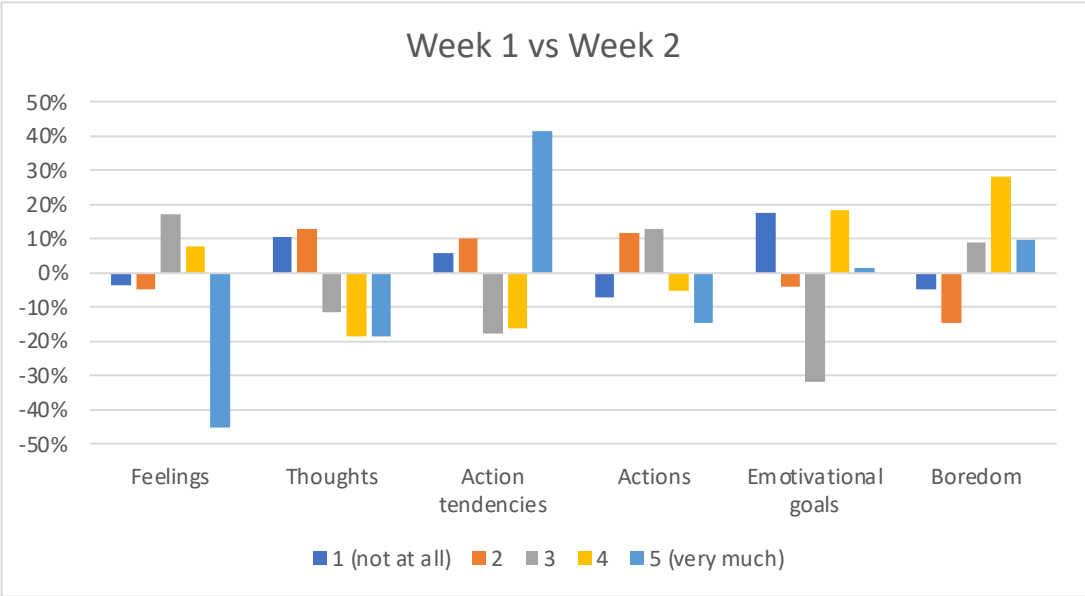


Figure 10: Percent change in feeling intensity in week 2 compared to week 1 in a 5-point Likert scale

6.3.1.5 Effects of Smartphone Use

The high percentage (over 70%) of app interactions started deliberately in both weeks was expected to result in mostly short and focused phone sessions, especially when compared to the average length of automatically started sessions. By contrast, participants' self-reported data indicated that the average use time was higher for deliberate sessions in both weeks: 24–28 minutes compared to only 20–15 minutes for automatic sessions. This result was largely caused by a small number of deliberate app sessions which were very long, such as using MS Teams for work-related purposes for 4–5 hours during both weeks [P9].

Participants' positive and negative affect after using the apps did not change significantly between weeks. Concerning positive affect, most participants felt moderately to extremely interested (72% in week 1, 74% in week 2) and excited (47% in week 1, 44% in week 2). For negative affect, moderate to extreme distress was the most reported feeling (17% in week 1, 19% in week 2). Overall, these findings indicate that nearly three-quarters of participants experienced their app interactions as interesting, while under a fifth of participants experienced them as distressing.

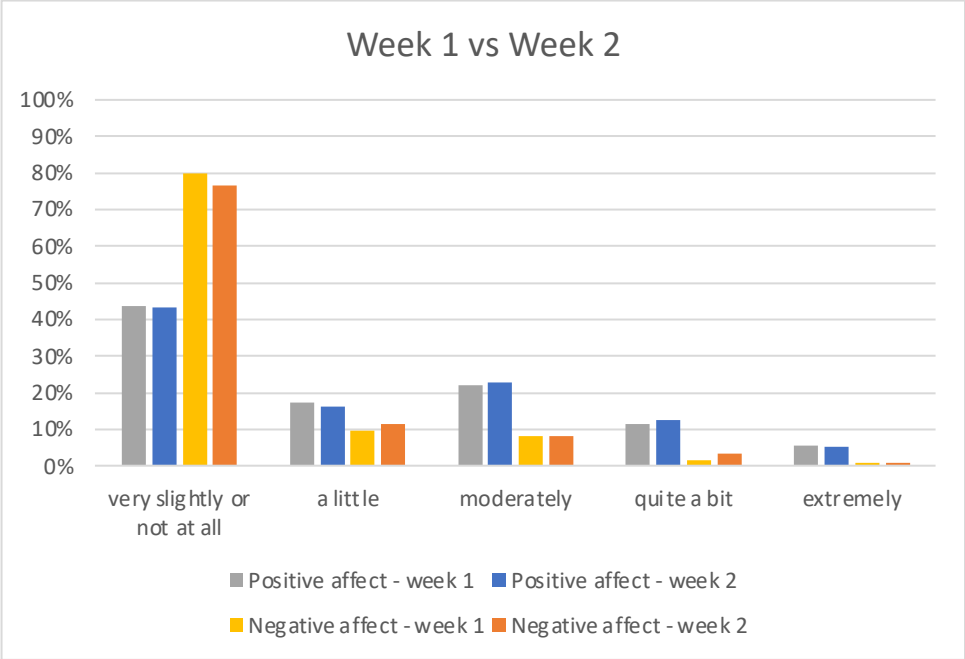


Figure 11: Changes in positive and negative affect between weeks

6.3.2 Discussion

6.3.2.1 Intrinsic and Extrinsic Motivations for Smartphone Use

When considering their motivations for using specific apps, most participants reported not being driven by any of the hedonic or eudemonic motive, or emotional states s, including around one third who were 'not at all' driven by them. However, these initial observations were not easily reconciled with participants' written answers, where many declared clear hedonic (e.g. mitigating boredom) or eudemonic (e.g. seeking connectedness) motives. This discrepancy resonates with previous research that found a weak correlation between psychometric scales and objective phone use (D. A. Ellis et al. 2019). Nevertheless, the main motive for using the smartphone (50% of all interactions) was distinctly extrinsic: checking new notifications. Most notifications were social push notifications about new messages or social updates which participants felt compelled to check due to FOMO (Rozgonjuk et al. 2020; Clor-Proell, Guggenmos, and Rennekamp 2017). These notifications were often unimportant, yet they still led to longer-than-intended app sessions as social notifications are designed to be attention grabbers that encourage users to be "always on" (van

Koningsbruggen, Hartmann, and Du 2017; Du, Kerkhof, and van Koningsbruggen 2019). By contrast, very few notifications were pragmatic (e.g. meeting reminders), indicating that most participants used the smartphone primarily for hedonic motives (Turel et al. 2020). Many participants also turned to their smartphones to address a lack of satisfying external stimulation in everyday contexts, such as while on a "boring" car ride or before going to sleep. This type of user behavior is associated with technology dependence, whose harmful effects include a higher attention deficit (Small et al. 2020).

6.3.2.2 Framing Meaningful Smartphone Use

We evaluated participants' affect (Watson, Clark, and Tellegen 1988) and reflections immediately after using specific apps to identify common themes associated with meaningful smartphone use. Initial observations revealed that most participants (60%) felt low intensity positive or negative affect during both weeks, which suggests that most recorded app interactions failed to signal events of personal significance.. However, consistent with previous studies (D. A. Ellis et al. 2019), we also found a low correlation between the assessed PANAS items and actual smartphone use: participants' written answers indicated that many app interactions were meaningful and worthwhile. The main theme associated with meaningful smartphone use was the attainment of enduring value, especially in the form of social connectedness, which is a key element of digital wellbeing (Chan 2015b; Holly et al. 2023). Enduring value was also associated with other elements of digital wellbeing, notably learning new information and working towards self-development, such as tracking food macros and other health statistics. However, participants did not seem to view these goals as closely aligned with their purpose in life as only around a third of all recorded app interactions helped participants to feel a sense of core goals and direction in life (George and Park 2013). This finding suggests that meaningful smartphone use is most often derived from purposeful short-term and medium-term goals rather than purposeful lifelong goals.

6.3.2.3 Self-awareness and User Bias

When comparing the self-reported and automatically recorded SPACE app data, we found significant evidence of user bias with a distinct prevalence of phone use being underestimated. Participants underestimated the duration of several app interactions, so the average use time calculated from the self-reported data (24 minutes) was 10 minutes shorter than the more accurate average determined from the SPACE log data. Discrepancies between self-reported and automatically recorded data are well-documented in the literature (Boase and Ling 2013; Junco 2013; Kobayashi and Boase 2012), especially phone use underestimation (Heyoung Lee et al. 2017; Muench, Link, and Carolus 2022; Wu-Ouyang and Chan 2022), which is often associated with smartphone addiction (Deng et al. 2019; Y.-H. Lin et al. 2015). Consistent with these studies, we found that 40% of participants were initially unaware of their smartphone use and, therefore, surprised by the extensive usage recorded by the SPACE app.

User bias also extended to participants' perceptions of problematic and non-problematic apps. Participants heavily underreported their use of seemingly non-problematic apps such as Safari and Chrome, which were among the most used apps according to SPACE data. **Interestingly, most participants maintained their app biases even after reviewing the SPACE results**, indicating a profound disconnect between their self-perceptions and the objective data provided by the app. This phenomenon can be attributed to individuals often developing psychological biases based on their habitual usage patterns, which can distort their self-awareness regarding app interactions. The extensive use of typically problematic apps such as Instagram and TikTok was recognized as problematic by most affected participants, yet the extensive use of Safari (the overall most used app) was only described as surprising by one participant throughout the study. This may be due to the use of Safari for meaningful or utilitarian purposes.

6.3.3 Interview Findings

6.3.3.1 Meaningful Aims

The interviews helped participants to openly reflect on their smartphone use experiences and associated perceptions of meaningful use. In doing so, many

participants identified common themes which underlined distinctly meaningful phone interactions: connectedness, pragmatic goals, learning, and self-development.

Connectedness, which is one of the five core elements of meaning (Mekler and Hornbæk 2019), was strongly associated with deliberate, positive smartphone interactions which enriched the user experience. Seeking connectedness with something or someone was consistently described as a highly desirable and meaningful aim which could be achieved using both synchronous and asynchronous messaging apps: "*WhatsApp, FaceTime, Gmail, Outlook, general messaging apps. They are very useful*" [P14]. Messaging apps provide "*ease of communication*" [P14] and generally allow users to satisfy their NTB: "*I can arrange meetings. I can arrange social events. I can talk to my friends. I can send them pictures of what I'm doing. They can send me pictures of them. I can talk to my mom, my sister, all of this is meaningful stuff that I wouldn't be able to do without a phone*" [P7]. These findings are consistent with those from previous work: the use of technology to increase connectedness is known to improve mental wellbeing (Wu et al. 2016; K. Lukoff et al. 2018). The connectedness theme included the notion of receiving meaningful notifications which led to meaningful phone sessions. Meaningful notifications were reported to originate from meaningful people, such as emails and WhatsApp messages from specific friends or university supervisors. Several participants reported that frequently receiving many notifications led them to prioritize the most meaningful ones to be able to "*figure out what's going on at a glance*" [P13]. A common prioritisation strategy consisted of identifying the sender to determine the potential level of meaning behind notifications*: "if there is some notification, like, I mean from like, let's say messenger, so I would like to check what happened. Right. So, who sent me a message*" [P15].

Pragmatic goals. The pursuit of *pragmatic goals* was also associated with meaningful smartphone use. Five participants highlighted using their phones to complete collaborative work and other productive tasks including purchasing items, making payments, obtaining directions, and general problem-solving: "*it helps my work and, it helps me solve problems that I'm facing*" [P18]. The smartphone was described as a useful tool for remote working "*I need to control*

a virtual machine" [P18], and a convenient alternative to computers: "*equipment that we need to buy at work or something. And then, my computers on the other side of room and then I just put on my phone*" [P5]. Similarly, P20 noted that the smartphone is a convenient option to complete payments "*at the moment*".

Similarly, Chrome and MS Teams were often associated with work-related tasks as they "*help with the productivity*" [P5]. Other pragmatic apps used with clear, meaningful aims included Uber to "*order a taxi*" [P15] and Google Maps to obtain directions: "*I use them only for the purpose that I intended to. For example, Google Maps… I want to get there. I look how to get there*" [P10]. Third-party booking and delivery tracking apps were also viewed as useful: "*if I need to order something… And if I have to book a flight or train*" [P6]; "*parcel tracking apps that's one of the useful ones, like a general Royal mail tracking apps, tracking for your parcels*" [P14].

Meaningful notifications were also cited in relation to pragmatic goals such as attending scheduled meetings or events. For example, calendar or email reminders can be important and meaningful: "*like today I said this in Calendar. So then when it pops, I know it's time*" [P5]. Meaningful notifications were also sent by the user to themselves. For example, many digital wellbeing apps allow the user to specify phone-level or app-level usage limits so that they can be notified when they reach those limits: "*I'm really, really into a news and then it notifies me, well, you've used, you've reached your limit of usage*" [P9].

Learning. Another theme associated with meaningful smartphone use was *learning*. The participants reported using browsing apps such as Chrome, Safari, and even Google Maps in meaningful ways to meet specific information needs: "*search around any food places when you are outside location*" [P15]. Social media apps such as Snapchat or Telegram were also mentioned as information and news sources which can be used in meaningful ways: "*I go to Telegram and search for this channel because I want this information*" [P1]; "*I see some news I think is very useful. Recently I can use my application for certain news*" [P8].

Self-development. Lastly, participants identified *self-development* as a way to engage in meaningful phone use. Several participants mentioned using social media apps to find inspiration and tips for self-improvement: "*I'm actively, using*

these apps to personally improve in certain areas and they make me feel good and it's, I don't feel guilty or anything also while I'm using social media, because of the way I use social media, especially Instagram. I follow positive people and lots of fitness people. And I, I get inspired a lot so that my app usage is very inspirational to me" [P4]. Similarly, other participants listened to audiobooks and podcasts to achieve "*an increased to quality of life*" [P19]. Overall, participants described this sort of planned, targeted use of social media and entertainment apps as valuable and worthwhile: "I don't feel like it's a waste of my time" [P4].

Across these themes, meaningful smartphone use was generally described as structured and purposeful. Moreover, participant answers indicated that meaningful activities such as doing work or studying typically involved a degree of planning: the participants had clear, specific goals and used the phone pragmatically to achieve them.

6.3.3.2 Meaningless Aims

As they reflected on their smartphone use, participants also identified several themes related to distinctly meaningless phone interactions: boredom, FOMO, negative emotions, relaxation, and meaningless notifications.

Boredom. Boredom was frequently cited either explicitly or implicitly as a trigger for habitual, mindless phone use throughout the day, from when users "*wake up in the morning*" [P3], while travelling "*on the bus*" [P5] or "*waiting for dinner*" [P18], up to "*before falling asleep*" [P19]. Participants noted that mindless phone use was particularly likely when boredom was caused by a lack of stimulation, such as when "*nobody is around*" [P5]. In such cases, the smartphone was the preferred tool to mitigate boredom because it was more appealing than offline activities, and more likely to be readily available than other technologies: "*I'm not at computer and I need to pass time, I will be on my phone*" [P12]. Most participants reported turning to messaging and social media apps to mitigate boredom: "*I will actually go on Instagram, scroll*" [P10]; "*open Twitter.. to see what is happening*" [P15]. While many participants preferred to simply scroll through available content [P10, P12], others were more selective and sought specific content or environments such as new WhatsApp chats: "*you could just end up in a group chat and start discussing by something that is not important*

at all" [P14]. Other users reported using multiple technologies to reduce boredom: "*when I was sat in the living room, watching TV, I would just also sit on my phone at the same time*" [P12].

Fear of Missing Out (FOMO). FOMO was frequently reported as a source of mindless phone use: "*it's not the phone that is asking me to, uh, open it, but it is me. Like, since I've turned it off, I'm. Uh, yeah, I might miss something*" [P20]; "*my hand just goes there, and I unlock for no reason, more than half the time*" [P20]. FOMO led some participants to wonder *"why no one is messaging*" [P19] and frequently checking the phone as "*an impulse, as opposed to something that I actually want to do*" [P12]. Some participants reported not trusting their phone's silent mode, which is a symptom of FOMO: "*I usually, um, hold my phone on mute. So usually I won't have a, like, even if there's a new notification, I won't be able to hear it or see it. So, I just usually check my phone often to see if there's like people messaging me*" [P18]. Phantom notifications, which are imagined rather than real notifications, are another symptom of FOMO: "*I'll get like, I don't know how to call it like a Phantom notification and like, I'll think I'll hear something and then I'll, I'll check my phone and nothing, nothing actually has caught off*" [P3].

Negative emotions. Meaningless use was also reported after using the smartphone to cope with negative emotions. Some participants used the phone to relieve stress and 'escape' from reality: "*when I'm so stressed that you're in the work, you need to escape to just get it. Get your phone*" [P1]. Negative feelings can also encourage avoidance and procrastination; in such cases, the smartphone helped the user to self-comfort: "*I wasn't feeling very good. Um, so I just laid on the couch and just stayed on my phone the entire day*" [P3]. Previous studies have also found that stressful situations can lead to 'micro escapes' (K. Lukoff et al. 2018) and habitual, extended scrolling (Cho et al. 2021).

Seeking relaxation was identified as a major source of habitual, mindless phone use. Several participants used their phone aimlessly to take breaks from cognitively demanding tasks: "*when I'm like studying, sometimes I, I notice that phone kind of distracts me and like, as soon as like, kind of loads my focus a little bit, I have this urge to reach for it*" [P10]; "*maybe in my office, you know, just I'm tired of the work and let's open, open the Twitter*" [P15]. While study or work

breaks can increase productivity after the break, the lack of clear goals and time limits effectively encouraged procrastination as many participants continued *"just scrolling [on] social media*" [P12]. This is consistent with the literature as procrastination is a known way to cope with stressful situations such as deadlines (J. Wang et al. 2019). Mindless, excessive phone use was particularly common with negative content, such as "*watching some videos for hours on Twitter" [P12] or "doomscrolling"* [P13] bad news feeds on Reddit and Twitter.

Meaningless notifications. Lastly, participants identified checking meaningless notifications as a source of meaningless phone use, notably unimportant updates from messaging and social media apps: "*I get added to these group chats and then loads of people like start messaging and then I get loads of notifications*" [P13]; "*people keep sharing random stuff*" [P15]. Generic notifications such as adverts, spam emails, and updates from entertainment apps were also viewed as meaningless: "*If I receive notification from like, I don't know, YouTube and new video uploaded. I won't pay attention*" [P15]. Some participants noted that potentially relevant notifications were less meaningful or completely meaningless depending on their timing, such as social media updates received while being "*sat at my desk doing work*" [P7] or "*out for dinner with someone*" [P13].

Across these themes, participants consistently associated meaningless smartphone sessions with a lack of clear aims, structure, and purpose, which is consistent with the literature (K. Lukoff et al. 2018). Compulsive behaviors were mostly associated with boredom and negative emotions and ranged from merely checking the phone's screen for new notifications to unlocking the phone and opening specific apps, most often messaging and social media apps, to scroll on content. These findings were broadly expected as meaningless smartphone use is typically hedonic, driven by the attainment of short-term relaxation and pleasure rather than long-term excellence and happiness (Busch 2020; Merčun and Žumer 2017).

6.3.3.3 Unintended Changes and Consequences

Participants demonstrated awareness of the distinction between meaningful and meaningless smartphone use. Several participants recognized that meaningful phone interactions can inadvertently turned into meaningless ones, both while using the same app, and multiple apps. A common example was social media

apps, which can be used in meaningful ways to interact with friends, or to complete pragmatic tasks. Once a meaningful activity is completed, the user may be tempted to keep using these addictive apps without a clear aim, leading to meaningless, unintended use: "*I have to check the Instagram comments for my job… I guess it makes me check it more frequently or if I'm already on the app, then I can just go to my own page and then just scroll on that*" [P3]. Similarly, P13 highlighted the lack of a clear aim as a potential trigger: "*instead of doing like an actual thing, I will tend to just scroll along on the internet*". Some participants reported this as a frequently recurring phenomenon: *"I think I always end up with leisure, like, I mean, I might open for a meaningful thing, but I end up with something else*" [P20]. Others noted that meaningful phone interactions are more likely to become meaningless when they last longer than intended: "*I would say like even a call to my parents, um, it's like, sometimes it goes unnecessarily for an hour. I think even that is bad… Yeah, it's unnecessary*" [P20]. These findings highlight the complex and dynamic nature of smartphone use, especially how the user's context and the timing of use influence the perceived meaning of the interaction. This is particularly the case for connectedness interactions, which can quickly change from eudemonic (purposefully interacting with specific people) to hedonic (aimlessly scrolling on social media apps).

6.3.4 Discussion

6.3.4.1 Meaningful Smartphone Use: Opportunities and Challenges

The interviews revealed that meaningful smartphone use can result from both internal aspects such as emotional states and motives related to the pursuit of eudemonic goals, and from extrinsic cues in the form of meaningful notifications. The main eudemonic goals cited by the participants were seeking social connectedness, and completing planned meaningful tasks associated with work, learning, and self-development. These findings indicate that a structured life allows users to define clear eudemonic goals, and pursue them through the moderate, purposeful use of technology on a regular basis. This means that structure and routine in life are key factors to help users regularly engage in meaningful smartphone use that enhances their physical, emotional, and social wellbeing (Mohideen and Heintzelman 2022). Similarly, expanding one's social

network can increase the percentage of notifications from meaningful social connections (Clark, Algoe, and Green 2018; Hui et al. 2023) and, therefore, the likelihood of meaningful smartphone use. Furthermore, a fulfilling social network can help users meet their NTB through positive and voluntary social interactions, thereby reducing habitual phone checking and FOMO.

Participants' responses also revealed that meaningful smartphone use is hindered by several emotional states notably boredom and FOMO-induced habits, and external cues such as generic social media notifications, and spam emails. Participants recognized that these internal states derived from a lack of clear plans and goals when picking up the phone, suggesting that a lack of structure and routine encourages meaningless smartphone use (de Freitas et al. 2022). articipants also described meaningless notifications as unimportant and distracting, however, most of these notifications still resulted in smartphone use due to FOMO (Rozgonjuk et al. 2020; Blackwell et al. 2017). Therefore, it is possible that limiting meaningless notifications from problematic apps can help prevent meaningless smartphone use.

6.3.4.2 Perceived Lack of Control

Many participants noted that smartphone use can seamlessly shift from meaningful to meaningless when switching between apps [23] or even while using the same app for longer than intended. Interestingly, participants often described these events as something that *happened to them*, and was largely or entirely out of their control. For example, some participants regularly struggle to maintain their use of specific apps as strictly pragmatic, and most often start "just scrolling" on content. This is a known phenomenon associated with technology, especially addictive entertainment and social media content, whereby users feel strongly compelled to check "just one more" social media post, video, or episode (Heitmayer and Lahlou 2021; Terzimehić et al. 2022; Walton-Pattison, Dombrowski, and Presseau 2018). Other participants reported being unable to end phone calls with relatives that went on for longer than intended. Such smartphone interactions are challenging to end as they help to satisfy the user's NTB while also causing a "coordination problem" where neither party knows when the other party would like to end the conversation (Mastroianni et al. 2021).

Glossary of Terms

Term	**Meaning**
Habitual use	Automatic smartphone behavior triggered by internal cravings or external stimuli, such as notifications or screen alerts.
Meaningless use	Habitual, automatic actions that lack significance or purpose, such as passively browsing social media or engaging in entertainment solely to pass the time.
Meaningful use	Intentional or aware smartphone use where the user engages actively with a clear goal or purpose in mind, resulting in the completion of a productive task.
Friction	Any obstacle that hinders the creation of an optimal user experience.
Smartphone addiction	Behavioral addiction characterized by compulsive and excessive smartphone use, resulting in an inability to regulate usage and leading to negative consequences in daily life.
Eudemonic use	Instrumental and goal-driven phone use.
Hedonic use	Non-instrumental and pleasure-driven phone use.
NTB	Need to Belong
FOMO	Fear Of Missing Out

Chapter 7: Co-design Workshops

7.1 Aim and Rationale

This co-design workshop explores users' feedback and input into how to design for reducing meaningless phone use, particularly through different types of frictions, and for increasing meaningful phone use.

For this, we focus on the following research questions:

1. How can we design for different types of friction to limit meaningless use?
2. How can we design for meaningful use to support goals related to emotional and physical wellbeing, work productivity, time management and attention training?

The findings from diary study suggest that problematic use often stemmed from boredom or fear of missing out, while meaningful use was tied to connectedness or personal development. Our findings highlight the value of introducing flexible frictions and positive motivational feedback to enhance meaningful use and limit habitual, less meaningful behaviours.

7.2 Method

7.2.1 Participants

All 20 Participants from the diary study were invited to take part in individual co-design workshops. However, only 19 participants (6 females and 13 males), aged between 19 and 37 years took part in the co-design workshops. Fifteen participants later, took part in the final individual one hour interviews. The workshops took place in small groups, attended by 2 or 3 participants. This group represented a diverse range of educational backgrounds and occupations. Participants were predominantly students, including undergraduates and PhD students. Specifically, 8 participants were pursuing their PhD degrees, while 2 were engaged in undergraduate programs. One participant was a high school student currently undertaking their undergraduate studies, reflecting a range of

educational stages. In addition to students, the group included individuals in professional roles such as teaching assistants, researchers, and a social media community manager. For instance, 4 participants worked as researchers, and one participant held a postdoctoral position. Participants also varied in their higher levels of education, with 3 holding PhDs, 10 holding master's degrees, 2 holding bachelor's degrees, while 4 were working toward completing diploma and undergraduate degrees. The age distribution and professional diversity among participants ensured a balance of perspectives, ranging from younger individuals in the early stages of their education to experienced researchers and working professionals.

7.2.2 Procedure

This study comprised of co-design workshops followed by interviews. The co-design workshop included three parts: an introduction session where participants were introduced to the aim of workshops and brief presentation of the summary of diary study findings to support participants' understanding of the value of these co-design workshops. The second part included two main activities focused on designing for limiting meaningless interaction, and for supporting meaningful interaction (Figure 12).

Participants were then encouraged to explore design concepts for the design frictions and proposed new ones. They were asked questions about the perceived benefits, challenges, suitable timings, and trade-offs associated with each friction type: cognitive, emotional, motivational, social and physical friction. For instance, they were asked: "*What is your overall feeling about [friction type]? Can you see any benefits? Any challenges? Would you prefer to use such friction? If so, for which apps and why? Can you think of other examples of this type of friction that may work better for you?*"

To support design for meaningful phone interaction, we focused on five main goals of emotional and physical wellbeing, work productivity including also time management, and attention training. For each of these goals, participants were provided examples of mobile apps supporting them, and asked if they have used their phone to promote these goals, i.e., *can you think and share 2 common situations when you intentionally and successfully have used your phone to*

improve your emotional wellbeing? We also asked what challenges they encountered with such apps and how they overcome them. Participants were further asked about other ways in which they may use their phone to support that aspect of wellbeing or to hinder it.

The third part consisted of individual interviews to explore participants' feedback on the impact of diary study on their phone use and reflection on co-design activities and proposed design, and in particular participants' views of the different types of friction discussed in the workshops.The workshops were conducted online, and facilitated through the use of the Miro digital whiteboard, which helped to articulate and collect participants' ideas and thoughts. The two main co-design activities are further described, including materials used in the workshops.

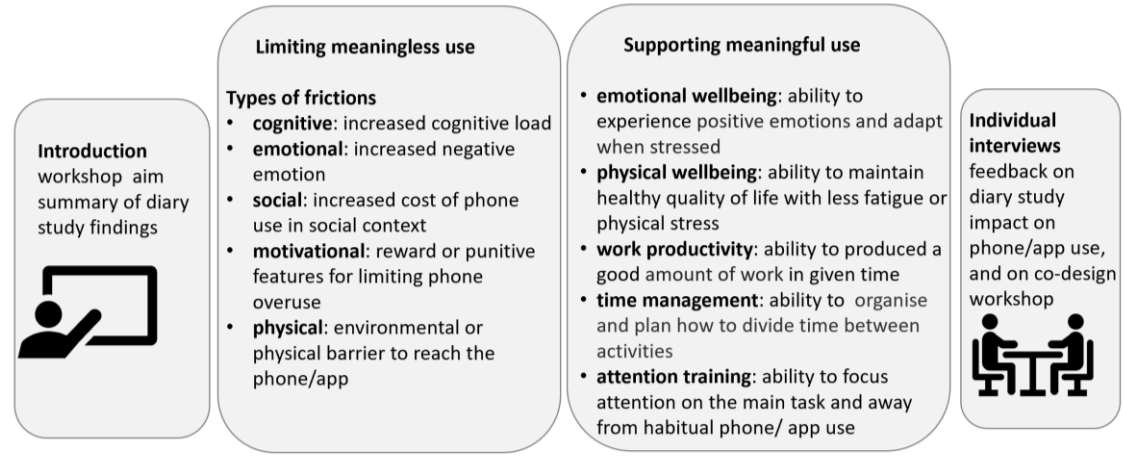


Figure 12: Co-design workshop procedure consisting of four parts: introduction, co-design activities for limiting meaningless phone use through five types of frictions, co-design for supporting meaningful use towards five goals, and individual interviews

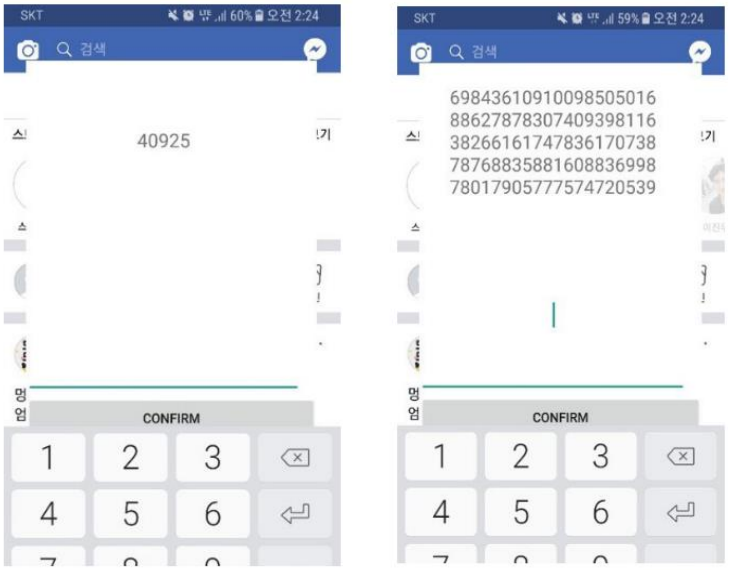
7.2.3 Materials: Conceptual Design for Types of Frictions

To scaffold the first co-design activity, participants were introduced to the concept of frictions as minor barriers or interruptions aimed to discourage meaningless use, and to the five types of frictions that we generated and aimed to explore through the workshops: cognitive, emotional, motivational, social and physical frictions.

Lastly, they ordered the friction types in decreasing order of importance and explained which types they would uninstall from their phones.

The identification of these types of friction is grounded in the still limited theoretical exploration of frictions and how they can be designed for. The rationale for the proposed five types of frictions is based on main cognitive, emotional and motivational aspects underpinning them, while social and physical frictions relate to the context in which the frictions are experienced. To better communicate these types of frictions, they were introduced with brief definitions, and illustrated with design exemplars identified from the state-of-the-art, although the articulation of different types of frictions has been limited in previous work. These are further described.

Cognitive frictions. We defined these as those frictions that increase the cognitive load prior to overusing the phone or app users, in order to limit it. For example, these include small cognitive tasks that require users' attention before using the phone or a specific app. The rationale for cognitive frictions is grounded in some previous work highlighting the value of small cognitive tasks such as entering a random set of digits intended to make users stop before engaging in phone overuse (J. Park et al. 2018; J. Kim et al. 2019). Figure 13 provides screenshots from Park et al. (2018) illustrating this cognitive friction. This friction may be used whenever the user launches specific apps whose use they aim to limit (the user decides in advance which are these apps), and the task challenge increases with the amount of time spent on that app.



(a) Minimum intensity (b) Maximum intensity

App Usage Interval	Number of Inputs
~ 1 min.	100
1~5 min.	89
5~10 min.	72
10~15 min.	58
15~20 min.	29
20~25 min.	14
25~ min.	5

Table 1: Parameter table that represents usage interval time versus total required numbers to type in.

Figure 13: Example of cognitive task (entering series of randmon numbers, increasing in length to increase intensity of task) (J. Park et al. 2018)

Users were introduced to a second exemplar of cognitive friction as puzzles of different types such as Maths, Word, General knowledge puzzles including short cognitive tasks which users could decide to use prior to engaging in the use of specific apps whose screen time they would like to limit. Figure 14 provides an overview of some screen shots illustrating this design concept for cognitive friction.

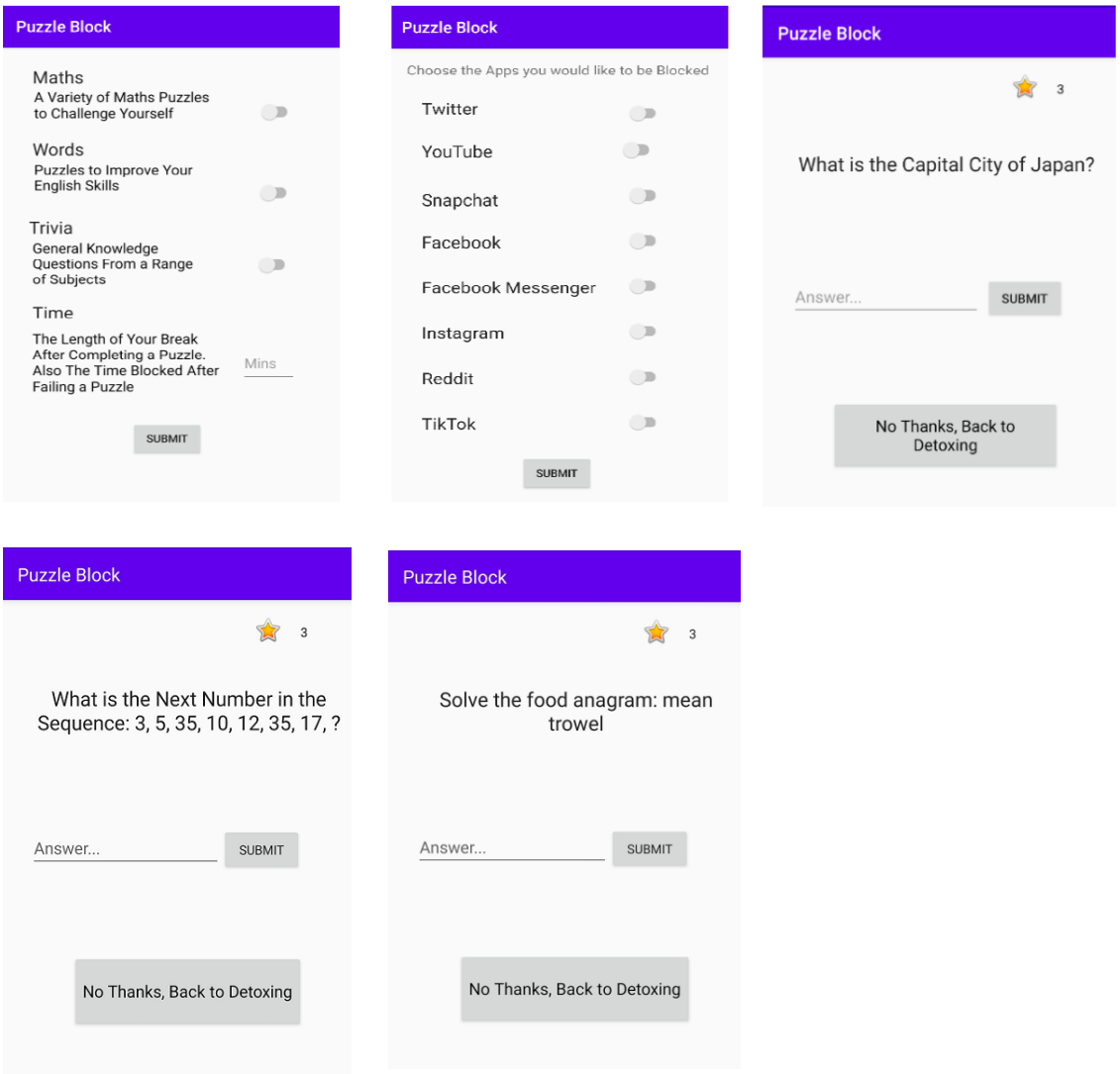


Figure 14: Puzzle Block app screens showing selection of puzzle (top lef), apps to target (top middle) and examples of the puzzles (Trivia, Math, Words)

Emotional frictions. We defined these as those frictions that lead to a low intensity negative emotions or emotional discomfort, such as mild frustration, before engaging with the targeted apps whose use people would like to limit. These frictions are in sharp contrast with the prevalent focus on positive users experience (Eyal 2014) which however can lead to addiction to problematic use (Elhai et al. 2016). Emotional friction is illustrated with micro intervention of screen dimming which will make it more challenging to continue use, triggered for instance by using a specific app beyond the allocated time limit (Mobifolio 2022) as shown in Figure 15.

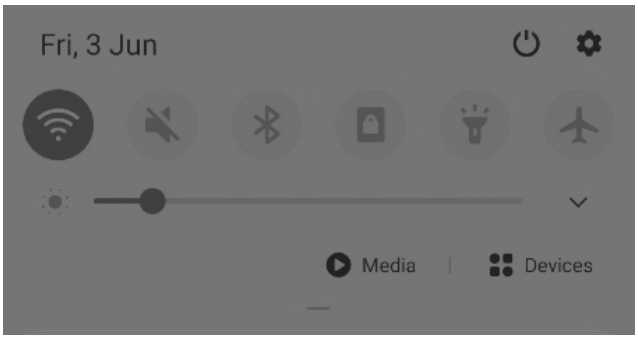


Figure 15: Android operating system screen - Example of dimmed screen display as an emotional friction (Mobifolio, 2022; (Almoallim and Sas 2022))

Motivational friction. We define these as frictions as those delivering reward or punitive features for limiting phone overuse. An example of a reward is a growing tree as part of a virtual forest (H. H. Lee 2021) as shown Figure 16 right.

Example of punitive feedback is the wilting of the virtual tree if users fail to limit their user as previously set, or the collapse of a virtual town which has been built, if apps are used during the set sleep time (Seekrtech 2022b; You 2020) (Figure 17, left).

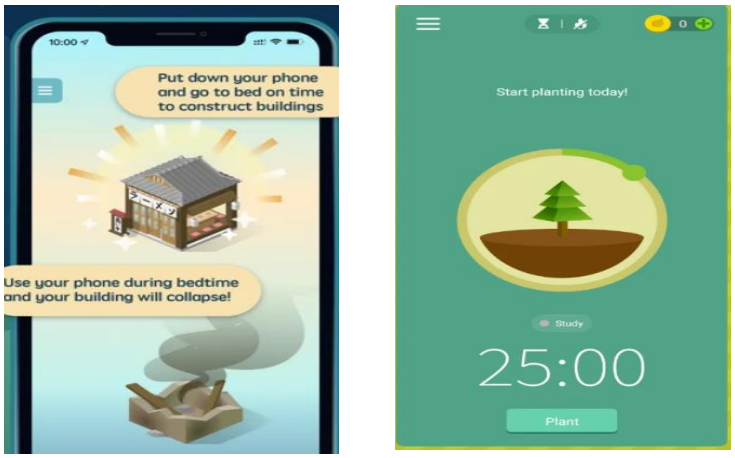


Figure 16: Examples of motivational friction

Social friction. We defined social frictions as the increased cost of phone or app use in social context. The rationale for this is the rich findings on the value of social support for behavior change (Kelly, Zyzanski, and Alemagno 1991). This type of friction was illustrated with screenshots of an app that allows people to

limit phone use together (Ko et al. 2016). It provides synchronous social awareness of each other's phone limiting behavior (Figure 17). This synchronous social awareness can arouse feelings of connectedness among group members and can mitigate social vulnerability due to smartphone distraction.

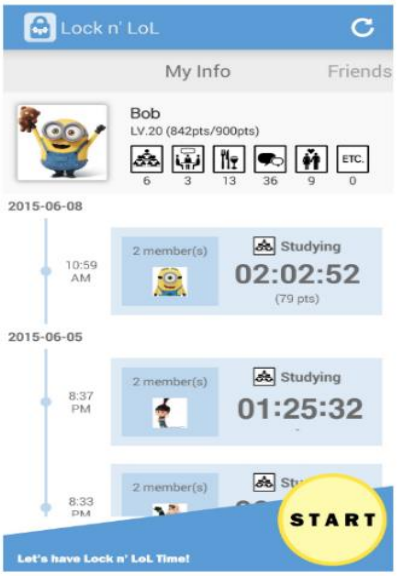


Figure 17: Examples of social friction (Ko et al. 2016)

Physical friction. environmental or physical barriers to reach the phone. This type of friction was illustrated by app which leverages location to prevent for example phone or app use in specific places such as campus (I. Kim et al. 2017) (Figure 18). This can be used by individual or a group, showing its value for acting also as a social friction: for instance by a group of classmates who can limit phone or app use together when they are in a specific classroom. This uses Wi-Fi fingerprints to identify the location of phones so when they are at the classroom it will nudge them to enter a virtual classroom to limit use.

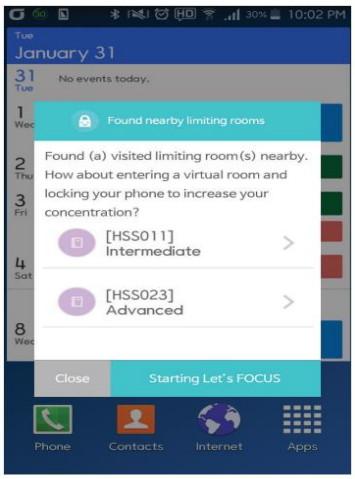


Figure 18: Example of physical friction (Kim Inyeop et al. 2017)

7.2.4 Materials: Conceptual Design for Meaningful Use

To explore how meaningful phone use may be supported, we identified five goals that literature on positive psychology (S. Jeong and Breazeal 2016) and meaningful experiences (K. Lukoff et al. 2018; Mekler and Hornbæk 2019) has also pointed to namely emotional and physical wellbeing as prerequisites for flourishing, work productivity including also time management, and attention training as promoted by mindfulness training (Daudén Roquet, Sas, and Potts 2023; Daudén Roquet and Sas 2021).

Emotional wellbeing is the ability to experience positive emotions and adapt when stressed. To support thinking about emotional wellbeing can be supported, we provided screenshots of an app providing Cognitive Behavioral Therapy (CBT) (Gugushvili et al. 2020; Bakker and Rickard 2018)for tracking emotions, identifying negative thinking patterns and how to deal with them.

Physical wellbeing is the ability to maintain healthy quality of life with less fatigue or physical stress. Typical examples for physical wellbeing apps are fitness apps such as Samsung Health and Google Fit (Berkovsky et al. 2009; Stuckey, Carter, and Knight 2017).

Work productivity is the ability to produce a good amount of work in given time. This was illustrated with screenshot of an app aimed to support focus on an offline task in order to increase work productivity (Lazy Geniouz Pvt. Ltd. 2022).

Time management is the ability to organise and plan how to divide time between activities. To illustrate this, we show screenshot of an app called 'Todiost. People and teams may manage tasks and work together on shared projects on devices, desktops, and web browsers (Doist Inc. 2022).

Attention training is the ability to focus attention on the main task and away from habitual phone/ app use. This focused attention can be implicit through the monitoring and limiting of phone or app overuse. It can also be explicit by focusing on offline activities without phone use, including also exposure to white noise to support concentration. For example, Forest app (Figure 19) which promote users to focus on their tasks for specific amount of time. The app provides visualisation of a tree being grown while the user in a focus mode (Seekrtech 2022a) .

Figure 19: Forest app with attention training feature (Seekrtech 2022a)

7.2.5 Data analysis

The qualitative data from the co-design workshops, and the interviews was analysed via thematic analysis (Joffe 2011; Terry and Hayfield 2020).

7.3 Findings

Before giving the findings in detail, first it's necessary to frame the presentation. In qualitative research, the focus is on depth and context rather than quantity, making numerical reporting inappropriate. It can oversimplify complex phenomena and mislead about representativeness (Cresswell 2013; Patton 2014). Instead, themes and patterns are emphasized to capture the richness of participants' experiences (Braun and Clarke 2006). This approach ensures a nuanced understanding without implying statistical generalisability (Denzin and Lincoln 2011).

7.3.1 Types of Friction and Value for Limiting Meaningless Phone Use and Supporting Meaningful Use

An important finding is that participants associated types of friction not only with limiting meaningless smartphone use, but also with supporting meaningful use. The latter was associated with pragmatic apps which are rarely used for hedonic purposes (e.g. Gmail), so feedback or reward from motivational friction, were deemed highly appropriate to encourage meaningful use of these apps. By contrast, punitive feedback of motivational friction, and more invasive types of friction such as physical frictions were viewed as inappropriate and excessive. The opposite was true for meaningless use: more intense types of friction such as lockouts and intense cognitive tasks were deemed suitable, and indeed appropriate, to mitigate meaningless phone use. Instant messaging and social media apps were frequently cited as problematic apps that would benefit from more friction.

7.3.1.1 Cognitive Friction

Cognitive friction forces the user to address a cognitively demanding task before continuing their original task. Before seeing the cognitive friction examples, some participants responded positively to the idea "*I have to do like a really hard math equation to get access to it. So, I do see quite a good potential*" [P4], and others believed its use may be appropriate "*where there's not really any sort of purpose with the interaction*", such as "*scrolling forever with Twitter*" [P17].

In contrast, some participants described cognitive friction as "*distressing*", noting preference for "*more kind of gentle ways that you could discourage meaningless phone use*" [P12].

Interestingly, after seeing design exemplars of examples of cognitive friction, participants seemed more open to such measures, which were described as "*engaging*" [P9, P15] and even "*fun, so I'd probably enjoy it*" [P3]. With respect to different types of puzzles, Maths questions were most preferred "*I would pick the Math one cause I feel like more general, I guess*" [P17], and especially Maths games such as Sudoku, "*because it's gamified, I guess it's more fun than just answer some random math question*" [P17].

However, cognitive friction could also negatively impact by interrupting the "*flow of ideas*" [P3]. As a result, only hedonic social media apps such as Facebook, Instagram, and TikTok were deemed suitable candidates for cognitive friction. The timing for when specific types of friction are best delivered also emerged as an important factor with a strong preference for preventive measures: "*Kill it before you open it. So I think that would the best time to actually use that friction*" [P15]; "*That's the best time instead of, you know, halfway while I'm engaged and then something just pop up*" [P9]. Notably, one participant suggested a 'smart' cognitive friction measure based on usage: "*I would maybe suggest like putting it when the app is open repeatedly*" [P10]. These comments were made mostly in the context of cognitive friction, however the participants did not mention other types being ruled out.

7.3.1.2 Emotional Friction

Emotional friction mitigates traditional design practices that result in emotionally rewarding phone interactions: by causing minor, temporary emotional discomfort, it helps users to slow down and limit phone or app overuse. Before seeing emotional friction examples, the participants reported strong negative views "*It seems really inappropriate that a friction would be negative and not something positive. It just seems quite dangerous or very questionable*" [P12]. Many recognized they did not want to experience negative emotions [P3, P19], while very few acknowledged this approach could also "*lead to do good things*" [P11].

After seeing the examples of emotional friction, participants expressed strong preference for app-level interventions as "*it would be too extreme to lock the whole phone*" [P10]. Several reasons were provided to support this preference, including the possibility of disrupting productive work sessions [P17], and suddenly needing the phone for emergencies [P3, P6]. Nevertheless, some participants cited messaging and social media apps as suitable candidates for emotional friction, especially TikTok to prevent mindless scrolling [P3, P8, P12, P19].

7.3.1.3 Motivational Friction

Motivational friction employs positive and negative feedback to encourage the user to avoid the phone or specific apps for long periods. Before seeing specific examples, the participants already seemed familiar with this friction type, which some described as "*very helpful*" [P11] and potentially "*quite good*" [P3]. After seeing the examples, participants still viewed motivational friction positively and the focus shifted to the feedback element. Positive feedback was strongly preferred as it can "*give people a really good mindset*" [P6] and convert negative experiences into positive ones [P15]. Notably, one participant felt motivated after trying an app that used badges to encourage increasing physical steps [P5]. Others preferred a more pragmatic, goal-focused approach: "*prefer my motivational friction to be more geared towards my personal goals, more personalized*" [P5]. Negative friction was largely dismissed since it may "*dissuade people rather than encouraging them*" [P5]. Participants cited messaging and social media apps, especially TikTok [P3, P11, P12] and Instagram [P10, P17], as target apps for intervention, whereas rarely or infrequently used apps (e.g. banking apps) did not need friction [P6, P17].

7.3.1.4 Social Friction

Social friction increases the cost of using the phone in a social setting by increasing user's social awareness and encouraging behavioral change. Initially, participants responded positively to emotional friction: "*I'm positive at the moment about it. I think it might be just a kind of safer way to give frictions to people*" [P12]; "*You might be able to compare how you're using your phone with your friends. I think it could be useful*" [P12]. However, the social element was also viewed as a potential drawback as social friction depends on the participation

of other users and could result in negative pressures [P17, P6]. After seeing social friction examples, participants still viewed it favorably as "*Seeing two members are studying. I think it would work really well. I would also be kind of motivated and encouraged to study*" [P10]. Social friction was reportedly "*helpful for parents and teachers*" [P6] at the phone and app levels and only potentially problematic with apps that store sensitive information, such as health and banking apps [P6, P17].

7.3.1.5 Physical Friction

Physical friction prevents users from using the phone or specific apps by making the phone harder to access, such as putting it in another room. Many participants expressed strong concerns about situations where the phone is needed to do work [P3], complete time-sensitive tasks [P12], and manage emergencies [P3, P6, P10, P13, P4]. A few participants viewed physical friction as helpful to avoid unnecessary phone use at the gym [P6] or before going to sleep [P16].

After seeing the design exemplars, most participants still viewed physical friction as ineffective and unnecessary: "*I'm not going to use it as long as the kind of apps have lots of ability to control the phone and the apps*" [P11]; "*I don't need to go for location-based services or any Wi-Fi fingerprint techniques to eliminate my access*" [P11]; "*I don't really see this working for like a home*" [P3]. Participants suggested employing physical friction at the app level to reduce mindless scrolling of social media apps such as Facebook, Reddit, and TikTok [P12, P6], but not pragmatic apps such as Calculator [P17] and Google Suite apps [P3]. In this instance, many participants classified communications apps, including calling, email, and messaging apps, as pragmatic, noting that "*they should not be restricted in any way because they are important*" [P12].

7.3.2 Supporting Meaningful Phone Use: Relationship between User Goals and App Perceptions

Participants consistently identified apps such as Google Drive, Gmail, and MS Teams as pragmatic 'for work' apps which resulted in meaningful smartphone use. They also distinctly associated 'for leisure' phone use with social medial platforms such as Facebook, Instagram, and TikTok, and entertainment apps

such as Spotify and YouTube. These findings are consistent with the literature (Beyens, Frison, and Eggermont 2016; K. Lukoff et al. 2018; Mardhiyyah et al. 2022). Across workshop sessions, participants mentioned leisure apps more than other app types, suggesting these apps are more frequently used and important to them.

Moreover, several apps were used for multiple goals. For example Discord app was used for both work and leisure, Snapchat for leisure and phone checking, and Chrome for all three purposes work, leisure, and phone checking due to its many possible uses. This indicates that user goals, rather than the inherent properties of an app, determine the use of the app.

Throughout the workshops, three additional user goals were identified and investigated: work productivity, time management, and attention training. Work productivity was a major reason to avoid phone-level friction since many participants required the smartphone to work, study, or complete similar activities. At the app level, different measures were considered to avoid unnecessary sessions with addictive apps, such as employing social friction for Facebook or motivational friction for WhatsApp. Consistent with the literature (Bertschek and Niebel 2016; Pinochet et al. 2020; Ng et al. 2017), instrumental apps such as Calendar and Remainder were viewed as non-problematic and thus not in need of friction.

Many participants identified time management as both necessary for work productivity and difficult to achieve with ubiquitous access to smartphones. Some participants reported using instrumental or pragmatic apps such as Calendar and OneNote for effective time management. However, many cited Facebook and YouTube as problematic apps which encouraged mindless, endless scrolling sessions and resulted in poor time management. This then reduced productivity and quality of life, including causing difficulties in achieving work-life balance [P5, P15, P17] and reduced quality of sleep [P5]. All of these are known effects of poor time management caused by smartphone overuse (Kheirinejad et al. 2022; Rathakrishnan et al. 2021). Most participants were receptive to the use of friction to reduce problematic app use, including cognitive friction to avoid habitual YouTube use [P16] and physical friction to avoid Facebook while at work [P6]. Attention training refers to training undergone to improve one's focused

attention and concentration skills. Similar to time management, attention is needed to be productive, yet difficult to achieve and maintain due to the ubiquitous access to smartphones and other devices (Liebherr et al. 2020; Skowronek, Seifert, and Lindberg 2023; Wilmer, Sherman, and Chein 2017; S. H. Jeong et al. 2016; Uncapher, K Thieu, and Wagner 2016). Participants discussed attention training options such as the Pomodoro Technique [P11], i.e. alternating 25-minute work sessions with 5-minute breaks, and white noise, which is task-irrelevant auditory input containing many frequencies of equal intensities (Broadbent 1958). Some participants viewed white noise positively, such as listening to rain sounds or library noises while studying [P3, P19]; others preferred listening to music or working in silence [P4, P10].

7.3.3 Novel Design for Friction to Support Digital Wellbeing

Workshops findings showed that, overall, participants sought to achieve a healthy balance between completing pragmatic tasks such as work, study, making arrangements with colleagues and enjoying moderate leisure sessions such as watching videos or chatting with friends; in other words, they sought digital wellbeing. For instance, participants also reportedly use fitness apps and related technologies (e.g. Apple Watch) to improve their physical wellbeing and social media apps to improve their emotional and social wellbeing.

This is an important outcome has it underpin the working definition of digital wellbeing grounded in our empirical findings; digital wellbeing is the state of maintaining a healthy relationship with technology, using it in meaningful ways to achieve goals and generally improving one's mental, emotional, physical, and social health. This definition echoes previous findings (Roffarello and De Russis 2019b; Vanden Abeele and Nguyen 2022).

Emotional wellbeing was particularly important to participants: emotional friction provoked the strongest negative reactions and remained the least preferred option across the workshops. This means that emotions should be carefully considered in the design of all friction types.

Participants' preferred personalizing different types of friction for instance to inject 'fun' in cognitive friction, positive motivational friction, and positive social friction. For cognitive friction, participants suggested using Sudoku puzzles, Maths puzzles which can be answered by drawing, and open-ended questions such as "*What do you want to achieve today?*" [P5]. For motivational friction, suggestions included encouraging reminders and 'gamification'. For social friction, most suggestions focused on increasing the social component to provide users with a stronger support group and satisfy NTB. Suggested features included a shared progress bar for group study sessions, setting goals and time limits with others; and receiving positive feedback for adhering to shared targets (e.g. studying for two hours).

7.4 Discussion

7.4.1 Friction Design for Subjective Smartphone Use

To recall, the purpose of the co-design workshop was to explore users' diary study results, to help inform an understanding of their view on meaningful and meaningless and gather feedback into how to design for reducing meaningless phone use, particularly through different types of frictions. The overall research questions were:

1. How can we design for different types of friction to limit meaningless use?

2. How can we design for meaningful use to support goals related to emotional and physical wellbeing, work productivity, time management and attention training?

In this section the findings from the workshops will be presented with reference to those questions, walking through the subjective nature of meaningless and meaningful, and feedback across the categorisation of different types of friction.

Participants had consistent views on which apps are typically used for work (e.g. Gmail) and leisure (e.g. TikTok). However, they also reported that many apps can be used to achieve context-dependent goals which are not strictly aligned with app's primary function. This highlights the need for friction designs that can adapt to user goals in real time. For instance, instead of categorising apps as

strictly ‘productive’ or ‘distracting,’ friction tools should allow users to set dynamic preferences based on their current tasks or mood. This approach would acknowledge the flexible and evolving nature of smartphone interactions. For example, previous research by Lukoff et al. (2018) shows that Snapchat is a passive, officially ‘social’ app, yet 66% of their study participants used it as an active ‘communication’ app.

Multipurpose apps lend themselves particularly well to meeting different user goals as they are designed to offer multiple functions and flexible features that can be easily adapted to different contexts of use. For example, different participants reported using the Discord app to complete work tasks and for leisure purposes across our workshops. Another example is the WeChat app, which integrates core social media functions such as instant messaging and photo sharing with more pragmatic functions such as mobile payment services (Montag, Becker, and Gan 2018). Therefore, there is a need to offer friction mechanisms that support goal tracking within such multipurpose apps. For instance, apps could include pop-up reminders tied to user-defined goals, such as alerts for completing a task or time limits for leisure activities. This ensures that friction works as a subtle guide rather than an intrusive block, aligning the app’s use with the user’s intentions.

The subjective nature of smartphone use was clearly reflected in the participants’ reactions to different types of friction. All five friction types elicited strong and often contrasting reactions: emotional friction was both “inappropriate” and a measure that could lead to positive outcomes; cognitive friction was viewed as “fun” by some participants and “distressing” by others. Even motivational friction, which was generally the preferred option among participants, was not universally welcomed as it could also discourage users from using the smartphone to engage in meaningful social interactions. As a result, friction tools should include an adjustable intensity feature, enabling users to modify the level of friction depending on their goals and tolerance. For example, motivational friction could range from subtle nudges, such as inspirational quotes, to stronger interventions like enforced breaks from the app. While social apps are prone to overuse and meaningless use, there are many beneficial and desirable benefits of

mobile phone mediated social interaction, particularly relating to psychological health (Chan 2015a; Valkenburg and Peter 2009).

Buidling on these findings personalisation emerges as the cornerstone of effective friction design. Personalisation can support meaningful smartphone use and help users limit meaningless interactions (Barros et al. 2013; Terzimehić et al. 2022). Emotional and cognitive friction could include playful or gamified elements, such as interactive puzzles to unlock certain apps, making the process less tedious. Additionally, users should have the ability to define what constitutes "meaningful" and "meaningless" interactions themselves, ensuring that frictions are tailored to their unique needs and contexts. However, this design implication is in contrast with other research work and existing apps that promote a more invasive, stricter approach that effectively forces user to adapt to the friction rather than the other way around. Digital locks are particularly common: several apps are designed to block problematic apps or automatically lock the phone's screen based on smartphone usage data (Almoallim and Sas 2022; Kim Inyeop et al. 2017; J. Kim et al. 2019). By shifting to a user-first perspective, friction design can empower individuals to take control of their smartphone use rather than feel controlled by the app or device itself.

7.4.2 Friction Features and User Acceptance

Workshops allowed us to identify several key features to design effective types of friction compatible with subjective, context-dependent smartphone use. Participants indicated a strong preference for app-level friction to account for the manifold uses of smartphones in everyday life (Szyjewski and Fabisiak 2018; D. Wang, Xiang, and Fesenmaier 2016). To make this actionable, app-level friction should include customisable options such as adjustable timers or usage thresholds for specific apps. For example, users could set limits for TikTok during work hours but allow unrestricted use in the evenings. For the same reason, the timing of the different types of friction was important. For example, blocking notifications from social media could be desirable in some contexts and undesirable in others. Adaptivity was another desirable feature, such as blocking notifications reflecting user's current context (e.g. in class, travelling on a bus), or recent smartphone usage (for example switching from one app like mail, or

another like Facebook). Designers could incorporate contextual AI into friction features, allowing apps to detect the user's environment through calendar events, location data, or usage patterns. For instance, an app could automatically suppress notifications during meetings while allowing urgent calls to come through. These adaptive frictions should also be easy to override to prevent frustration in unpredictable scenarios. This feature requests closely reflect the nature of smartphone notifications, which are typically designed to seem new and important (Du, Kerkhof, and van Koningsbruggen 2019; van Koningsbruggen, Hartmann, and Du 2017).

In addition to these desirable features, participant responses highlighted two key user needs that must be met to ensure the long-term use of friction: emotional wellbeing and privacy. Emotional friction was heavily criticized by participants for deliberately aiming to cause emotional discomfort; many participants also rejected physical friction because it may cause FOMO-induced anxiety (Rozgonjuk et al. 2020). These reactions indicate that friction with perceived negative impact on user's emotional wellbeing are unlikely to be used in the long term or indeed even installed. As an alternative, friction tools could promote positive reinforcement strategies rather than punitive measures. For example, users could be rewarded with motivational messages or small achievements for limiting meaningless phone use. This approach could enhance emotional wellbeing by turning the experience into a supportive process rather than a negative one. Concerning privacy, many participants rejected social friction measures that rely on data sharing as this may cause embarrassment or uneasiness, suggesting that most smartphone-related data is viewed as personal, rather sensitive information (Audrey et al. 2016). Therefore, designers must implement clear privacy policies and transparent data use practices. For example, friction tools should allow users to opt out of social sharing entirely and keep their data anonymized. Providing detailed explanations of how data is processed can also increase user trust and acceptance. This suggests that types of friction with clear, comprehensive privacy settings are more likely to be adopted and used in the long term.

7.5 Interview Findings

7.5.1 General Friction Preferences

In assessing and comparing various types of friction, participants generally preferred app-level friction to phone-level friction, which was viewed as excessive: "*where your phone is locked till midnight and there's nothing you can do, that would be a massive annoyance*" [P19]; "*Absolutely not willing in a case where I can't use my phone*" [P19]. Participants also indicated a strong preference for positive or rewarding rather than negative or punitive motivational friction [P5, P13, P16, P17]. Moreover, participants consistently highlighted the need for adaptivity and personalisation of friction types as "*certain people will have to use certain apps more than others just because of their personal circumstances*" [P13]. Key personalisation options included being able to choose the target apps for friction [P3] and set custom goals and targets [P1, P16]. These requirements were partly driven by practical considerations to ensure the friction types can fully address unique user needs such as targeting specific apps during user-specified periods. However, the requirements also indicate a need to always feel in control of the smartphone to avoid negative feelings such as anxiety [P5] or worrying about having "missed something" [P17]. Anxiety, FOMO, and general distress are known effects of smartphone separation, particularly for users struggling with overuse (Beyens, Frison, and Eggermont 2016; Gui et al. 2023; Yildirim and Correia 2015). Nevertheless, flexibility should be embedded in the design of frictions, as many participants noted, inflexible solutions may cause excessive frustration and the subsequent uninstallation of the friction.

Participants also indicated a clear preference for interventions that encourage meaningful interactions rather than discourage meaningless ones. In this case, motivational friction were particularly preferred: it evoked the least stress, was deemed the best option for attention training [P4] and behavioural change [P17], and positive feedback (e.g. rewards) could be highly motivational. These findings are consistent with those from previous work showing that people naturally prefer, and have more positive reactions to, positive feedback (Young et al. 2017), including feeling more motivated (Burgers et al. 2015).

7.5.2 Cognitive Friction

Cognitive friction was viewed as an effective option to prevent the mindless use of social media apps but unsuitable for pragmatic apps, including instant messaging apps (Table 11). Cognitive games or puzzles were the preferred type of friction as they are inherently rewarding and may also lead to learning [P10]. However, the puzzles should not repeat or be excessively difficult [P10]. Several participants also highlighted that cognitive friction could be more beneficial when paired with contextual triggers, such as reminding users to engage in a puzzle after spending a set amount of time on an app [P8, P14]. Some participants were more supportive of cognitive friction when it was seen as an optional, non-intrusive choice [P11].

Table 11: Apps for cognitive friction

Suitable Apps	**Reason**
Instagram, TikTok, Twitter	Prevent habitual, mindless scrolling
Facebook, YouTube	Prevent long sessions and excessive distraction
Unsuitable Apps	**Reason**
Snapchat, WhatsApp	Fear of missing important communications
Email	Reduced productivity
Google Fit	Might discourage beneficial long-term use
Duolingo	Might discourage learning

The table reflects the views of many, but not all participants. For example, P15 noted that cognitive friction "*it's not really helpful because it would create a negative experience for users*" who expect a "*seamless experience*" from messaging and social media apps. Others, like P9, mentioned that cognitive friction might be less effective for apps like Google Fit, which they use for health tracking, as it might discourage long-term beneficial use if it feels disruptive. Similarly, some participants rejected cognitive friction in apps like Duolingo, noting that it might interfere with the learning experience.

7.5.3 Emotional Friction

Emotional friction was viewed positively by some participants and "*like muddying the waters*" [P12] by others. Many of them feared missing important communications and being unable to handle emergencies [P10, P15], so emotional friction was only deemed suitable for selected social media apps (Table 12). Participants expressed that emotional friction should provide users with flexible control over activation, such as the ability to set temporary overrides for urgent needs [P9]. Others noted that emotional friction was more acceptable when linked to specific app usage thresholds, for example, triggering reminders or warnings after extended use of platforms like Instagram or TikTok [P13]. Some participants considered minor interventions such as 15-minute timeouts for non-essential apps like TikTok [P10], while others suggested subtle nudges, like notifications summarizing time spent on apps, as a less intrusive method to influence user behaviour [P8, P14]. Many were unwilling to accept any trade-offs [P1, P3, P4, P11].

Table 12: Apps for emotional friction

Suitable Apps	**Reason**
Instagram, Snapchat, TikTok, Twitter	Prevent habitual, mindless scrolling
Unsuitable Apps	**Reason**
Facebook, Snapchat, WhatsApp	Fear of missing important communications
Email, MS Teams	Avoid workflow disruptions
Navigation apps	Need for directions

7.5.4 Motivational Friction

Motivational friction was the most popular friction type, especially when implemented with positive feedback features such as rewards [P1, P5, P10, P14] which can help users to feel accomplished [P19] and achieve their goals [P16]. Several apps were identified as suitable for positive feedback, such as health and learning apps, and negative feedback, such as social media and gaming apps (Table 13). Participants emphasised that motivational friction should be flexible,

allowing users to tailor the frequency and intensity of feedback based on their preferences [P6, P13]. The most desirable feature was adaptivity, from setting custom time targets to study or avoid problematic apps [P11, P15] to choosing whether to use friction at all [P15]. Importantly, phone or app lockouts should not be excessively long and repeating feedback should be avoided since it may lead to mindless routine [P13]. Many participants also suggested that incorporating a gradual escalation of motivational friction, starting with mild nudges and increasing as needed, could enhance user engagement without causing frustration or resistance [P7, P9].

Table 13: Apps for motivational friction

Suitable Apps	**Reason**
Facebook, Instagram, Snapchat, TikTok, Twitter	Prevent habitual, mindless use
Duolingo	Encourage meaningful use
Notion, Trello	Redirect focus from the app to actual work
Gaming apps (e.g. Candy Crush), podcast apps, YouTube	Reduce excessive use
Health apps	Improve health
Unsuitable Apps	**Reason**
Email apps, Messaging apps	Fear of missing important communications
Slack	Avoid workflow disruptions
WhatsApp	Frequently used, meaning negative feedback is inevitable
Google Translate	Might need instant access to it

7.5.5 Social Friction

Social friction evoked mixed responses and suggestions from the participants. Employing other users to discourage smartphone use was viewed as effective and encouraging, especially seeing friends studying [P10], but also potentially counterproductive. For example, it could be harmful in emergencies or during

'bad days' when seeing productive friends could cause "*a bit sadness*" [P10]. Social friction was deemed appropriate for social media and gaming apps (Table 14), although many participants did not cite any apps since "*the goal of this friction is to kind of do some specific activity outside your phone*" [P10]. For this reason, many participants cited contexts suitable for social friction, such as studying in groups, or spending time with family or friends [P1, P9, P14]. Nevertheless, the main concern around social friction remained privacy, particularly regarding the sharing of app usage information [P5, P19] and personal information [P17].

Table 14: Apps for social friction

Suitable Apps	**Reason**
Facebook, Instagram, TikTok, YouTube	Prevent habitual use
Gaming apps	Prevent excessive gaming
Unsuitable Apps	**Reason**
Email and work apps	Fear of missing important communications
Tinder	Avoid embarrassing conversations

7.5.6 Physical Friction

Despite the wide range of app-level and phone-level features, physical friction was largely unappealing among participants: for example, it was described as too extreme, and more annoying than useful [P13, P17]. Several participants rejected more extensive interventions such as putting the phone in another room as this may cause anxiety [P5] and lead to missing important calls or messages [P3, P15]. However, some noted this could be viable in specific circumstances, such as before visiting a library [P12] or going to bed [P16]. At the app level, location-based friction using Wi-Fi fingerprints was viewed more positively: it was described as "*quite cool*" [P4] and even helpful to prevent phone overuse in school and worship environments [P4, P11, P19]. Suitable apps included social media apps, and pragmatic apps which may be used unnecessarily (Table 15), such as checking MS Teams outside working hours [P13].

Table 15: Apps for physical friction

Suitable Apps	**Reason**
Facebook, Instagram, TikTok	Prevent habitual, mindless use
YouTube	Encourage a healthy, active lifestyle
MS Teams	Improve work-life balance
Banking apps	Avoid fraud
Gaming apps (e.g. Pokémon)	Reduce excessive use
Burger King	Break junk food addiction
Unsuitable Apps	**Reason**
Calling, email, and messaging apps	Fear of missing important communications
Learning and studying apps	Might discourage learning

Further thematic analysis of the participants' reactions to this friction type revealed that most negative views stemmed from concerns about finding themselves in emergencies without a phone. Nomophobia, the fear of being without a smartphone, is a known phenomenon (Notara et al. 2021; Rodríguez-García, Moreno-Guerrero, and Lopez Belmonte 2020) which is strongly correlated with smartphone overuse (Kaviani et al. 2020).

7.6 Discussion

Findings from co-design workshop emphasized the concept of meaningfulness, which is central to eudaimonic well-being. Though meaningfulness often aligns with positive feelings, it diverges from simple happiness. Meaningfulness is linked to giving in relationships, enduring challenges for future gains, and reflecting on one's ideal self. Habitual smartphone use, entertainment, and passive social media engagement contributed to a lower sense of meaning. Participants expressed a sense of lost autonomy in these situations. Interestingly, they also acknowledged that, despite the lack of meaning in some interactions, their phone use occasionally provided brief escapes from negative emotions.

7.6.1 Positive Psychology and Design for Friction

The reflections and real-life examples shared by the participants during the concluding interviews provided valuable insights into their preferences related to frictions. Participants reaffirmed the desirability of several friction types and features discussed during the workshops, notably their clear predilection for motivational friction and the pivotal role of personalisation of all types of frictions to accommodate different, dynamic user needs.

Participants also reiterated and contextualized their preference for friction features where they saw some intrinsic value, like answering a general knowledge question and might learn something, highlighting the connection between positive psychology and meaningful smartphone use (K. Lukoff et al. 2018; Mekler and Hornbæk 2019). For example, preventive use of frictions such as targeted app locks were preferred to post-interaction feedback such as warnings triggered by opening a problematic app. Within preventive use of frictions, participants indicated a clear preference for features that encourage meaningful smartphone interactions rather than discourage meaningless ones. Many participants described positive feedback or rewards associated with motivational frictions as highly desirable as they associated these with positive affect and higher self-motivation. By contrast, negative or punitive feedback was undesirable and consistently associated with negative feelings including anxiety and stress, negative emotions, and reduced motivation. Consistent with previous studies (Marciano and Saboor 2023; S. Jeong and Breazeal 2016), these preferences indicate an awareness of the benefits highlighted by Positive psychology research for improving digital wellbeing. Positive psychology is a field within psychology that emphasizes the study and promotion of well-being, happiness, and human flourishing (Riva et al. 2012). It focuses on building strengths and fostering positive experiences, such as positive emotions, engagement, relationships, and meaning, which collectively support fulfillment in life (Buzguţa 2024). In the context of smartphone use, positive psychology encourages design approaches that not only limit negative behaviours but also support users' psychological well-being (Gaggioli et al. 2017), essentially using the device as a tool to actively cultivate happiness and resilience. It advocates for features that enhance positive emotions, motivation, gratitude, mindfulness,

social connection, and personal growth, as opposed to punitive designs that may foster stress, anxiety, or disengagement. When incorporated into smartphone design, positive psychology principles can guide users toward more mindful, productive, and fulfilling interactions (S. Jeong and Breazeal 2016), encouraging behaviors that promote long-term well-being and discourage the mindless, excessive use of mobile phones. These findings suggest that Positive psychology (S. Jeong and Breazeal 2016) such as motivational feedback can help users adopt and reinforce desirable smartphone use behaviors, leading to more meaningful interactions and less frequent meaningless interactions.

7.6.2 Gamification: Advantages and Challenges

Many participants recognized that gaming apps, which are notoriously addictive (Liu et al. 2016; J.-L. Wang, Sheng, and Wang 2019), are problematic apps that often lead to excessive smartphone use and detrimental health effects (Lopez-Fernandez et al. 2018). As a result, several gaming apps were deemed suitable targets for different types of frictions, particularly social, motivational, and physical friction (Tables 13–15). At the same time, gamification was repeatedly suggested as a design approach to increase the appeal and uptake of friction, such as having to solve a cognitive game or puzzle to unlock the phone's screen or specific apps. Effectively, games were viewed as both a potential trigger of, and solution to, problematic smartphone use. In turn, these behaviors can unintentionally increase meaningless smartphone use: for example, users may pick up the phone solely to win an enjoyable game that unlocks the screen. Therefore, the benefits of gamifying frictions should be carefully weighed against its potential drawbacks.

Chapter 8: Exploration of Cognitive Frictions: Puzzle App Use in-the-wild

8.1 Aim and Rationale

The outcomes from co-design workshops have shown the value of cognitive frictions, particularly for limiting meaningless overuse of social media apps which previous research has shown to be particularly problematic. There has been however limited empirical exploration of cognitive frictions (J. Kim et al. 2019), and even less in-the-wild. To further explore cognitive frictions, this chapter presents a novel mobile app: Puzzle Block app whose design leverages cognitive frictions for locking the phone, which was built by Luke Welsh, while student at Lancaster University. The Puzzle Block app was selected because it uniquely integrates cognitive frictions into a practical solution aimed at addressing meaningless phone overuse. Unlike other existing apps that focus solely on time-based restrictions or app-blocking mechanisms, Puzzle Block introduces an innovative approach by requiring users to solve math, trivia, or word puzzles as a form of cognitive effort to unlock their specific apps. The app's ability to operate seamlessly over other apps and provide customisable lockout options further enhances its applicability for real-world scenarios. It allows users to selectively block problematic apps, tailoring the experience to their individual needs and habits. By leveraging cognitive effort through puzzles, the app challenges impulsive phone use, encouraging users to reflect on their behavior.

This chapter provides an overview of the app, and a user study focused on the use of this app in-the-wild, with the aim to address the following research questions:

- What is users' perceived value of different types of cognitive frictions for limiting meaningless phone overuse in-the-wild?
- What is users' perceived value of different types of cognitive frictions to increase meaningful phone/app use in-the-wild?

8.2 Method

8.2.1 Material: Puzzle Block App

The Puzzle Block app uses different types of puzzles as cognitive frictions to lockout the phone in order to limit meaningless overuse of social media apps.

Puzzle Block is an Android app which runs over other apps to activate its blocking functionality for these apps, tracks and stores data on the use of these selected apps locally on the phone, alongside its own data on the use of specific puzzle, and of blocking information: app being blocked, blocking time/duration, and time of using the puzzle.

The Puzzle Block app contains 4 main screens: home screen, set up screen, set up screen for puzzle type and lockout duration, and selection of apps screen from where users can select the apps to which the lockout applies, i.e., apps to be blocked (Figure 20).

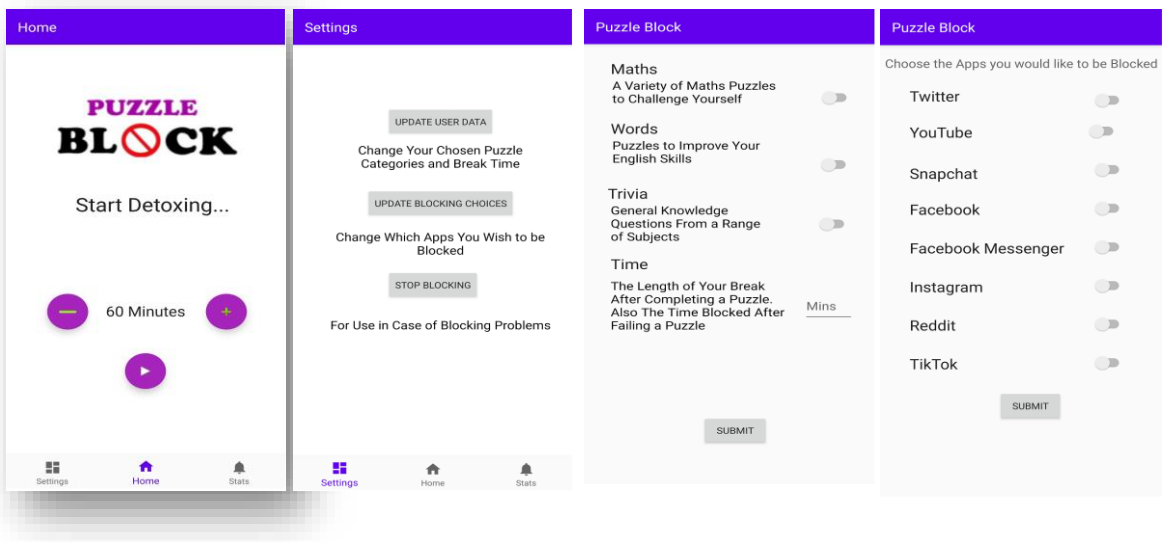


Figure 20: The Puzzle Block app main screens including home screen (left), set up screen (left middle), set up screen for puzzle type and lockout duration (right middle), and selection of apps screen for apps to be blocked (right)

The Puzzle Block app contains three types of cognitive puzzles: Math, Trivia, and Words puzzles, targeting small algebraic problems, general knowledge, and anagrams, respectively.

8.2.2 Participants

Participants were drawn from diverse educational and professional backgrounds. They were recruited through online social networking sites, and university flyers, with inclusion criteria of having an Android phone since the Puzzle Block app is an Android app. In total, 20 participants (9 male, 11 female) took part in the study.The participants' ages ranged from 19 to 40 years, with an average age of 28.9 years. Participants included students at various academic levels, researchers, senior research associates, an HR assistant, a business development manager, and a lecturer, reflecting a wide range of occupations. The educational qualifications of the participants ranged from secondary school to college, bachelor, A-levels, masters, PhD, and professional doctorate. The participants were studying or working in different capacities, including part-time and full-time roles, and others were employed in another country. This mix not only enriches the data but also ensures that the findings are reflective of a diverse population, crucial for the app's evaluation in real-world settings.

8.2.3 Procedure

Participants were given an initial briefing about the aim of the study and how to set up and configure the Puzzle Block application. They were also introduced to how to use the app and the tasks they would perform.

The Puzzle Block app was set up to be used for common online social media apps namely Instagram, TikTok, Twitter, Facebook, YouTube, Reddit, as well as Snapchat, WhatsApp, given that both empirical findings from the diary study and previous work have highlighted that such apps are more prone to be habitually used (Bayer, Anderson, and Tokunaga 2022). Also, as per previous studies, a two-week time period was chosen to explore the app in-the-wild (Roffarello, De, and De Russis 2021).

During each day of the two weeks, participants were to use the Puzzle Block app for a lockout duration of 5 minutes.

In week 1, the puzzles were randomized, so that participants could engage with all three different types of puzzles: Math, Trivia, Words.

At the end of week 1, participants were interviewed about their experience with the app, what worked well and main issues, app's impact on their phone/app use, and how the Puzzle Block app could be improved. They were also asked to select the type of puzzle they liked the most, to be used exclusively during the week 2.At the end of week 2 participants participated in a final semi-structured interview about their experience.

8.3 Findings

This section details the findings of the app evaluation study and shows the potential of cognitive frictions to reduce specific elements of phone use.

8.3.1 Findings of Week 1

8.3.1.1 Users' Preference for Puzzle Types: Difficulty Matters

Most participants mentioned that they preferred specific puzzle based on their perceived difficulty, aiming for the easiest puzzle. Almost most participants preferred Math puzzle (11 participants), followed by Trivia puzzle (5 participants), and fewer participants selected the Word puzzle (4 participants), while 1 participant not mentioned their preferred puzzle in week 1.

Criteria for being easiest to solve, for Math puzzle, were "*strongest subject*" [P4] and because it involves problem solving more than the other puzzles [P10]. For Trivia puzzle they can obtain "*the correct answer from the first attempt compared to the others*" [P3]. Some participants (2 participants) selected because they enjoyed its subject.

Less preferred puzzles were mostly Trivia; "*it gave me weird questions like what is the capital city of unknown country*?" [p14]. In some instances Math puzzle "*I cannot stand them*" [P9]. Notably, the Words puzzle was the least preferred because of difficulty with English words (P19).

With respect to suggestions for matching users' expertise with puzzle's difficulty, participants provided feedback on three areas; making the questions easier, making them more diverse, and for Trivia and Words to increase their accessibility to non British users or those whose English is not first language (P1).

Some participants suggested customisation and choice of the topics and some pointed that the app could better support user experience by being "*more attractive*" [p20] and "*a bit more fun*" [P11].

Participants continued suggestions to make the app more visually appealing (P8) or adding "*some gamification*" [P18], for instance through rewards [P14] [P16].

8.3.1.2 Puzzle Block App's Impact on Phone Use

An important finding is that 14 participants mentioned that the Puzzle Block app may have helped them reduce their phone use either because "*sometimes the puzzle too difficult, so I couldn't use the app*" [P8] or "*it made me more conscious of how much time I spend on my phone*" [P5].

The remaining 6 participants did not perceive an impact of the Puzzle Block app on their phone use, due to the rather limited 5-minute break time, perceived as too short to make a difference, or because they were not heavy users anyway so there was little to change. With respect to the Puzzle Block App impact on meaningful use, participants mentioned that it didn't change the apps they use on their phone (P8) on the one hand, on the other it transferred meaningless use into meaningfulness by the realisation that something more productive can be done (P2). Participants also mentioned the targeted apps were being used meaningfully "*I want to see something important like cooking*" [P10].

In terms of the app's impact on limiting meaningless phone or app use, participants mostly said there was an effect of "*improved self-management*" [P16], but some added "*helpful for the short term*" [P10]. Those who answered no, mentioned the time was too short or not using the phone much anyway.

Participants were equally split in relation to Participants' perception on changes to their habits and their own satisfaction.

The majority (12 participants) of users mentioned they became aware of how many times they checked their phone. Some mentioned it made no difference to them, but many mentioned the increased awareness motivated them to pick up the phone less or use certain apps less (8 participants) "*I'd have to solve another puzzle and that would reduce my screen time by a few minutes*" [P15], "*whatever the app I had blocked for the day, there were days I never went back to it, even*

though I had given a minute of a break time and that happened like 95% of the time" [P12] . Several (6 participants) mentioned that social media usage went down, though as per P14 one week is not enough to affect their social media usage.

Participants were divided over satisfaction on their level of social media usage "*the puzzle block helped with my scrolling habit*" [P20] but the narrow focus was also seen as counterproductive as the user think they are now over using LinkedIn in the same way they did with Instagram "*LinkedIn has replaced Instagram for me currently and I think that's not a very healthy sign*" [P12].

8.3.1.3 Puzzle Block App' Impact on Limiting Meaningless Use of Social Media Apps

Apps used for passing time were mostly TikTok, Instagram, Facebook, Messenger, YouTube and to a lesser extent LinkedIn, Snapchat, Reddit and Telegram. Some games were also referenced such as Legend of Slime which was referenced by 1 participant, while 3 participants did not identify specific games but mentioned that they need to reduce such use. When talking about reducing time, most participants mentioned the fact they could see their time being tracked and reported as an influential factory, rather than the puzzle app itself. Others mentioned being too busy and not using the phone much to pass the time - for example, having to attend classes again and so free time was reduced.

Where the puzzles were mentioned, it was often mentioned (5 participants) that the 5-minute break time was too short to affect behaviour, though it also had an impact for a few users who mentioned it as an interruption and prompt to remind them about their use.

8.3.1.4 Puzzle Block App' Impact on Meaningful App Use: Self-development, Productivity

Participants mentioned that the block only restricted certain apps, and didn't encourage other apps, so it had less impact on self-development or productivity. Some users mentioned that they considered the puzzles themselves to be meaningful and possibly supporting self-development, for example, learning trivia or improving English skills "*I guess the puzzles can be considered self-*

development in itself" [P7], "*I think you know, every time I answered the puzzle, I feel like there is something I'm going to learn today*" [p9].

Self-development use was tailored to specific social media apps, e.g. Instagram, LinkedIn, YouTube "*If I'm looking for any improvement in my skills for example in managing my time or something I'm using YouTube*" [P14]. Separately mentioned were Chrome (browser), Duolingo (Language) and Google (search). Work/productivity apps also included Email apps, Calendar, Teams/Zoom, WhatsApp, and Study Bunny which were used for purposeful things related to work or study "*I use an app called Study Bunny which it's it is just like it's a you can time how much you're studying*" [P13].

In brief, to be covered in the more general conclusion for both week's findings. The findings indicate that the entire experience, not just the design friction played a part; reflection with questions, and the puzzles in terms of interruption as well as giving a challenge or alternative activity option. Thus, such subjective views of Puzzle Block app on supporting more meaning phone use and less meaningless phone use was less clear as one week is insufficient to fully perceive such impact.

8.3.2 Findings of Week 2

8.3.2.1 Users' Preference for Puzzle Types: Difficulty Matters

An important finding is that the difficulty level of the puzzles must be adjusted depending on the user's ability and preferences, as indicated by many users (10 participants). Some participants complained of repeated or too simple questions, suggesting that puzzles, especially Math one, should match user's educational level. For example, P8 spoke of balancing the difficulty level depending on user's academic level, from high school students to PhD holders. Regarding personalisation, P2, p3, and P19 added that it would be helpful to include more random questions and to have the Trivia puzzles ranging from easy to hard.

Moreover, fun was experienced with Math puzzles (P5); however, some users noted that the puzzles were too difficult (P15) or otherwise not solvable without additional tools like calculators. Some potential solutions could be reducing the complexity of the puzzles, or making them more visual with shapes or graphics to better support the user solving them "*adding some graphic could help*" [P8], "*Or*

maybe making them a bit more visual as well" [P2]. There should also be more variety in Math and Trivia puzzles to increase engagement "*it's better to have more bank of questions*" [P10], "I would already know the answer because they've done them before, so possibly in the future more range of questions".

8.3.2.2 Puzzle Block App's Impact on Phone Use: Increased Awareness and Control

Study outcome suggested that the puzzles significantly impacted participants' awareness of time management concerning phone usage (9 participants). According to P13, the interruption caused by the puzzle allowed them to stop and think before they mindlessly use social media in a way that does not seem productive. This impact on conscious phone usage was observed primarily in the kind of puzzle interference on social media interaction and other applications. P13 said that due to the interruptions, they became conscious of how much time they were spending on social media platforms and, as such, started cutting down on their time. "It did limit some of the my app usage quite significantly because I struggled to solve the puzzles" [P15], "*the puzzles actually make me think rather than rather than I'm just scrolling*" [P11].

Trivia and Math puzzles helped participants to be more conscious of their phone usage. For example, P20 said they stopped using apps like Instagram after a Trivia puzzle as the frustration caused by the puzzle prevented them from continuing "*I actually was like frustrated with not having enough time to solve the puzzle, not having enough lives to solve the puzzles I was like, OK, I'm not even using this app*" [P20]. As recalled by P16, the puzzle worked as a "*kind of reminder for the time*". These puzzles serve as an intervention supporting uses to become more aware of their phone interaction.

8.3.2.3 Puzzle Block App' Impact on Limiting Meaningless Use of Social Media Apps

Findings indicate that the puzzles reduced meaningless phone usage, which contributed to doing more constructive activities. For instance, some (10 participants) participants also said that the puzzles had a positive impact on countering mindless scrolling through social media apps, and other non-productive applications. P15 pointed out that the difficulty of the puzzles made

them not want to use apps meaninglessly because they were focused more on solving the puzzles "*It's discouraged me from using and apps meaninglessly because the puzzles are hard to solve, so I'd spend more time solving the puzzle than meaninglessly scrolling*" [P15].

P10 also mentioned that since there was limited time for breaks, users became more selective of the apps to use during the time off "*sometimes I realize about the time constraint for the time break so I do not use it anymore*" [P10]. Nonetheless, P3 and P4 reported that meaningless use was reduced to a lesser extent, although this could have been attributed to the Digital Wellbeing app rather than to the puzzles "*with the awareness that it is running in the background and it is having some sort of record of how often you unlock your phone, how often you are using certain type of apps in general, it probably has decreased the usage for that and just made it less meaningful to pick up the phone and just scroll through*" [P4].

Trivia puzzles were considered effective in enhancing a more productive phone interaction. For instance, P7 mentioned that after engaging with the puzzle, they undertook self-development activities such as reading or studying using their phones "*So obviously because the meaningless time has been reduced, the overall share of meaningful phone usage has increased and I have been quite frequently using my phone for work related communications as well as kind of overall reading and studying*" [P7]. P16 even described the Trivia puzzles as 'very good' for time management "*I feel like it is a very good mean to manage time*" [P7], acknowledging their usefulness in facilitating better phone habits. Math puzzles helped to foster the positive use of phones since they encouraged more purposeful and less mindless scrolling in apps such as Facebook "*the puzzle prompted me to using my social media apps a bit less, so I had more free time of actually using it a bit more purposefully*" [P2].

8.3.2.4 Puzzle Block App' Impact on Meaningful App Use: Self-Development and Productivity

Puzzles impacted participants' personal development and efficiency. P14 shared that due to the puzzles, they have become more conscious of the time they spend online, and thus changed their usage for learning math and programming on

YouTube "*I started to use YouTube to develop my skills. I started to learn some Math. I think the puzzle helped me somehow to learn something and improve my skills and programming through YouTube*" [P14].

Although the puzzles did not directly contribute to self-development over the phone, they encouraged participants to use devices such as laptops for learning (P2). However, P15 and P18 mentioned that their phone usage had not impacted self-development, for example, because they only use the phone for some university matters or because there are other forms of entertainment, for instance, gaming console instead of self-improvement applications. To some, the puzzles helped them refresh prior knowledge for instance in Math domain (P19). Mixed responses indicate that although self-development may be a positive outcome of an individual's engagement in puzzles, it is contingent on the existing habits and motivation.

8.3.2.5 Puzzle Block App' Impact on Meaningful App Use: Social Connectivity and Intentional Use

Regarding social connectedness, puzzles played a moderate but notable role in the ways participants used communication applications, such as WhatsApp and Instagram. For instance, P6 expressed that they began to wonder whether their interactions were purposeful or just time-passing activities "*sometimes it came in my mind that I am using this app so for what purpose? just pass time?*" [P6].

P12 and P20 were mindful of their social media engagements, which made them spare minimal time on Instagram or Facebook for mere entertainment. However, the puzzles did not affect the emotional and social significance of the perceived importance of maintaining connections with friends and family. Although they realized they spent a lot of time on applications, the need for social connectivity did not change. Apps such as WhatsApp, Instagram, and Facebook are still considered essential for relationships and friendships, especially when staying connected with friends and families in different countries (P12, P13). This implies that while puzzles can help promote more conscious engagement with social media, they do not reduce the perceived relevance of digital connectivity for maintaining meaningful relationships.

8.3.2.6 Puzzle Block App' s Long-Term Use

Regarding participants' willingness to continue using the puzzle apps, there were different responses, with many of them expressing willing to continue using the app, with some adjustments. Some possible reasons why some participants (10 participants) said they would continue to use the puzzles include reducing meaningless phone use and having educative value, particularly in math skills. For instance, P2 perceived it as supporting feelings of entertainment and as avoiding mindless phone use. The Trivia puzzles were also valued for their efficiency in preventing time wasting, especially when participants had to focus on particular tasks "*I quite like being able to kind of prevent myself from mindlessly using certain applications, especially when I'm trying to focus on specific tasks like studying*" [P7].

Nonetheless, P12 refused to fully commit long-term to the puzzles due to problems such as a lack of user-friendly interfaces. P19 and P18 suggested more gamification elements, such as Duolingo's streak system, to increase motivation and engagement.

Another important outcome is that giving users more control over their puzzle experience may enhance their desire to continue working on the puzzles. For instance, P4 and P7 suggested that leniency should be applied when choosing trivia categories or topics related to users, as this would make the puzzles more relevant and, thus, easier to solve. Such flexibility minimizes the sense of being 'controlled' by the app (P3). At the same time, introducing more personalized elements, including new fields for users to select, can also improve motivation (P9). P4 elaborated on how it could make the puzzles more 'personal' by allowing users to reflect on their goals of using specific app before opening it "*making it a little bit more personal and I think maybe making it longer as well, so not just having one question*" [P4]. Personalisation is not limited to the content of the puzzles, but also how they are presented with recommendations on making them user-friendly (P18). This would make the experience more enjoyable and compel its continuity through the use of the app.

8.4 Discussion

8.4.1 Users' Preference for Different Types of Puzzles

Participants' preferences for different puzzles affected their engagement with other applications on their smartphones. According to Rahmillah et al. (2023) (Rahmillah et al. 2023), people positively perceive their phones and their impacts. The study found that Math puzzles were most preferred due to their ease, the subjects they were associated with, and the Trivia puzzles preferred by the knowledge enthusiasts. Word puzzles were the least preferred due to their perceived high difficulty level. The enjoyable nature of Math puzzles, where participants felt a sense of achievement after solving them, enabled them to shift focus away from addictive applications such as Instagram and TikTok. The ability to recognize how smartphone use affects overall well-being and a goal-focused attitude can be influential, too (Dennison et al. 2013; Parry et al. 2023). To create an environment for long-term behaviour modification, the puzzles must be freedom-oriented while offering content that inspires the users (Fitzgerald and McClelland 2017). From user's perspective, puzzles should be enjoyable, support existing habits, allow for goal setting and change, and offer rewards and sharing functionalities.

8.4.2 Impact of Puzzle Block App on Phone/App Use

Increased self-awareness aligns with digital wellbeing by encouraging meaningful phone usage (H. Park and Gweon 2015; Lynch 2021). Developing self-monitoring of social media activity, avoiding specific platforms, and incorporating mindfulness are effective ways of improving wellbeing (Johannes et al. 2018; Bentley and Tollmar 2013). Participants reported that doing simple puzzles allowed them to step back and reassess their usage of the apps. This behaviour concurs with Lukoff's (K. Lukoff et al. 2018) findings that brief, mindful interruptions make phone use more meaningful. However, not all participants reported a change in behaviour due to increased self-awareness. While some found the puzzle app helpful, they only used it briefly before returning to the previous meaningless app use. The uses and gratifications theory aids in

understanding how motivation and types of use (information searching or communication) create meaning in mobile phone usage (Cho et al. 2021). Users may sometimes experience low perceived control or a sense of purpose, resulting in phone-driven gratification (J. Kim et al. 2019). This could be evident with puzzle apps, which, in their design, create barriers, bring awareness of set time limits, and maintain focus and motivation among users (Almoallim and Sas 2022).

8.4.3 Puzzle Block App's Long-term Use

Personalisation has been widely acknowledged as one of the significant factors of user engagement (Jones et al. 2014). Kim (2013) (Y. H. Kim, Kim, and Wachter 2013) notes that motivation can result from tasks that are autonomous and have personal relevance. When participants had to select different difficulty levels in the puzzle task, they were more engaged and willing to continue using the app. This shows that voluntary lockout tasks are more effective when they are personalized (J. Kim et al. 2019). Also, the addition of a streak system, like Duolingo, suggests incorporating competitive elements to motivate users (Bitrián, Buil, and Catalán 2021). However, the lack of customisation in different puzzles affected the number of users who could not find the puzzle app engaging enough to ensure long term use (Chiappetta 2019). Participants who felt the puzzles were boring and irrelevant to their interests did not find any novelty in the app. This aligns with Tondello et al. (2020) (Tondello and Nacke 2020), who established that gamification and personalisation enhance user engagement. Participants would have preferred a system that allowed them to choose the type of puzzles they wanted, especially for Ttrivia ones, which they recommended should be given according to the area of interest. Likewise, for those participants who said they liked Math puzzles, findings showed that they wanted more diversity in the tasks to avoid repetition (Back, Brumby, and Cox 2010).

8.4.4 Puzzle Block App's Impact on Digital Wellbeing

Several participants pointed out that the Puzzle app increased their awareness of time spent on non-productive apps. This aligns with Howells et al. (Howells et al. 2016), who emphasized the role of digital interventions in fostering meaningful

smartphone use. As a result, participants reduced their time on entertainment apps, choosing more productive activities like studying. Tools that encourage time management can promote healthier smartphone habits by prompting users to reflect on their behaviour (Roffarello and De Russis 2023). However, not all participants experienced lasting improvements in their digital wellbeing. Some noted that although the puzzles temporarily disrupted their usage, they quickly reverted to previous habits after completing the task. This indicates that voluntary lockout tasks may provide only short-term benefits for individuals with entrenched smartphone behaviours (J. Kim et al. 2019). These findings suggest that mindfulness and self-monitoring practices could encourage reduced distractions and perceived stress, contributing to improved self-awareness (Cavanagh et al. 2013; Bennike, Wieghorst, and Kirk 2017; Hill and Updegraff 2012; Gámez-Guadix and Calvete 2016). Meaningful use enhances awareness of media habits, while self-monitoring offers insight into time spent on smartphones, potentially limiting overuse (Bakker and Rickard 2018; Gainsbury 2014; Bakosh et al. 2018). Therefore, these strategies enhance meaningful use and support behaviour change (Schuman-Olivier et al. 2020).

8.4.5 Limitation and Future Work

A limitation of this study is that it relies on self-reported data, which may lead to bias in participants' responses. Furthermore, the nature of puzzles is that users engage with them for a relatively short time, and our two week study does not capture app's long-term enduring impact. Thus, future research should investigate the impact of voluntary lockout frictions for extended periods and among various users. Including more objective data, such as screen time analytics, could offer better analysis. Examining the relationships between the level of personalisation in puzzle difficulty and rewards might also improve the overall intervention, thus providing a better approach towards regulating the overuse of smartphones.

8.5 Conclusion

This chapter explored the use of the Puzzle Block app as an a form of cognitive friction to address meaningless phone overuse and promote meaningful smartphone use. Through a two-week study involving 20 participants from diverse educational and professional backgrounds, the findings provided valuable insights into the app's effectiveness. Participants' preferences for puzzle types, particularly Math and Trivia puzzles, underscored the importance of difficulty balance and personalisation in ensuring engagement and continued use. Math puzzles were often perceived as enjoyable and manageable, while Trivia puzzles were appreciated for their educational value, though inconsistent difficulty and repetition reduced overall satisfaction. A significant outcome was the app's role in increasing self-awareness and conscious phone use. Many participants reported becoming more aware of their app usage patterns due to the puzzles' interruption. This awareness often led to reduced time spent on non-productive apps like TikTok and Instagram, with some participants redirecting their focus toward meaningful activities such as studying, self-development, or work tasks. However, the short duration of the app's lockout feature and limited personalisation prevented long-term behavioral changes for some users. Ultimately, cognitive frictions, like puzzles, as tools for digital wellbeing, foster reflection, self-control, and intentional phone use. However, there is a need for app improvements, such as gamification, enhanced personalisation, and adaptive puzzle difficulty, to increase long-term engagement. This research demonstrates that cognitive frictions can disrupt habitual smartphone use, but their effectiveness depends on user motivation, engagement, and customisation.

Chapter 9: Discussion

This chapter brings together findings from the scoping review and four studies to discuss the thesis's three main research questions and novel research contributions.

The PhD thesis focused on three research questions:

1. What is digital wellbeing and what are users' smartphone/app use, both meaningless and meaningful?
2. How can we better design to limit meaningless smartphone overuse and to support more meaningful smartphone use?
3. What is users' perceived value of micro-interventions illustrating different type of cognitive frictions for use on everyday life?

These are accompanied by three objectives:

1. What are users' experiences of phone/app meaningless and meaningful use?
2. How can we design novel technology-based micro-interventions to limit meaningless phone/app use, and support meaningful phone/app use?
3. What is users' perception of such micro-interventions when used in everyday life?

9.1 What is digital wellbeing and what are users' smartphone/app use, both meaningless and meaningful?

The scoping review highlighted that Digital Wellbeing was not only loosely defined but also organized around separate definitions. The most frequent one was the overuse of digital technologies including smartphones (Harris et al. 2020). Another definition encompassed delivery of 'traditional' healthcare, psychological support, and associated wellness activities (Bhatt et al. 2020; Burr et al. 2020; Craven et al. 2019). The third one focused on management of personal information and the threats enabled by digital technology (Forno 2019; Arslan et

al. 2019). Expanding further on this, the research mostly considered the negative impact of overuse of digital technologies, but within this, some of the research questioned the assumptions or sought to clarify the meaning.

This thesis adopted a definition of digital wellbeing that addressed problematic phone overuse and how it can be limited, as well as meaningful phone use and how it can be supported.

The research adopted Framework of Meaning (Mekler and Hornbæk 2019) to understand meaninglessness within smartphone overuse. It also references eudemonic and hedonic goals to understand motivation (Mekler and Hornbæk 2016; Busch 2020).

Users found meaningful interactions to be related to social connectedness and mitigating boredom, but also boredom was a trigger for much of users' perceived meaningless use; often social media apps were mentioned as being used to pass time or mitigate boredom meaninglessly. Meaningless use was attributed to managing mental states such as stress, low mood or providing relaxation. A final category of meaningless use centred around unnecessary interruption of fear of missing out (FOMO) – picking up the phone to check unnecessary notifications, or unnecessary checking for notifications out of habit, expectation or a "phantom notification" episode (Y.-H. Lin et al. 2013; Pareek 2017).

Participants recognised that often meaningless use followed the completion of a meaningful activity (e.g. continuing to scroll on a social media app without a clear aim after concluding a conversation).

In comparison with their self-reported usage, participants drastically underestimated the frequency and duration of their phone use, particularly browser apps which were less well reported, but also media apps such as TikTok. They did elaborate more on motivations which linked the usage of apps to eudemonic goals such as organising a social event or learning as much as to hedonic goals such as passing time or relieving negative feelings.

The work coalesced around connectedness as the target area of meaningful and meaningless usage, based on the findings of this phase of the research, informed by one of the Framework of Meaning attributes (connectedness, purpose, coherence, resonance, and significance). Particularly social media is a key area to

target for intervention since participants frequently use these apps; it provided the most scope for change, and evidence showed this was often due to continuation after meaningfully perceived activities, or as an automatic habitual reaction. The majority of motivations for using the phone were based on hedonic intentions (passing time, mitigating boredom, relaxation), with limited eudemonic scope such as “pursuing excellence”. This indicated a rich scope for investigation since it was observed that participants considered managing emotional state to be meaningful, purposeful, and therefore more eudemonic, which was not closely recognised with correlation to psychometric metrics collected as per observations in other research (D. A. Ellis et al. 2019). It has been shown in research that smartphone use, particularly social media is not a particularly effective method to manage emotional states such as anxiety, stress or low mood (P. Wang et al. 2017; Fioravanti et al. 2021).

Concerning the first objective, the main findings provided a more nuanced understanding of meaningful and meaningless interaction – predominantly based on extended use of apps without a clear purpose, or where more effective means may be available for users to achieve their goal. The identified relevant types of mobile applications included social media such as chat and media-sharing applications based on substantial usage time, reports, and observations of significant use within the scope of meaningless interactions.

9.2 How can we design novel technology-based micro-interventions to limit meaningless phone/app use, and support meaningful phone/app use?

The aim of this research question was to identify different strategies to manage smartphone use namely:

- Obstacles for the phone or app use
- Supporting awareness of reaching the set use limits
- Supporting focused attention

- Supporting motivation to keep within limits of use

Additionally, with the research emphasis on design friction (obstacles),we explored different types of design frictions that designers may employ:

- Cognitive friction
- Emotional friction
- Motivational friction
- Social friction
- Physical friction

For this, we draw from findings captured through complementary research methods.. The first included autoethnography-based investigation into existing digital well-being apps, a technique also successfully used by Roquet and Sas (2018). The second exercise continued the user-centred design approach started under the previous objective and took input from participants for suggestion, prioritisation and selection of potential interventions.

The functionality review of existing digital well-being apps revealed a range of strategies used for interventions to limit use namely: creating obstacles for the phone or app use, supporting awareness of reaching the set use limits, supporting focused attention, and supporting motivation to keep within limits of use.

These findings echo those form previous work on digital welbeling features and screen time focus Terzimehić et al. (2023). Focusing on the obstacles used it was possible to categorize them as per Table 16:

Type	**Range**
Force	Strong or Weak
Saliency	Explicit or Implicit
Temporal Aspect	Activated before, during or after excessive use
Social Aspects	Parental control or social commitment
Obstacle source	Generated by the digital well-being app or by users

Table 16: Classification of interventions

Strong obstacles cannot be circumvented including lockout of the phone/apps after a time limit was reached, interrupting use at a time limit and unchangeable time limits. Weak obstacles permit flexibility or limited monitoring of apps, relying more on notifications to users. Two apps directly implemented a UI-based microboundary obstacle, modifying the phone's home/launcher screen to limit the visibility of apps and require more effort (clicks) to find and use 'undesired' apps. One app (Forest) stood out by using a social commitment as an obstacle, targeting a context of use (with friends) to reduce phone usage.

The co-design workshops aim to extend the findings from the functionality review and autoethnographic study. They explored five types of design friction with findings summarised in Table 17. Findings indicated users' preference of r cognitive friction, such as engaging puzzles and open-ended questions, and toward motivational friction, like positive feedback and personalized goals. Social friction raised concerns about privacy, and physical and emotional friction raised concerns about anxiety and non-maleficence (Sanches, Janson, et al. 2019). A summary of this is included in Table 17.

Type	Range
Cognitive Friction	Participants had mixed reactions, with some finding it engaging and others distressing. It was deemed suitable for hedonic social media apps but not for pragmatic apps.
Emotional Friction	It was generally viewed negatively, with concerns about appropriateness and potential harm. It was considered suitable for social media apps but not for essential communication or productivity apps.
Social Friction	It was viewed positively for increasing social awareness but had potential drawbacks like dependency on other users and privacy concerns. Suitable for social media and gaming apps, but not for apps storing sensitive information.
Motivational Friction	Positive feedback was strongly preferred for its motivational benefits. Suitable for social media and

	gaming apps, but not for essential communication apps.
Physical Friction	It was largely viewed as ineffective and unnecessary, with concerns about emergencies and productivity. Suitable for social media apps but not for essential communication or productivity apps.

Table 17: Summary of findings from codesign workshops relating to microboundary types

Participants found cognitive friction, such as engaging puzzles and open-ended questions, and motivational friction, like positive feedback and personalized goals, desirable for encouraging meaningful smartphone use. Social friction through group support, location-based physical friction, and minor timeouts (e.g., 15-minute breaks for non-essential apps) were also favoured, while emotional friction was less preferred due to potential negative impacts.

Strong barriers, like phone-level lockouts, were generally viewed as excessive and anxiety-inducing, while weak barriers, such as app-level interventions and flexible, personalized measures, were preferred for their balance between potential effectiveness and user control.

These two activities achieved the objective of proposing and evaluating potential microboundary-based cues to manage meaningful or meaningless interactions. A surprising result was the focus on using puzzles as a form of cognitive friction, coming from the participants themselves during the co-design workshops. They suggested engaging activities like Sudoku puzzles, Math puzzles, and open-ended questions as potential measures to prevent mindless smartphone use.

Findings from users' interviews contribute to the research question, highlighting the need to support personalisation of cognitive friction tasks. Participants reported issues such as some tasks being too hard (or easy) and that the choice of subject matter was sometimes not helpful – for example, English word questions for people whose first language is not English, or general knowledge questions on topics that the user is not very familiar with. Therefore, a clear finding in the research was that to be successful the design has to take into account the personalisation of appropriate cognitive tasks to the user, not only once, but

ongoing; supported by the finding that users also became familiar with the pool of challenges and thus the tasks became easier than intended.

A final component of the answer to this research question is about the target of the app or intervention. It was seen that users preferred app-level interventions rather than phone level, and a combination of non-permanent lockout, interruption and friction. Non-friction-based interventions were also seen as complementary (for example supporting awareness of screen time spent on apps).

The design recommendations support the premise of this thesis on meaningful or meaningless interactions, which is a nuanced and context-sensitive judgement, but participants often found the puzzle-based friction to redirect them to more positive, more eudemonic goals (improving knowledge by learning answers to trivia questions for example).

Finally, on this matter, careful consideration must be taken in the design to avoid the tendency of users to circumvent the intention of the intervention by simply switching apps to another of the same category. In later discussion, the Theory of Planned Behaviour will be examined as a framework towards motivation relating to this (Ajzen 1991). A good implementation of friction can increase satisfaction (Mejtoft et al., 2019) while at the same time may continue to steer behaviour (A. T. Adams et al. 2015).

To conclude the response to this research question, it can be seen that this thesis has contributed details and learning from an extensive and rich design process, backed by a review of interventions both in practice and from a theoretical standpoint.

9.3 What is users' perception of such micro-interventions when used in everyday life?

For this research question, we explored a microboundary-based intervention capturing different types of cognitive frictions, and users' perception after using them in-the-wild. . This comprised a 2-week study with 20 participants using a specifically designed app that offered three puzzle-based microboundary

interventions including Math, Word, and “Trivia” general knowledge questions. Users were required to report data of their app usage, manually capturing and sending screenshots from screen-time application logs as well as responding to emotional and motivation scales, followed by interviews.

The challenges in the Puzzle Block app were found to be effective in deterring meaningless smartphone use. Participants reported that the interruptions caused by the puzzles made them more conscious of their phone usage, and led to reduced meaningless use of social media apps. The puzzles served as a reminder to avoid using apps for time-passing.With respect to users’ perception of different types of puzzles, findings indicate their preference for Math puzzles due to their simplicity and connection to familiar subjects, making them effective in shifting focus away from addictive applications like Instagram and TikTok. Trivia puzzles also had a positive impact, though they sometimes required external searches, which could momentarily increase phone use. Word puzzles were the least effective, often causing frustration due to their complexity and lack of clear instructions.

The puzzles encouraged mindfulness-based interactions, supporting meaningful smartphone use by promoting self-awareness and intentionality. Participants began to question the purpose of their interactions on apps like WhatsApp and Instagram, leading to more mindful engagement, at least they reported sparing minimal time on social media for mere entertainment, focusing instead on meaningful interactions and shifting from entertainment to self-improvement activities. Also important, participants became more conscious of their online time, using their devices for learning math and programming instead of mindless scrolling. However, the impact on self-development varied among participants. While some found the puzzles beneficial for refreshing skills and promoting growth, others did not experience significant changes, continuing to use their phones for university matters or other forms of entertainment.

The study findings also highlighted the importance of personalisation and sustained engagement in the effectiveness of these interventions. Participants suggested that puzzles should be tailored to their educational level and interests to maintain engagement. Gamification elements, such as streaks, were recommended to increase motivation. The lack of customisation in the puzzles

affected long-term engagement, with some participants finding the app boring and irrelevant.

Overall, the puzzles increased participants' awareness of their phone usage, promoting healthier habits. In particular, the microboundary-based interactions, such as puzzles, effectively deter meaningless smartphone use by promoting self-awareness and intentionality. This aligns with the findings by Cox et al. (2016) and Terzimehić et al. (2022)) who demonstrated that design frictions, or microboundaries, can reduce habitual and mindless interactions with smartphones. Similarly, Kim et al. (2019) showed that lockout tasks like LocknType effectively discouraged excessive app use by creating intentional pauses.

However, the current study also highlighted the importance of personaliation in maintaining engagement with microboundary tasks, and even the user-centred design approach had an immediate impact on the effectiveness of the intervention compared to other work (Collins et al. 2014). Participants preferred puzzles tailored to their educational level and interests, suggesting that one-size-fits-all solutions may not be as effective. This need for personalisation is supported by Bitrián et al. (2021), who found that gamification and personalized content significantly enhance user engagement in mobile apps.

While the long-lasting impact of these benefits has not been explored, findings also indicate tht some participants reverted to previous habits after completing the puzzles, indicating that voluntary lockout tasks might provide only short-term benefits for individuals with entrenched smartphone behaviours. The study suggests that combining microboundary-based and mindfulness-based interactions with personalisation and gamification could enhance their effectiveness in promoting meaningful smartphone use and deterring meaningless use.

To crystalise this thesis' answer to the research question: microboundary-based interactions, such as puzzles, are effective in deterring meaningless smartphone use by promoting self-awareness and intentionality. Mindfulness-based interactions support meaningful use by encouraging users to reflect on their app engagement and shift towards productive activities. Personalisation and

sustained engagement are crucial for the long-term effectiveness of these interventions. Combining these approaches can enhance digital well-being and promote healthier smartphone habits.

Mindfulness-based interactions in the study facilitated through puzzles, supported meaningful smartphone use by encouraging users to reflect on their app engagement. Participants reported increased awareness of their phone usage and a shift towards more productive activities. This finding is consistent with Howells et al. (2016), who found that a smartphone-based mindfulness intervention significantly enhanced well-being. Johannes et al. (2018) also support this, showing that mindfulness can mediate the relationship between online vigilance and well-being, promoting more intentional and meaningful interactions. The current study extends these findings by demonstrating that even brief, puzzle-based mindfulness interventions can have a similar impact.

The study found that microboundary and mindfulness-based interactions increased participants' awareness of their phone usage, promoting healthier habits. However, the benefits were not always long-lasting, with some participants reverting to previous habits. This finding is consistent with Schuman-Olivier et al. (2020), who noted that mindfulness interventions could promote behaviour change but require sustained engagement and personalisation to be effective long-term.

In summary, the research confirms that microboundary-based interactions effectively deter meaningless smartphone use, while mindfulness-based interactions support meaningful use. Personalisation and sustained engagement are crucial for the long-term effectiveness of these interventions. These findings align with and extend existing research, emphasizing the importance of tailored, engaging, and mindful approaches to promoting digital well-being. Combining these strategies, particularly reflection (Ghajargar et al. 2017) can enhance their effectiveness, helping users develop healthier smartphone habits and achieve greater digital well-being.

This study has several limitations. Its duration of 2 weeks, and consequent engagement, prevented longer-term effects from being studied. The limited range of participants, recruited via social networking and university campus, within a

similar socio-economic background and age group similarly limited the generalisation of our findings to different user groups.

9.4 Conclusion

To conclude this discussion chapter, the final section will recap the contributions made by the thesis, as described in the introduction and place them in the context of state of the art literature.

To begin, the thesis has made a clear contribution by elaboratinged on the key terms and concepts of digital wellbeing and meaningful phone use. To tackle the first one, digital wellbeing, the concept was explored using a scoping study, drawing together a broad range of definitions. To date, research has individually addressed topics of, primarily, excessiveng use of mobile devices or social media, as exemplified by (Harris et al. 2020), wellness activities enabled by or supported by digital technologies (Bhatt et al. 2020; Burr et al. 2020; Craven et al. 2019)(Bhatt et al. 2020; Burr et al. 2020; Craven et al. 2019) or alternatively digital competence and resistance to digitally enabled threats. As a conclusionconclusion, this thesis promotes the more generally accepted understanding of problematic phone overuse, which concurs with contemporary and well cited research such as Roffarello and De Russis (2023). In combination with this, the definition extends beyond the assumption of assuming problematic use to be simply overused, echoing recent work by Büchi (2024), who proposes a framework for digital wellbeing considering digital practices, and societal and subjective harms and benefits. This thesis contributesp further by populating thopulae tes this framework with the theory backed exploration of meaningful and meaningless usage as a mean to navigate benefits and harms within observed digitals practices. This is grounded in the real-world evidence and data from diary studies, focus groups, interviews, codesign and reflective evaluation. The contribution remains relevant as a means to bridge the gap between research communities predominantly in Information Technology, and more health focused, where the understanding of digital wellbeing remains fragmented, as evidenced by Smits et al. (2022).

The real-world evidence this thesis also contributes, represents a highly relevant body of evidence on attitudes, subjective judgements, behaviours and responses to interventions within the realm of smartphone overuse.

The diary study, interviews observations and log data that was collated adds multidimensional primary research on how and why people use their smartphones, what constitutes smartphone overuse from the user's perspective, and how meaning and meaningless are assigned to smartphone sessions. Contemporary researchers such as Büttner et al. (2022) have conducted observational research, but in a contolledcontrolled setting, in which other research considering screen-time tools has been quastionairrequestionnaire based (Oeldorf-Hirsch and Chen 2022), similarly, rich data remains sparse.

Moving to the evaluation of the puzzle block application itself and the intervention, this has made a useful contribution in the evolution and design of digital wellbeing, screen-time management apps, particularly demonstrating the effectiveness and further potential for microboundary interactions. While similar concurrent work such as Olson et al (2023) has explored similar concepts, they focussed on total screen time and did not consider participants' understandinginterpretations of meaningful and meaningless phone use as part of the study. Kent et al. (2021) performed a similar intervention on smartphone use, withusing methods based behavioural interventions (goal setting, personalised feedback, mindfulness, and behavioural phases), their findings are reinforced by this research; both saw some positive outcomes and previewed improvement in digital wellbeing with a reduction in problematic or meaningless use. As with this research, their work was limited in duration and number of participantss, and there was difficulty in separating the effects of participation and observation from the intervention itself. Precht et al. (2023) recently also conducted research on an "intervention" to reduce phone use and increase physical activity with approximately 500 participants, however while finding positive wellbeing benefits this was not a behaviour change intervention as participants were specifically asked to reduce usage and/or increase activity as part of the experiment, and Brailovskaia et al. (2023) who also specifically requiere particiapants to modify behaviour. It is also possible to compare the positive results of this research with an unsuccessful intervention that disabled

notifications for one week (Dekker et al. 2025), this concurs with research findings and observations that users often find workarounds or opt-outs of inconvenient measures, ces and that more motivating interventions are desired.

Finally, distilling the contributions into more actionable insights, the thesis adds design guidelines incorporating learnings from the research as summarised below:

- Leverage social support as a mechanism to enhance self-regulation in digital wellbeing apps
- Provide customisation in digital wellbeing apps for the user to add their meaningful apps, particularly the ones used for hedonic goals, considered meaningful by the user
- Provide a way of gamification for the cognitive frictions, for example, a game like Sudoku as friction
- Provide a way to adjust the duration of the cognitive friction
- Provide a way to adjust the timing of the appearance of the cognitive friction (e.g. before use, after some time of use, or when the app is opened repeatedly)
- Contain an educative value in the cognitive puzzle (e.g. math)
- Enhance user control through choice; preferred type of cognitive friction (e.g. trivia categories or topics related to users)

As was noted in the research, research evidence if existing in-the-wild apps shows little evidence of research validation in their intervention methods. Given the design guidelines, further work may be conducted to re-review those applications against the new criteria.

The Puzzle Block application also contributes a novel app implementing different types of cognitive frictions to capture users' perceptions of them. This may serve as a platform for reuse, or as inspiration for further experimentation to improve the tools, data collection and research quality in the field.

The author presents the thesis with the intent to make a difference toin quality of life with respect to balancing digital practices with wellbeing and happiness. As discussed, many research agendas begin with the assumption that smartphone screentime must be reduced, and do not consider the subjective and societal

meaningfulness of that screentime. Thus, the author calls upon the research community to evolve the debate and instead think about how people can fill their lives with increased meaning with or without smartphones, as they choose.

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Appendix

App ID	App name	Rating score	Number of app raters
	Commercial apps		
1	Google Family Link for parents	4.6	347376
2	Forest: Stay focused	4.7	162902
3	Parental Control - Screen Time & Location Tracker	4.1	40983
4	YourHour - Phone Addiction Tracker & Controller	4.6	37483
5	Focus To-Do: Pomodoro Timer & To Do List	4.7	37278
6	UBhind: No.1 Mobile Life Tracker/Addiction Manager	4	33358
7	SPACE: Break phone addiction, stay focused	4.3	27606
8	StayFree - Phone Usage Tracker & Overuse Reminder	4.6	26437
9	AppBlock - Stay Focused (Block Websites & Apps)	4.5	24385
10	Stay Focused - App Block & Website Block	4.4	21389
11	MMGuardian Parental Control App For Parent Phone	4.1	16909
12	Screen Time - Restrain yourself & parent control	4.7	16887
13	SaveMyTime - Time Tracker	4.5	8968
14	Detox Procrastination Blocker: Digital Detox	4.3	7609
15	Boosted - Productivity & Time Tracker	4.7	7116
16	AntiSocial: phone addiction	4.2	6933
17	App Usage - Manage/Track Usage	4.3	6720
18	Smarter Time - Time Management - Productivity	4.3	5619
19	ActionDash: Digital Wellbeing & Screen Time helper	4	4972
20	Digital Detox: Focus and fight phone addiction	4.5	4403
21	Keep Me Out	4.1	4048
22	Block Apps - Productivity & Digital Wellbeing	4	3728
23	Instant - Quantified Self, Track Digital Wellbeing	4	3367
24	LessPhone - The Original Distraction Free Launcher	4.3	2696
25	Minimalist launcher for focus | Before Launcher	4.4	2186
26	Focus - Be Productive!	4.5	2152
27	My Phone Time - App usage tracking - Focus enabler	4.4	2002
28	Usage Analyzer: Apps, Data & History	4.5	1685
29	Pomodoro Smart Timer - A Productivity Timer App	4.6	1287
30	Screen Time & Parental Control App by ZenScreen	4.1	1163
31	Brain Focus Productivity Timer	4.5	8947
32	SleepTown	4.4	6921

33	Engross: Focus Timer, To-Do List & Day Planner	4.4	5027
34	Visual Timer - Countdown	4.7	4702
35	Lock Me Out: Freedom from phone addiction	4.3	2920
36	HelpMeFocus - Block Apps, Stay Focused.	4	2873
37	Hold - make it happen	4.5	2386
38	Sma-Phospital	4	2203
39	Quiet for Gmail	4.7	1478
	Academic apps including references		
1	Focus (Potapova, Cetinkaya, and Liebchen 2020)	None	None
2	Socialize (Roffarello and De Russis 2019b)	Not available	Not available
3	Toringo (Abreu 2021)	Not available	Not available
4	FeelHabits (Bravo 2020)	Not available	Not available
5	Coco's Videos (Hiniker et al. 2018)	Not available	Not available
6	MyTime (Hiniker et al. 2016)	Not available	Not available
7	Good Vibrations (Okeke et al. 2018)	Not available	Not available
8	Let's FOCUS (Kim Inyeop et al. 2017)	Not available	Not available
9	PomodoLock (J. Kim, Cho, and Lee 2017)	Not available	Not available
10	Interaction restraint (J. Park et al. 2018)	Not available	Not available
11	GoalKeeper (J. Kim, of Korea HAYOUNG JUNG, and of Korea 2019)	Not available	Not available
12	LocknType (J. Kim et al. 2019)	Not available	Not available
13	AppDetox (Löchtefeld, Böhmer, and Ganev 2013)	4.4	3000
14	Lock n' LoL (Ko et al. 2016)	Not available	Not available
15	FamiLync (Ko, Choi, et al. 2015)	Not available	Not available
16	NUGO (Ko, Yang, et al. 2015)	Not available	Not available
17	The SAMS (Heyoung Lee et al. 2014)	Not available	Not available

Table 4: The reviewed top rated digital wellbeing apps and academic apps, their user rating scores from 1 to 5, and their numbers of raters.

App ID	Tracking phone use	Tracking apps use	Visualizing tracked data - formats	Profiling users
Commercial apps				
1	None	Yes	Charts/Reports	None
2	None	None	Metaphors	None
3	None	Yes	Charts/Reports	None
4	None	Yes	Charts/Round diagrams/Reports	The app defines levels of phone addiction based on tracked data: addicted, obsessed, dependent, habitual, achiever and champion. The app categorizes some used apps as productivity apps (and not considered in addiction level)
5	None	Yes	Metaphors/Reports	None
6	Yes	Yes	Charts/Reports	None
7	None	Yes	Metaphors/Round diagrams/Charts/Reports	Usage patterns are extracted from user quiz
8	None	Yes	Round diagrams/ Charts/Reports	None
9	None	Yes	None	User can create different profiles for limiting use based on time, location, Wi-Fi, usage limit, or launch count
10	None	Yes	Charts/Reports	User can create different profiles with different settings, i.e., daily usage limit.
11	None	Yes	Charts/Reports	None
12	None	Yes	Charts/Reports	The app categorizes used apps based on tracked data, i.e., social, entertainment, tools
13	Yes	None	Reports	Users can create goals to limit use time or to maximize valuable time.
14	Yes	None	None	None
15	None	None	Round diagrams/ Charts/Reports for tracked offline activities	Users can set time to increase offline activities and track them.
16	None	Yes	Charts/Reports	None

17	None	Yes	Heatmap/Round diagrams/ Charts/Reports	The app categorizes used apps based on tracked data, i.e., social, news, productivity.
18	None	Yes	Charts/Reports	None
19	None	Yes	Round diagrams/ Charts/Reports	None
20	Yes	None	Charts	The app provides predefined levels of digital detox, i.e., easy, medium, hard, grand master
21	Yes	None	None	None
22	None	Yes	Charts/Reports	Users can add restrictions based on daily or week limits and launch count limit
23	None	Yes	Reports	None
24	None	None	None	None
25	None	None	None	None
26	Yes	None	Round diagrams	None
27	None	Yes	Charts/Reports	None
28	None	Yes	Round diagrams/ Charts/Reports	None
29	None	None	None	None
30	None	Yes	Round diagrams/ Reports	None
31	None	None	Charts/Reports	None
32	None	None	Metaphors/Charts for tracked offline activities	None
33	None	None	Reports for tracked offline activities	None
34	None	None	None	None
35	Yes	Yes	None	User can create predefined rules to lock phone on specific locations, times of day, total screen time.
36	None	Yes	None	Users can pay to create different profiles with different settings, i.e., work time
37	None	None	None	None
38	None	Yes	Charts/Reports for tracked activities	None
39	None	None	None	None
			Academic apps	
1	None	Yes	Charts	None
2	Yes	Yes	Charts, Daily/Widget Recap	None
3	Yes	None	Floating widget	Users specify the total time screen

4	Yes	Yes	None	Users can choose temporal context restriction: “working days”, “holidays”, “morning”, “afternoon”, “night” and from 3 categories of screen time: multi-device apps, smartphone while using PC, multi device.
5	None	None	None	None
6	None	Yes	None	User can set daily time limit for the tracked apps
7	None	Yes	None	None
8	Yes	Yes	Timeline	The app can detect users’ physical presence with periodic scanning of Wi-Fi fingerprints to provide location-based reminders of engaging in limited use with classmates
9	None	Yes	None	None
10	None	Yes	None	None
11	Yes	Yes	Timeline	User can create different use limits for weekdays vs weekends
12	None	Yes	None	None
13	None	Yes	Charts	None
14	None	Yes	Timeline	The app support setting use limit for a group of users
15	Yes	Yes	Timeline	None
16	Yes	Yes	Timeline	None
17	None	Yes	Timeline, charts	None

Table 6: Tracking functionality for phone/apps use, format for visualizing the tracked data, and user profiling based on tracked data

App ID	Setting scope of limited use	Setting place of limited use - locations	Setting place of limited use WIFI	Setting focus time for offline activi-ties	Visualizing Time use limits; or time for offline focus activities	Option to use allowance beyond time limit/ focus limit	Option to exclude apps from time limit	Option to disconti-nue tracking when limit reached
Commercial apps								
1	Some apps	None	None	None	Time spent out of time limit; Progress bar gradually filled with color	None	Some Apps	None
2	None	None	None	Yes	Time unspent out of time limit; Countdown timer	None	None	None
3	Some apps	None	None	None	Time unspent out of time limit; Progress bar gradually filled with color	Extra time given by parents to children	Some Apps	None
4	All apps	None	None	None	Time spent out of time limit; Circle gradually filled with color	Phone use allowed after set time limit; with notification: small counter showing the time spent on that app for today	All Apps	None

5	Some apps	None	None	Yes	Time unspent out of focus time limit; Countdown timer	Two modes for setting focus time limit: strict mode where allowance can be requested when the target app cannot be open until user stops the timer; and normal mode when user can open any app.	Some apps	Yes
6	Phone	None	None	None	Time unspent out of time limit; Text	The first time when apps are used during the set time limit is free; but the following uses of the apps incur financial penalty	Some Apps	None
7	All apps	None	None	None	Time spent out of time limit; Text	None	Some Apps	None
8	Some apps	None	None	None	Time spent out of time limit; Text	None	Some Apps	None
9	Some apps	Yes	Yes	None	Time spent – tracked only; Text	None	All Apps	None
10	Some apps	None	None	Yes	Time unspent out of focus time limit; Countdown timer	Only calls allowed for set focus time limit	Some Apps	None
11	Some apps	None	None	None	Time spent – tracked only; Text	Friction: admin password must be entered in order to use the	None	None

						apps after the set time limit		
12	Some apps	None	None	None	None	When the set time limit is reached, it can be ignored in 2 ways; to ignore the limit for today (whole day) or to choose “remind me in 15 mins”	Some Apps	None
13	Phone	None	None	None	Time spent – tracked only; Progress bar gradually filled with color	None	None	None
14	Phone	None	None	Yes	Time unspent out of time limit; Countdown timer	None	None	None
15	None	None	None	Yes	Time spent out of time limit; Text	None	None	None
16	Some apps	None	None	None	None	None	Some Apps	None
17	All apps	None	None	None	Time spent out of daily usage goal: Text	None	Some Apps	Yes
18	None	None	None	None	Time spent – tracked only: Text	None	None	None
19	Some apps	None	None	None	Time spent – tracked only; Text	None	Some Apps	None

20	Phone	None	None	Yes	None	Only calls allowed for set focus time limit	Some Apps	Yes
21	Phone	None	None	Yes	None	None	None	None
22	Some apps	None	None	None	None	None	Some Apps	None
23	All apps	Yes	None	None	Time spent out of time limit; Progress bar gradually filled with color	None	None	None
24	None	None	None	None	None	None	None	None
25	None	None	None	None	None	None	None	None
26	Phone	None	None	Yes	Time unspent out of focus time: Countdown timer; Circle progressively unfilled with color	Friction: Touch the screen while blocked for 5 sec to access the 30 sec break out of focus time to use the phone	None	Yes
27	All apps	None	None	None	Time overspent as % of time limit: Text	None	Some Apps	None
28	None	None	None	None	None	None	None	None
29	None	None	None	Yes	Time unspent out of time limit; Countdown timer	None	None	Yes
30	Some apps	None	None	None	None	Option ignore app from set time limit; no further notification for apps' overuse	Some Apps	Yes
31	None	None	None	Yes	Time unspent out of time	None	None	None

					limit; Countdown timer			
32	None	None	None	None	None	None	None	None
33	None	None	None	Yes	Time unspent out of time limit; Countdown timer	None	None	Yes
34	None	None	None	Yes	Time unspent out of time limit; Circle progressively unfilled with color	None	None	Yes
35	Phone, all apps	Yes	None	None	None	Free access for 20 sec; end block with penalty, i.e., ~£4	Some Apps	None
36	Some apps	None	None	Yes	Time unspent out of time limit; Circle progressively unfilled with color	None	Some Apps	Yes
37	None	None	None	Yes	None	None	None	None
38	None	None	None	None	None	None	None	None
39	None	None	None	None	None	None	None	None
					Academic apps			
1	Some apps	None	None	None	None	None	All apps	None
2	All apps, phone	Yes	None	None	Time spent per app – tracked only; Text, charts	Pop up notification with options: close the app, snooze, or delete	Some apps	Yes
3	Phone	None	None	None	Time spent out of time	None	None	Yes

					limit; Gradually filled with darker color - floating widget: > 50% (dark yellow), 75% (orange) and 100% (red-maroon)			
4	Some apps, phone	None	None	None	None	Users choose either “OK I won’t use it” or “Please, don’t block me again”	Some apps	Yes
5	None	None	None	None	None	None	None	None
6	Some apps	None	None	None	Time spent out of time limit; Text, Progress bar gradually filled with color	Users can always request extension for set time limit	Some apps	None
7	Some apps	None	None	None	Recent usage status: push notification	None	None	None
8	All apps	Yes	Yes	Yes	Total time unspent out of focus time limit	None	None	Yes
9	Some apps	None	None	Yes	Time unspent out of time limit; Countdown timer	None	Some apps	Yes
10	Some apps	None	None	None	None	None	None	None
11	All apps	None	None	Yes	Time spent out of time limit; Text,	When exceeding the limit goal for the first time,	None	None

					Time unspent out of time limit; Countdown timer	the phone is locked for 1 minute, followed by a 15 minute allowance time. After the 16 mins the lockout duration increases		
12	None	None		None	None	None	None	None
13	Some apps	None	None	None	None	None	All apps	None
14	All apps	None	Yes	Yes	Total limit time spent in specific activity e.g. study; Timeline	A cumulative five minutes is allowed after the group start limiting	None	Yes
15	All apps	None	None	Yes	Time unspent out of time limit; Progress bar gradually unfilled with color	The user can stop limiting if smartphone use is necessary by clicking a give-up button	None	Yes
16	All apps	None	None	Yes	Time unspent out of time limit; Progress bar gradually filled with color	The user can stop limiting if smartphone use is necessary by clicking a give-up button	None	Yes
17	All apps	None	None	None	None	None	None	None

Table 7: Monitoring functionality: setting use/focus time limits, scope and place of limited use, visualizing time limit, and flexibility through 3 options: use allowance beyond time limit, exclude apps from time limit, and for discontinuing tracking when limit was reached

App ID	Creating obstacles – types according to force (strong or weak)	Creating obstacles – saliency (explicit or implicit)	Creating obstacles – time (during use, after overuse)	Creating obstacles – social types	Creating obstacles levels tailored to user profile /preference	Creating obstacles – source (app vs user)
			Commercial apps			
1	Strong: strict mode that prevents the child from editing the limits	Explicit; block	After overuse	Parental control	The profile is tailored to specific child by parent	Customized by parent
2	None	None		Social commitment	None	None
3	Strong: strict mode that prevents the child from editing the limits	Explicit; block	After overuse	Parental control	The profile is tailored by parent to specific child	Customized by parent
4	Weak: notification on time limit, block app; Strong: phone block.	Explicit; notification, block app, phone block.	After overuse; for not use (blocking phone)	None	3 levels of challenges: basic, moderate, advanced for specific apps or phone	Automatic
5	None	None	None	None	None	None
6	Strong: apps block	Explicit; block	After overuse	None	None	Customized by user
7	Weak: allows altering the limits	Implicit; screen dimming	After overuse	None	Flexible either take a quiz and tailored to user profile or customized as needed	Customized by user
8	Weak: users choose the obstacle: push notifications on overuse, pop up warning of overuse or Strong: app block	Explicit; notification & pop up warning, phone block	After overuse	None	Users can limit their usage based on categories of usage (Game, Entertainment, Education, Utility)	Customized by user

9	Strong: apps block	Explicit; block	During use	None	User choose which app to block	Customized by user
10	Strong: app block or phone block	Explicit: phone block, apps block	After overuse & for not use (blocking phone)	None	3 modes: normal, lock mode, strict mode	Customized by user
11	Strong: apps block or phone block	Explicit: phone block or apps block	During use or after overuse	Parental control	None	Customized by parents
12	Weak: pop up notification of reaching time limit that can be ignored	Explicit: pop up notification	After overuse	None	User preferences	Automatic
13	None	None	None	None	None	None
14	Strong: phone block	Explicit: phone block	For not use	None	User preferences	Customized by user
15	None	None	None	None	None	None
16	Strong: apps block	Explicit: apps block	After overuse	None	User preference: daily limit, scheduled limit, or timer	Automatic
17	Weak: push notification reminding users of today's usage timer	Explicit: push notification	After overuse	None	None	Automatic
18	None	None		None	None	None
19	Strong: apps block	Explicit; block	During use	None	None	Automatic
20	Strong: phone block	Explicit: phone block	For not use	None	User preference or tailored to user profile: easy, medium, hard, grand master	Customized by user
21	Strong: phone block	Explicit; block	During use	None	None	Automatic

22	Strong: apps block	Explicit: apps block	After overuse	None	User preference	Customized by user
23	None	None	None	None	None	None
24	None	None	None	None	None	None
25	None	None	None	None	None	None
26	Strong: phone block	Explicit: phone block	For not use	None	None	Customized by user
27	None	None	None	None	None	None
28	None	None	None	None	None	None
29	None	None	None	None	None	None
30	Strong: apps block	Explicit: apps block	After overuse	Parental control	None	Customized by parents
31	None	None	None	None	None	None
32	None	None	None	None	None	None
33	None	None	None	None	None	None
34	None	None	None	None	None	None
35	Strong: apps block	Explicit: apps block	Scheduled or after overuse	None	None	Customized by user
36	Strong: app block	Explicit: apps block	After overuse	None	Instant block or users can profile blocking	Customized by user
37	None	None	None	None		None
38	None	None	None	None	None	None
39	None	None	None	None	None	None
			Academic apps			
1	Strong: app block	Explicit: app block	During use	None	User preference	Customized by user
2	Weak: pop un notification Strong: app block, phone block	Explicit: notification, app or phone block	During & after use	None	User preference	Customized by user
3	Weak: small floating widget turn to red-maroon color,	Explicit: red-maroon floating widget	After overuse	None	User preference	Automatic
4	Weak: pop up notification	Explicit: notification	After overuse	None	User preference	Automatic
5	None	None	None	None	None	None

6	Weak: pop up notification	Explicit: notification	After overuse	None	User preference	Customized by user
7	Weak: gentle vibrations every five seconds	Implicit: vibration	After overuse	None	User preference	Automatic
8	Strong: phone block Weak: notifications muted	Explicit: phone block, notifications muted	During use	classmates	User preference	Automatic
9	Weak: app block, deactivated if user stops the timer, mute notifications	Explicit: app block, mute notifications	During use	None	User preference	Customized by user
10	Prior interaction. Weak: entering 5 random numbers displayed Strong: entering more random number displayed	Explicit: friction; entering random numbers	Before use	None	User preference	Automatic
11	Weak: phone block followed by allowance time Strong: phone block until midnight	Explicit: phone block; friction: password must be entered in order to use the apps after the set time limit	After overuse	None	User preference	Customized by user
12	Weak: press ok to launch app Strong: enter 30 random digits displayed to launch app	Explicit: press ok, enter 30 random digits prior to launching specific app	Before use	None	User preference	Automatic

13	Strong: app block	Explicit: app block	During use & after overuse	None	The app provides rules for the user to choose from: specific daytimes, number of launches, usage time, activity based, some time, forever	Customized by user
14	Weak: mute all notification	Explicit: mute notifications	During use	None	None	Automatic
15	Strong: app block	Explicit: app block	During use	None	limiting mode overrides all apps except for checking a notification drawer	Automatic
16	Strong: app block	Explicit: ap block	During use	None	None	Automatic
17	Strong: app block	Explicit: app block	After overuse	None	The app is tailored to elementary to high-school students	Automatic

Table 8: Interventions for limiting use: creating obstacles for limiting use differing in force, saliency, temporality, sociality, user profile, and source

App ID	Notifications for reaching use limits	Notifications for reaching use limit - type	Notifications for reaching phone time limit on digital wellbeing app	Notifications on reaching app time limit - on those specific apps	Screen dimming for reaching use limit	Daily reminders to review tracked data
Commercial apps						
1	None	None	None	None	None	None
2	None	None	None	None	None	None
3	None	None	None	None	None	None
4	Yes	Explicit: push notification	Yes: time up	None	None	None
5	None	None	None	None	None	None
6	Yes	Explicit: pop up notification	Yes: lock icon next to app name	Yes: pop up notification and closing the app	None	None
7	Yes	Implicit: screen dimming	Yes: time up	None	Yes	None
8	Yes	Explicit: push or pop up notification	None	Yes: push notification reminder	None	Yes
9	None	None	None	None	None	None
10	Yes	Explicit: pop up notification	None	Yes: pop up notification covers the app	None	None
11	None	None	None	None	None	None
12	Yes	Explicit: pop up notification	None	Yes: transparent pop up notification	None	None
13	Yes	Explicit: progress bar filled with color	Yes: progress bar filled with color	None	None	None
14	None	None	None	None	None	None
15	None	None	None	None	None	None

16	Yes	Explicit: pop up notification	None	Yes: pop up notification covers the app	None	None
17	Yes	Explicit: push notification	None	None	None	Yes
18	None	None	None	None	None	None
19	None	None	None	None	None	Yes
20	None	None	None	None	None	None
21	None	None	None	None	None	None
22	Yes	Explicit: push notification	None	Yes: pop up notification and closing the app	None	None
23	None	None	None	None	None	Yes
24	None	None	None	None	None	None
25	None	None	None	None	None	None
26	None	None	None	None	None	None
27	None	None	None	None	None	Yes
28	None	None	None	None	None	None
29	None	None	None	None	None	None
30	Yes	Explicit	Yes	Yes	None	Yes
31	None	None	None	None	None	None
32	None	None	None	None	None	None
33	None	None	None	None	None	None
34	None	None	None	None	None	None
35	Yes	Explicit: pop up notification	None	Yes: pop up notification and closing the app	None	None
36	Yes	Explicit: pop up notification	None	Yes: pop up notification and closing the app	None	None
37	None	None	None	None	None	None
38	None	None	None	None	None	None
39	None	None	None	None	None	None
Academic apps						
1	None	None	None	None	None	None
2	Yes	Explicit: pop up notification	Yes	Yes	None	None

3	Yes	Explicit: notification from the conversational agent (chatbot)	Yes	None	None	Yes
4	Yes	Explicit: pop up notification	None	Yes	None	None
5	None	None	None	None	None	None
6	Yes	Explicit: pop up notification	None	Yes	None	None
7	Yes	Explicit: gentle vibration	None	Yes	None	None
8	None	None	None	None	None	None
9	None	None	None	None	None	None
10	None	None	None	None	None	None
11	Yes	Explicit: notification dialog	None	None	None	None
12	None	None	None	None	None	None
13	Yes	Explicit: pop up notification	None	Yes	None	None
14	None	None	None	None	None	None
15	None	None	None	None	None	None
16	None	None	None	None	None	None
17	Yes	Explicit: pop up notification	None	None	None	None

Table 9: Interventions for limiting use: supporting awareness for reaching the set limit of use through different notification types, screen diming, and daily reminders.

App ID	Supporting focused attention - training	Supporting focused attention – white noise
	Commercial apps	
1	None	None
2	Yes	Yes
3	None	None
4	None	None
5	Yes	Yes
6	None	None
7	None	None
8	None	None
9	None	None
10	None	None
11	None	None
12	None	None
13	None	None
14	None	None
15	Yes	None
16	None	None
17	None	None
18	None	None
19	None	None
20	None	None
21	None	None
22	None	None
23	None	None
24	None	None
25	None	None
26	Yes	None
27	None	None
28	None	None
29	Yes	Yes
30	None	None
31	Yes	None
32	None	None
33	Yes	Yes
34	None	None
35	None	None
36	None	None
37	Yes	Yes

38	None	None
39	None	None
	Academic apps	
1	None	None
2	None	None
3	None	None
4	None	None
5	None	None
6	None	None
7	None	None
8	Yes	None
9	Yes	None
10	None	None
11	Yes	None
12	None	None
13	None	None
14	None	None
15	Yes	None
16	Yes	None
17	None	None

Table 10: Interventions for limiting use: supporting focused attention through training or white noise