Prediction of cyclic fatigue life of NiTi rotary files by Virtual Modeling and Finite Elements Analysis

Coping with Digital Wellbeing in a Multi-Device World

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While Digital Self-Control Tools (DSCTs) mainly target smartphones, more effort should be put into evaluating multi-device ecosystems to enhance digital wellbeing as users typically use multiple devices at a time. In this paper, we first review more than 300 DSCTs by demonstrating that the majority of them implements a single-device conceptualization that poorly adapts to multi-device settings. Then, we report on the results from an interview and a sketching exercise (N=20) exploring how users make sense of their multi-device digital wellbeing. Findings show that digital wellbeing issues extend beyond smartphones, with the most problematic behaviors deriving from the simultaneous usage of different devices to perform uncorrelated tasks. While this suggests the need of DSCTs that can adapt to different and multiple devices, our work also highlights the importance of learning how to properly behave with technology, e.g., through educational courses, which may be more effective than any lock-out mechanism.

CCS Concepts: • **Human-centered computing → Empirical studies in HCI**; *Ubiquitous and mobile devices.*

Additional Key Words and Phrases: digital wellbeing, multi-device, technology overuse, self-regulation, interview

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1 INTRODUCTION

In the technological era we are living in, users interact with a plethora of "smart" devices every day, ranging from personal computers to smartwatches and voice assistants. While users derive several benefits from using these devices, including an increasing opportunity for social support [81], the last few years have seen a growing amount of public discussion [2, 18, 51] and research attention [13, 61] on the negative aspects of overusing technology, from smartphones [9, 50] to social media [58] and the Internet in general [90]. Previous work, in particular, already demonstrated that many people feel conflicted about the amount of time they spend with digital technologies [9, 54], especially when devices are used passively [41, 86], or as a tool for detracting from people's lives [79].

In response, researchers started to analyze the benefits and the drawbacks of an intentional "non-use" of technology [35, 75]. Recently, even tech giants like Google and Apple have introduced tools for monitoring, understanding, and limiting technology use in their operating systems [5, 6]. This movement has resulted in a new type of wellbeing to be considered in contemporary society, the so-called *digital wellbeing*. As defined in recent works, this term refers to the impact of digital technologies on people's lives [29], and, in particular, it outlines *"what it means to live a life that is good for a human being in an information society"* [17].

Nowadays, several tools for monitoring and controlling device usage and achieving digital wellbeing exist as off-the-shelf products [39, 76]. These Digital Self-Control Tools (DSCTs) allow users to track their device usage and to define interventions, e.g., timers and lock-out mechanisms [62], to self-regulate their behavior with digital devices. Some of them, in particular, are used by millions of users [57]. Contextually, HCI researchers started to explore, design, and implement solutions for improving people's digital wellbeing, by using interventions inspired by different theories such as the social cognitive theory [45, 46] and the nudge theory [44, 63]. Furthermore, recent studies analyzed the factors that shape excessive and compulsive use of digital devices, especially smartphones [56, 82], by highlighting that habitual behaviors lead users to experience negative feelings that influence their overall wellbeing.

Despite a growing interest on improving people's relationship with technology, existing literature that can be related to the digital wellbeing context often considers single technological sources at a time [72], e.g., the smartphone [62]. Targeting a single source, however, may not be sufficient to capture all the nuances of people's digital wellbeing: in today's multi-device world, users typically use more than one device at a time [1], and more effort should be put into evaluating multi-device and cross-device interaction to enhance digital wellbeing [53].

In this paper, we move towards ***multi-device digital wellbeing***, with the aim of providing insights to better cope with digital wellbeing in a multi-device context. First, we analyzed 322 popular DSCTs [57, 62] in the form of smartphone apps or web browser extensions to understand whether and how they take into account multi-device settings. We found that the majority of the analyzed tools are rooted in a single-device conceptualization that prevent them from capturing all the nuances of people's multi-device experiences. Indeed, only a limited number of tools provide their users with both a mobile app and a browser extension. Furthermore, while some DSCTs allows data-synchronization across multiple devices, they rarely allow users to manage their multi-device behaviors, e.g., through cross-device interventions. To understand how to overcome such a single-device conceptualization, we then conducted a background interview and a co-design and sketching exercise with 20 users with different occupations and backgrounds. In the interview, we examined how the participants make sense of their habitual use of their different devices. We probed, in particular, the factors that shape multi-device experiences, and the triggers that make users switch from one device to another. In the co-design and sketching exercise, instead, we investigated what each participant would change about their behavior with their different devices, and what could help them facilitate and maintain these changes.

Consistently with previous work, participants described the smartphone as a major source of distractions, mainly due to its notifications [45, 89] and its natural susceptibility to self-interruptions [14, 85], e.g., checking social networks. According to some participants, however, distractions are not related to the smartphone *per se*, but to its Internet connectivity: in that sense, distractions can come from any connected device. Participants also reported that using more than one device at the same time can be either a positive or negative experience, depending on the underlying performed tasks. When devices are used together to perform a single, *coherent* task, e.g., as support for studying or working, the multi-device experience is considered as positive. When devices are used to satisfy multiple, *incoherent* tasks, e.g., browsing social networks on the phone while watching a film on the smart TV, the multi-device experience can negatively influence user's digital wellbeing, e.g., with a sense of frustration for not being able to follow the movie plot. As reported by the participants in the co-design and sketching exercise, this suggests the need of designing more integrated DSCTs able to analyze and make sense of data collected from a variety of sources, with cross-device interventions that can adapt to different technological sources and performed tasks: the same tool, for instance, may act as a notification filter on the smartphone, while it could limit the usage of web sites like Netflix or YouTube on the laptop. Thanks to the insights extracted from our study, however, we also call for digital wellbeing solutions that go beyond technological tools, encompassing social, educational, and even political factors. A consistent number of participants, in fact, shared a common sense of reluctance towards apps and browser extensions designed as digital wellbeing solutions, claiming to prefer "physical" interventions like turning off the device or putting it away in another room. Furthermore, they agreed on the importance of *learning* how to properly use technology since childhood. In our multi-device world, a "digital education" school course highlighting both positive and negative sides of using (and overusing) technology may contribute to the digital wellbeing of future generations, and may be more effective than any lock-out mechanism.

2 RELATED WORK

2.1 Technology Overuse and the Addiction Debate

While technology brings innumerable advantages to its users and to the whole society, a large body of literature demonstrates that users may experience negative feelings and severe breakdowns of self-regulation due to an excessive use of digital devices [22]. Indeed, an excessive usage of digital devices may be associated with negative effects on mental health [50] and social interaction [54]: mobile device use, for instance, can sometimes disrupt the introspective processes that accompany in-person social interaction [45], thus affecting the quality of face-to-face conversations [84] and relationships [30]. Furthermore, several studies demonstrate that devices like smartphones can become a source of distractions that interferes with daily activities and ongoing tasks such as studying, working, and driving [9, 32]. Distractions make users less productive [59] and more stressed [60], and can be caused by external stimuli, e.g., notifications, but also by internal stimuli [26], e.g., to check if there are new incoming e-mails [65].

In the past decades, several studies used a "technology addiction" framing to describe compulsive behaviors when using the Internet [28, 90], and, more recently, e-mails [83], social media [58] and video games [10]. Researchers also developed several tools to assess technology addiction: examples include the Smartphone Addiction Scale [49] and the Facebook Addiction Scale [11]. Smartphones, in particular, are nowadays frequently described as a source of addictive behaviors by both mainstream media [20, 70] and research studies [54, 74, 85], since they allow users to access any Internet-enabled service anytime and anywhere [34]. Despite such a research interest on technology addiction, however, the idea of considering widespread and everyday behaviors like mobile devices use under the umbrella of clinical addictions is currently debated [82], and not supported by sufficient evidence [51, 52]. What is clear, however, is that many people feel conflicted about the time they spend with Internet-connected digital technologies [79], thus experiencing difficulties in controlling device use [35, 54]. Users, for instance, often use their smartphones as a result of unconscious habits [65, 82], which are associated with a meaningless experience that erodes users' intentions and makes them feel a loss of autonomy over their own behavior [56].

Our work stems from the technology overuse research and aims at exploring novel solutions for achieving what Google called "digital wellbeing [5]" in a multi-device world.

2.2 Designing for Self-Control

Despite the number of problems it entails, technology overuse was and continues to be promoted by many tech companies adopting different dark patterns [24] to capture users' attention and maximize revenue [33]. There is therefore a contradiction between the business models of tech giants like Google and Apple and their recent efforts towards the promotion of a more conscious use of technology. The rising research and main-stream media attention on topics like digital wellbeing [62] and intentional "non-use" of technology [35, 75], however, is influencing the market, and even these companies recently announced the introduction in their mobile operating systems of tools for monitoring, understanding, and limiting technology use [5, 6]. Users themselves are now aware that habitual use of technology is typically a waste of time that becomes a problematic behavior over time [9, 46, 56]. Through a survey with 114 participants, for instance, Ko et al. [46] demonstrated that many users feel overusing their smartphones, and would like to change usage habits like frequent short usage and occasional long usage patterns. Given such an awareness, people are therefore willing to adopt different strategies to mitigate habitual technology use, e.g., uninstalling apps [46] or deactivating social media accounts [13].

To assist the numerous people experiencing difficulties in controlling device use [35, 54, 88], many different mobile apps and web browser extensions to control device use, the so-called Digital Self-Control Tools (DSCTs) [57], are nowadays available on the iOS and Google app stores, as well as on browser extensions web stores [57]. Often, such tools are the result of research efforts, as in the case of HabitLab [47], a Google Chrome extension that aims to help people achieve their goals online, e.g., waste less time on Facebook, by employing different strategies and interventions. Many research products also exist in the smartphone context. Hiniker et al. [35] proposed MyTime, an app to support people in achieving goals related to smartphone non-use. Similarly, AppDetox [55] is an app with which users can define simple rules to block the usage of certain smartphone's apps. Other previous works in the same context also explored more complex interventions. Ko et al. [45], for instance, developed Lock n' LoL, a mobile app that helps students focus on their group activities by allowing group members to limit their smartphone usage together. Similarly, the NUGU app [46] leverages social support to improve self-regulation, e.g., by empowering groups of people to share their usage statistics. Kim et al. [43] proposed LocknType, a proactive tool that discourages the usage of given apps by forcing the user to perform a lockout task to open them, e.g., typing a numerical code.

Some recent studies [57, 62] provide an extensive and comprehensive overview on the characteristics of contemporary off-the-shelf products and research artifacts for controlling device use. Monge Roffarello and De Russis [62] found that contemporary DSCTs for smartphones are mainly focused on supporting self-monitoring, i.e., tracking user's behavior and receiving feedback: they empower users in defining very simple interventions like timers and locking mechanisms, and they are not grounded in any particular underlying theory. By testing these interventions in-the-wild with 38 smartphone users, the same authors demonstrated that self-monitoring interventions are effective for temporary breaking some unwanted behaviors, e.g., the excessive use of social networks, but they fail in other circumstances. Since they can be easily bypassed, for instance, they do not prevent users from constantly checking their devices. Lyngs et al. [57] conducted another analysis of DSCTs by also including browser extensions. They analyzed common design features and strategies adopted by a large set of DSCTs through the application of an integrative dual systems model drawn from existing theories in the cognitive neuroscience of self-regulation. Thanks to the analysis, the authors identified three underexplored cognitive mechanisms that could improve the effectiveness of tools for controlling device use: scaffolding new desirable habits, delaying expected rewards, and encouraging users in suppressing unwanted behaviors.

Our work stems from the recent need of "designing for self-control" and aims at investigating how to effectively deal with digital wellbeing in multi-device scenarios, e.g., with the design of cross-device DSCTs that can automatically adapt to the used device.

2.3 Digital Wellbeing and Multi-Device Experiences

With the spread of new technological devices, e.g., smartwatches and voice-based home assistants, we are now completely engaged in a multi-device world. A recent consumer study conducted by Google [3] reveals that the majority of people in different parts of the world owned more than one device back in 2017. Another Google survey [1] (2016) reveals that users typically use more than one device at a time: 21% of multi-device owners, for instance, said that they typically use a second device, e.g., the smartphone, while using their computers.

Unfortunately, despite a growing interest on improving people's relationship with technology, multi-device has only been explored in studies that are not strictly related to digital wellbeing. Jokela et al. [42], for instance, conducted a qualitative diary study of multi-device use. Oulasvirta and Sumari [66] analyzed how mobile information workers migrate work across devices. Holz et al. [37] investigated how users use mobile devices when watching television. While users wish to leverage the diverse capabilities of the devices that surround them, how to properly support meaningful and productive multi-device interactions is still an open question, since the creation of useful and usable multi-device experiences is subjected to different barriers [27], e.g., difficulty of testing and emulating distinct devices. Furthermore, existing literature that can be related to the digital wellbeing context considers (nearly always) one "technological source" at a time [53, 72], be it a social network [58] or a single device like a smartphone [54]. Furthermore, while there exist DSCTs designed to work with multiple device (see Section 3 for further details), they essentially act as "statistic viewers" for each device [72], and they can sometimes produce negative users' reactions by displaying information like screen time [31]. Exceptions where cross-device interactions and multi-device scenarios have already been considered can be found in the field of notifications, a technological feature that can be easily related to the digital wellbeing context. Although notifications are useful to inform users about important information such as new messages and events [40], indeed, they may also interrupt the user's ongoing tasks, affecting users' performances, annoyance, and anxiety [8, 12]. While multi-device users prefer receiving notifications on their smartphones [87], studies demonstrated that the perceived importance of a notification may also depend on the device on which is received [78]. Prior work proposed different strategies to improve the user experience with notifications, ranging from predictive models for reducing interruptions [73] to solutions based on communicating (un)availability of users [68]. Considering multi-device scenarios, Okoshi et al. [64] developed Attelia II, a system able to detect breakpoints to deliver notifications when people use more than one mobile or wearable device. Corno et al. [25], instead, designed and implemented AwareNotifications, a semantic-aware system for dispatching notifications to different devices based on users' preferences and context.

Notifications, however, are only one of the aspects that can influence people's digital wellbeing. We claim that any kind of DSCTs should be able to deal with multi-device scenarios and cross-device interactions, since targeting a single source may not be sufficient to capture all the nuances of people's digital wellbeing. In the Internet of Things era [21], in fact, every device is connected to the Internet, and the type of use of an online service strongly depends on the adopted device [36], thus requiring digital wellbeing solutions that go beyond simple conceptualizations taking into account single technological sources.

In their workshop paper, Lascau et al. [53] state that multi-device is a yet underexplored topic in the digital wellbeing context, and may have an impact on people's productivity, as well as their emotional and psychological wellbeing. Under this assumption, in this work we aim at further analyzing gaps in the single-device conceptualization that largely characterize the contemporary digital wellbeing context. Furthermore, we provide insights on how to effectively cope with digital wellbeing in multi-device scenarios by presenting the results of a user study with 20 participants.

3 MULTI-DEVICE IN CONTEMPORARY DIGITAL-SELF CONTROL TOOLS

As a first step in our work, we conducted a systematic review and analysis of popular DSCTs [57] existing today in the form of smartphone apps or web browser extensions to understand to what extent the single-device conceptualization [53] is rooted in contemporary solutions for achieving digital wellbeing. We analyzed, in particular, whether

Feature	N	Description	Example
Data Synchronization	26	DSCTs allowing users to consult data from different devices in a unique place.	Apple Screen Time [6]
Parental Control	12	DSCTs allowing parents to monitor their children's devices.	ZenScreen [91]
Intervention Synchronization	7	DSCTs allowing users to set up interventions that can be executed on different devices.	Forest [76]
Cross-device Notification	4	DSCTs employing different devices to send notifications and display usage data.	QualityTime [39]
Cross-device Intervention	1	DSCTs adapting an intervention to different devices.	RescueTime [71]

Table 1. Multi-device features identified in contemporary DSCTs.

and how contemporary DSCTs take into account multi-device settings, looking for the gaps that prevent them from capturing all the nuances of people's digital wellbeing.

3.1 Method

3.1.1 DSCTs Identification. To get an exhaustive list of popular DSCTs to be analyzed, we exploited two publicly-available dataset recently scraped by Lyngs et al. [57] and Monge Roffarello and De Russis [62], respectively. The first dataset contains a list of 380 DSCTs extracted from the Google Play Store (mobile apps, 96), the Apple's App Store (mobile apps, 60), and the Chrome Web Store (web browser extensions, 224). The second dataset, instead, focuses on mobile apps, and it contains 42 popular DSCTs scraped from the Google Play Store.

As a first step, we merged the two datasets by removing duplicates, obtaining 412 different DSCTs. Then, we checked the URL associated with each tool, dropping 89 tools that were no longer available in the corresponding stores. We obtained a dataset of 322 tools divided in 187 mobile apps (127 from the Google Play Store and 60 from the Apple App Store) and 224 web browser extensions coming from the Chrome Web Store. However, 9 tools were available both as a mobile app (either from the Google Play or Apple App Store) and as a web browser extension. This means that the final dataset was at the end composed of 313 unique DSCTs.

3.1.2 Method of Analysis. We analyzed each identified DSCT looking for multi-device functionality. As in recent reviews [57, 62, 80], in particular, we coded functionality into multi-device features based on the information that can be found on a tool's store page, e.g., descriptions, screenshots, and user's reviews. In some cases, we also installed DSCTs on our devices to further understand a functionality which was otherwise unclear.

In a first iteration of the coding process, the authors independently reviewed and classified multi-device functionality of a subset of DSCTs composed of 20 mobile apps and 20 web browser extensions randomly chosen from the dataset. Then, they met to discuss disagreements and create a first codebook. Using this codebook, the authors reviewed all the remaining DSCTs, and they finally discussed their work by producing the final codebook.

3.2 Results

Table 1 reports the 5 multi-device features extracted by analyzing the identified DSCTs, while Figure 1 shows how many times, in percentage, such features are present in contemporary DSCTs.

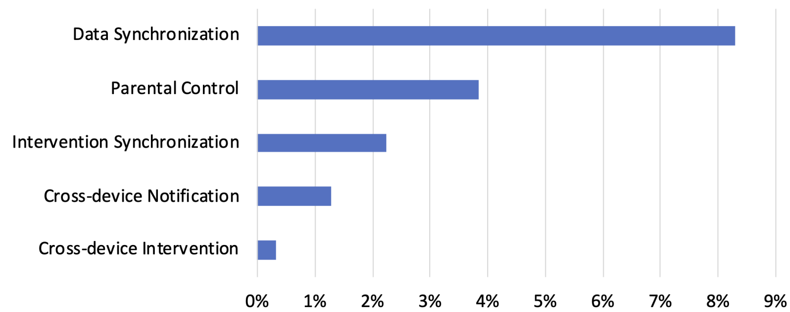


Fig. 1. Presence of multi-device features in contemporary DSCTs (N = 322).

Only 29 tools out of 313 (9.27%) actually provide their users with at least a functionality involving multiple devices. The most common multi-device feature is ***data synchronization***. Among the 29 tools with at least a multi-device functionality, 26 of them (8.44% of all the analyzed tools) can sync data about usage statistics and/or interventions among multiple devices, thus allowing users to consult data from different technological sources in a unique place. Of these 26 tools, 9 of them have both a mobile and a computer version, and they can be therefore installed as a mobile app on smartphones and tablets, and as a web browser extension[1] on PCs. Instead, 16 remaining tools are specifically designed for mobile devices, thus syncing data among smartphones and tablets, only, while another tool is available as a web browser extension, only. A popular example of a DSCT offering data synchronization is Apple Screen Time [6], a built-in feature that can be found in the latest operating systems released by Apple for its smartphones, tablets, and PCs. Through such a DSCT, users can see how much time they have spent on their different devices, they can manage notifications, and they can even limit the usage of computer and mobile apps through personalized timers.

A particular type of data synchronization is ***parental control***, a feature that we found in 12 tools (3.83%). Through DSCTs with parental control functionality, parents can monitor (and limit) the digital activities of their children from their personal devices. This requires installing the DSCT on different devices, by specifying which of them is the "controller," and which of them need to be monitored. Typically, such tools are designed for mobile devices, only. The only exception is ZenScreen [91], that is available both as a mobile app and as a web browser extension. As reported in its website, in particular, the tool is an *"AI-powered solution that can guide you and your family to track how you're spending time on your smartphone and computer."* With ZenScreen, parents can see the time spent by their children on digital devices, and they can set up daily limits on web sites and/or mobile apps.

Besides synchronizing data, some DSCTs (7, 2.22% of all the analyzed tools) also allow ***intervention synchronization***. With such a feature, the same intervention can be executed on different devices with no or limited differences. Some tools, e.g., BlockSite [15], allow the user to set up a lock-out mechanism for a web site, independently from the device used for browsing the web. Other tools like Forest [76] and HabitLab [47], instead, allow users to set up an intervention that acts on a web site for the PC, and on the corresponding mobile app for mobile devices.

The remaining two features are perhaps the most interesting from the point of view of multi-device environments, but they only characterize a very small subset of DSCTs. We found 4 tools (1.28%) able to generate ***cross-device notifications***. These DSCTs can natively warn users about their usage statistics and defined interventions by exploiting different devices. QualityTime [39], for instance, can be integrated with external services like IFTTT [38], a trigger-action

[1]except Apple Screen Time [6], which is provided as an operating system tool by Apple.

programming platform that allows the definition of simple if-then rules to connect Internet of Things devices and services. By exploiting these connections, the tool can warn users in different ways, e.g., by flashing a Philips Hue lamp when users exceed the usage threshold for a mobile app. Pavlok [67], instead, can release a mild electrical stimulus on a wearable device to notify the user when she is excessively using her smartphone.

Finally, we only found one DSCT (RescueTime [71], 0.31%) using an intervention that can be classified as a ***cross-device intervention***. Differently from the intervention synchronization feature, where the same intervention is executed on different devices nearly at the same way, a cross-device intervention is adapted to the device on which it is executed. When users define a goal in RescueTime, in particular, the tool can block distracting web sites on the PC, and at the same time it can automatically put the user's smartphone in do-not-disturb mode, thus protecting the user from multiple sources of digital distractions.

Overall, our analysis shows that the majority of popular DSCTs (90.73%) are still targeting single devices, only: they collect data from single technological sources, and they (sometimes) allow users to set up mono-device interventions like timers and blocking mechanisms [62]. In today's multi-device world, however, people typically use more than one device at a time [1], and this conceptualization may not be sufficient to capture all the nuances of people's digital wellbeing. Therefore, we can empirically confirm what Lascau et al. [53] qualitatively said in their workshop paper: digital wellbeing applications are not tracking cross-device data, but they essentially act as simplistic productivity overviews for users [72].

4 USER STUDY

Despite very few exceptions, our review of contemporary DSCTs demonstrates that the road towards multi-device digital wellbeing is still long. To take a step forward, we conducted a background interview and a co-design and sketching exercise with 20 participants with different occupations and backgrounds. Our aim was to understand, directly with users, how digital wellbeing is affected by the usage of multiple devices, and how to take into account multi-device experiences in the context of digital wellbeing, e.g., through novel DSCTs.

4.1 Method

4.1.1 Participants. We recruited participants through convenience and snowball sampling, by sending private messages to our social circles. To minimize self-selection bias, we selected participants from a larger sample to a) enroll users that regularly use more than one device, b) have a mix of participants caring/not caring about technology overuse, and c) balance our population in terms of occupation and educational background. We stopped the recruiting process after reaching saturation, i.e., when no new information was being generated by new interviews. Our final sample included 14 participants who self-identifed as male and 6 who self-identifed as female, with an average age of 25.30 years (SD = 3.22). 11 participants were students, while 9 participants were workers. Students were enrolled in different university courses: 7 of them had a technical background, while the remaining 4 were enrolled in humanities programs. Workers, instead, ranged from office workers (4) to factory workers (1). All participants currently live in Italy and the study was conducted in Italian.

4.1.2 Procedure. All participants completed a two-part study session composed of a background interview and a co-design & sketching exercise. Due to the Covid-19 pandemic [4], all the one-to-one study sessions were conducted and video-recorded online between the spring and the summer of 2020. To this end, we used the Zoom video conferencing tool [7]. On average, study sessions lasted 22 m 43 s (*SD* = 4 m 5 s).

Background interview. We first conducted a background, semi-structured interview to understand how users make sense of their habitual use of their different devices. Our goal was to probe the factors that shape multi-device experiences, and the triggers that make users switch from one device to another. We started the interviews by asking participants to describe the devices they regularly use, including their usage differences. Then, we proceeded with questions analyzing users' multi-device experiences. Examples include: *"Do you happen to use more than one device at the same time? How does that make you feel?"* and *"What makes you switch from one device to another? How often does this happen?"*. Contextually, we also asked participants to provide at least a practical example of one of their multi-device experiences.

Co-design and sketching exercise. After the background interview, we conducted a co-design and sketching exercise to elicit, directly from the interviewed participants, how to effectively move towards digital wellbeing in multi-device environments. The exercise was introduced by a set of open questions. We asked participants whether they would change something about their behavior during their multi-device experiences, and if they had already tried to make some behavioral changes before, e.g., through existing DSCTs. These questions were included to contextualize the importance of such changes for the participants. Then, we asked participants to reason about what and/or who could help them in improving their digital wellbeing in a multi-device context. They were allowed to come out with whatever solution they could think of, be it technological or not, even if not feasible for them. We finally asked them to translate their envisioned solutions into a sketch on a sheet of paper. Depending on the participants' answers, the sketch could range from a use case depicting some user's behaviors to a design concept of a novel DSCTs. At the end of the exercise, participants sent us a photo of their sketch through the Zoom's chat.

4.1.3 Data Analysis. Inspired by the work of Tran et al. [82], we used a reflexive thematic analysis method [16] that is consistent with a grounded-theory approach. Following such a method, we periodically analyzed the collected data as participants were interviewed to identify emergent themes, if any, and to understand when saturation was reached. This allowed us to iteratively revise the interview protocol as themes solidified, with the aim of gaining more targeted insights into emerging themes. Revisions, however, involved minor details, e.g., asking more details on a particular multi-device interaction, if mentioned during an interview. A complete analysis exploiting all the collected data was performed at the end of the 20 interviews to identify the final set of themes.

4.2 Results

We derived four main themes from our user study: (1) the role of the technological source, (2) the role of the underlying task, (3) the desire to improve, and (4) from adaptable interventions to educational solutions.

4.2.1 The Role of the Technological Source. Participants declared to regularly use different "smart" devices during their daily activities. On average, each participant mentioned 3.80 technological sources (*SD* = 1.06), from mobile devices to video game consoles and action cameras. As shown in Figure 2, smartphones and laptops were the most common devices. All the participants, in particular, owned at least a mobile phone. They declared to use it for a variety of tasks, e.g., communicating with friends, browsing social networks, and studying. 85% of participants, instead, stated to regularly use laptops. Also in this case, the usage of such devices varied across users, and ranged from entertainment activities, e.g., watching films, to studying and working.

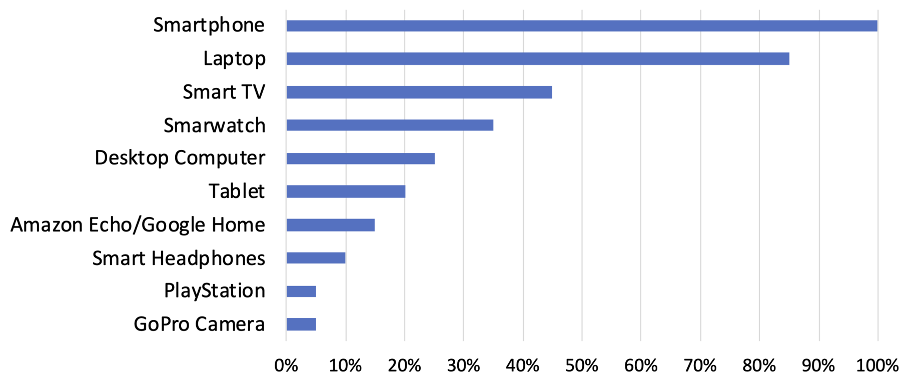


Fig. 2. Percentage of users regularly using the listed devices (N = 20).

As stated by the participants, other common devices, e.g., smartwatches (35%), desktop computers (25%), and tablets (20%), have a more specific type of usage. Smartwatches, for instance, were mainly used as a wellbeing tool, e.g., to track sport activities. Desktop computers were typically present in the worker's office, and were therefore used as a working tool, only. Tablets, instead, were used for watching TV series and playing music, mainly.

Stemming from the participants answers in the background interview, we analyzed the role of the technological source in people's digital wellbeing. Consistently with previous work [82], all the participants described the smartphone as a problematic device that can negatively influence their own digital wellbeing, mainly because it is a major source of distraction. While smartphones are nowadays an essential tool in our lives, indeed, they can distract us from our current activities. The following quote accurately describes the common feeling of our participants:

> *"The smartphone is causing the atrophy of our brain. You can't pay attention to anything anymore. When was the last time you watched a movie without looking at your phone?"* (P15)

The problem, in particular, is amplified by the ubiquitous nature of mobile devices, and by their ability to generate notifications [45, 89]. P12, for instance, said that *"the smartphone is always in your hands, it is always available: you look at the time and then you unconsciously end up on a social network"*. Also P8 confirmed this characteristic of the smartphone: *"it's almost an obsession: I turn on the screen to check the time, and then I go through all the notifications"*.

Besides mentioning smartphones, participants described negative experiences with other devices as well. They reported to compulsively access social networks on desktop computers, laptops, and tablets, even during important activities like studying and working. When reasoning on other devices as a source of distraction, participants acknowledged that the problem is often the used service, rather than the technological source *per se*:

> *"With an Internet connection and a screen, any device can be a source of distraction."* (P7)

Notifications received on a smartwatch, for instance, can cause frustration to a user engaged in meeting, as highlighted by P11. Even a device playing music or videos can be problematic. Here is how P16 described his typical day at the office, for instance: *"I regularly use my laptop to listen to music while I'm working on the desktop computer. Sometimes, this is distracting, especially when the music is on YouTube and there is a video in the background."* A similar scenario was

Factor	Type	Description	Example	Feeling
Convenience	Alternate	Switching between devices to improve the usability of a service.	*"When I move from one room to another, I can switch from watching Netflix on the PlayStation to watching it on my smartphone, automatically."*	Positive
Support	Simultaneous	Using a device to support a main task over another device.	*"Sometimes, I have some notes on my phone, and I watch them while I'm working on the computer."*	Positive
Notifications	Alternate	Reacting to notifications received on other devices.	*"Sometimes I forget to disable smartwatch notifications. It's really annoying."*	Negative
Negative Emotions	Alternate	Using another device to overcome negative emotions, e.g., boredom and stress	*"When I am particularly stressed, it's likely that I interrupt my work on the PC with the smartphone to relieve the tension."*	Negative
Unconscious Habits	Alternate	Switching between devices without conscious awareness	*"It's something you do out of control, it makes you lose the focus. It bothers me."*	Negative

Table 2. The factors that shape multi-device experiences.

described by P20. While working on his laptop at home, he admitted to usually leave the TV on in the background. In describing such an experience, he said *"it can be a support, but it becomes negative behavior when I really need to focus."*

4.2.2 The Role of the Underlying Task. The need of overcoming the contemporary single-device conceptualization was further confirmed by several multi-device experiences that we collected from our participants. Multi-device usage characterizes users' daily lives, and have the potential to positively and negatively influence digital wellbeing. Table 2 summarizes the factors shaping such common experiences. We were able to differentiate two different types of multi-device usage: alternate, i.e., seamlessly switching between different devices, and simultaneous, i.e., using different devices at the same time.

Convenience. A common factor shaping multi-device experiences was convenience. Participants told us that they regularly switch between different devices for convenience, with the aim of accomplishing a given task more easily. P18, for instance, often alternates the usage of smartwatch and smartphone, if necessary: *"when the smartwatch screen is not big enough, I switch to my smartphone to get a better view of what I'm looking at."* P7, instead, sometimes uses both a laptop and a tablet to edit the same document: *"some interactions are easier on my iPad, so I often edit my documents in a sort of 'collaborative way', by alternating the PC and the tablet."* Switching between devices for convenience was typically perceived as a positive experience:

> *"When I move from one room to another, I can switch from watching Netflix on the PlayStation to watching it on my smartphone, automatically. Such a convenience is the positive aspect of technology.* (P15)

Support. Another factor shaping multi-device experiences turned to be the need of using a given device to support a main task performed over another device. In this case, multiple devices are used simultaneously. During the lockdown due to the Covid-19 pandemic, for instance, P10 regularly used the smartphone to chat with his classmates and get feedback on the videolessons he was following on his laptop. The usage of the smartphone as a sort of "external monitor," in particular, was a recurrent situation across students:

"I don't have a external monitor, so sometimes it's useful for me to look at some documents on my smartphone while I'm studying on my laptop." (P5)

As P19 confirmed, participants liked the possibility of using more than one device to accomplish a task: *"I often try to use two devices as if they were one. I feel wrapped up in technology, I like it."*

Notifications. Participants agreed that one of the most common triggers that make them switch from one device to another is reacting to notifications. As highlighted by previous work in the smartphone context [77], participants stated that notifications, independently of the technological source on which they are received, can negatively influence people's digital wellbeing. P11, for instance, was annoyed by receiving notifications on his smartwatch while attending virtual meetings on his laptop. Switching between devices because of a notification, in particular, make users divert attention from the primary task, especially when the included messages are not related to the current activity:

"You can no longer pay attention to what you're following, be it a film on the TV or a podcast on Alexa. You receive a notification on your smartphone, and you inevitably look at it. (P15)

Negative Emotions. Another reason to alternate the usage of different devices turned to be the need to escape from negative emotions. Consistently with previous work in the smartphone context [45, 82], participants described such self-interruptions as a negative experience arising when they are bored or stressed:

"When I'm bored at the PC, I typically turn on the phone. I think it would be better to distract yourself by doing something else." (P10)

"When I am particularly stressed, it's likely that I interrupt my work on the PC with the smartphone to relieve the tension." (P20)

Unconscious Habits. The last factor shaping multi-device experiences was unconscious habits. Not surprisingly [56], such a behavior was negatively perceived, and it was typically associated with smartphones. Several participants described situations during which they could not control the impulse of checking their mobile devices. Besides happening during important activities like studying or working, participants stated that unconscious habits can disrupt entertainment activities as well, e.g., watching a movie:

It's frustrating sometimes. You're watching a movie on the smart TV and then that moment comes, you take the smartphone out of your pocket. Just the fact that you have to go back with the video makes you say 'I'm such an idiot!' But it's an automatic reflex, it's not something you can control. (P15)

Such situations can even interfere with interpersonal relationships, as stated by P17: *"I should watch movies without getting distracted by the smartphone, my boyfriend makes fun of me all the time, he says I'm not able to follow anything."* Furthermore, unconscious habits may result in awkward behaviors that make users feel addicted to technology:

Sometimes, when I'm on Facebook on my computer, I take my smartphone, I go on Instagram, and then I unconsciously open Facebook, too. So I have it opened on my smartphone and my PC at the same time. When this happens, I feel really addicted to social networks. (P12)

Our analysis on the factors shaping multi-device experiences suggests that the influence of multi-device usage on digital wellbeing can be associated with the underlying task. When devices were used together to perform a single, *coherent* high-level task, indeed, the multi-device experience was considered as positive by participants. This includes switching between devices for convenience, e.g., to improve the readability of a given document, but also synchronously using two devices as a support for studying or working. When devices were instead used to satisfy multiple, *incoherent* tasks, the multi-device experience turned to be a negative influence for the digital wellbeing of the participants. Reacting to a smartphone notification while working on the desktop computer, for instance, was described as a waste of time. Similar negative feelings were experienced by participants that reported to regularly browse social networks on the smartphone while watching a film on the smart TV, a situation that made them experience a sense of frustration for not being able to follow the movie plot.

4.2.3 The Desire to Improve. Overall, only 5 participants out of 20 (25%) said to have good self-control over their own devices, with sentences like *"if I decide to focus, I don't get distracted for any reason"* (P11) or *"I don't mind, I'm satisfied with the way I use my devices"* (P7). When reflecting on the usage of their different devices, instead, the majority of the participants revealed their desire to improve the multi-device experiences they considered as negative:

> *"I'm used to check emails on the smartphone, so while I'm studying on my laptop I often interrupt myself to check if there are new messages. Avoiding this behavior would be important, it would change the way I study."* (P1)

In line with what participants said when describing their devices (Section 4.2.1), several desired improvements involved smartphones. As P9 explicitly said, for instance, *"it's the smartphone that distracts me while I'm using the PC. It would be important to limit notifications, for instance"*. A consistent number of envisioned changes, however, also involved other devices, as in the situation described by P8: *"while I'm watching the smart TV, I'm used to take the laptop or the tablet to browse the web and look for different information, like a new recipe. So I'm distracted on both devices: I should do one thing at a time."*

According to the participants, digital wellbeing is strictly related to productivity, especially during specific activities like studying and working (P11). This confirms that productivity and digital wellness, i.e., how digital technologies influence how people perceive their life in an information society, are two interrelated concepts [19]. Moreover, pursuing digital wellbeing in the contemporary multi-device world would positively influence user's mood (P12) social relationships (P17). That is the reason why the majority of the interviewed users admitted that they had already tried to change their behaviors with their devices in different ways, ranging from leaving the smartphone in another room to disabling notifications on smartwatches and computers. The common feeling, however, was that such solutions cannot always be successful, for various reasons. In describing her attempts to improve her digital wellbeing, P1 said: *"when all I need is one device, I turn off the other. It doesn't always work, because then sometimes I need the device that I turned off."* By disabling notifications, P14 experienced the widespread fear of missing out [69] (*"I'm worried I won't be reachable"*). P12, instead, admitted that leaving the smartphone physically away *"doesn't work, often: I regularly get up from lunch to check my phone anyway."*

Participants, however, demonstrated to prefer such "physical" interventions, e.g., turning the device off, with respect to using existing DSCTs. Overall, 9 participants our of 20 (45%) stated not to use any DSCTs, with 3 participants who admitted to not being familiar with these instruments at all. The main reason for not using DSCTs was the participants' presumption of being able to control technology use on their own:

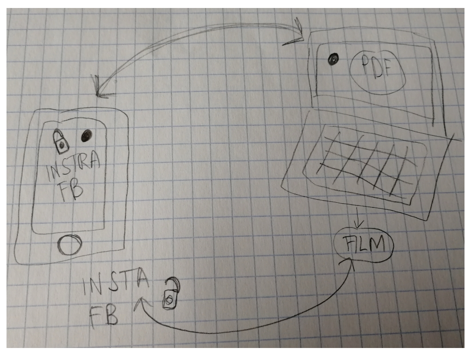
> *"I know these tools, but I've never really been able to use them. I refuse to use an app for controlling my behavior: I feel I can do it on my own, even though I often fail.* (P20)
> *"I'd rather be the one deciding when to use Instagram or not."* (P2)

Also the participants that already used some DSCTs shared a common sense of reluctance towards contemporary apps and browser extensions designed as digital wellbeing solutions. As already highlighted by mainstream media [31], for instance, consulting usage statistics like screen time can sometimes produce negative user's reactions that may induce the user to stop using the service:

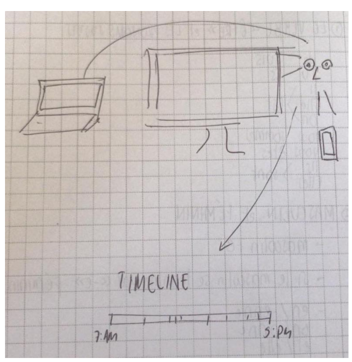
> *"I looked at the Instagram usage statistics a few times but then I stopped. I hate to know how much time I spend on it, it made me anxious."* (P15)
> *"I am happy when I'm able to reduce the usage of the smartphone. When I use it compulsively, however, I get anxious and, for a few days, I don't look at usage statistics anymore."* (P8)

Our participants also criticized the low level of restrictiveness of timer and locking mechanisms implemented by contemporary DSCTs, thus confirming what Monge Roffarello and De Russis [62] found by analyzing user's reviews extracted from the Google Play Store. As reported by P18, indeed, *"you can always bypass locking mechanisms: if you want to get distracted, you always find a way"*. A similar concern was reported by P1: *"you can always ignore an app, I would prefer more 'drastic' solutions"*.

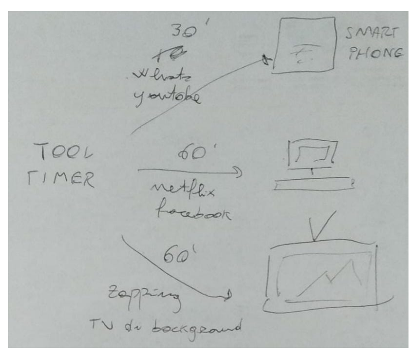
4.2.4 From Adaptable Interventions to Educational Solutions. When asked to reason about what and/or who could help them in improving their digital wellbeing in a multi-device context, participants came out with different ideas.



(a)



(b)



(c)

Fig. 3. Sample design concepts of novel DSCTs from participants. Participants called for more integrated solutions, with DSCTs able to intelligently combine information coming from different devices (a and b), and to adapt interventions to the involved technological source (c).

In the co-design & sketching exercise, half of the participants opted for a technological solution, by sketching the design of their own DSCT (see Figure 3 for some examples). The envisioned tools, however, significantly differed from existing DSCTs, thus reflecting the participants' concerns about contemporary digital wellbeing solutions. Looking at the sketches, participants highlighted the need of having more integrated solutions, with DSCTs able to apply interventions by combining information coming from different devices (Figure 3(a)):

> *"I'd like a system that blocks distractions on my smartphone while I'm using my computer, for example. I imagine an application installed on both devices, with an 'exchange' of information between the two devices. When I'm reading a PDF on my computer, for instance, the smartphone app blocks Facebook and Instagram. That shouldn't happen when I'm watching a film."* (P1)

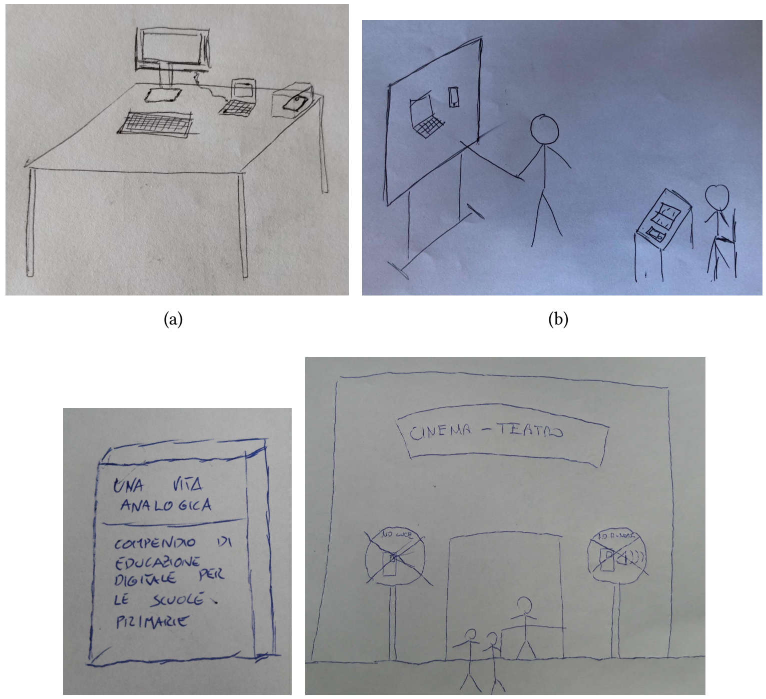
In a multi-device context, in particular, DSCTs should be able to analyze and make sense of data collected from a variety of sources in different contexts. As highlighted by P1, indeed, a necessary condition for better using your devices is to know *"how you use them together."* P16, for instance, called for *"a multi-device application that can analyze what is happening on each device, and that can provide you with an 'intelligent' analysis, with some statistics about what you have done"* (Figure 3(b)). According to the same participant, that cannot happen until existing DSCTs will measure low-level information like screen time. The variety of available devices we have today, indeed, opens up new possibilities: *"screen time is not enough: the system should figure out where you're looking at, through a camera for example."* Interventions, moreover, should adapt to different devices, according to the user's context. P13, for instance, would like a sort of blocking mechanism that can be adapted to her different devices while she is studying: *"I tell the system that I have to study from 2 to 7 PM, and the system blocks Instagram and Facebook on my smartphone and Netflix on the TV, for example."* Figure 3(c), instead, is a design concept proposed by P19, who imagined *"a cross-device tool, with the possibility to set a limit of one hour of Netflix per day on the PC, 30 minutes of YouTube on the smartphone, and maybe a block on excessive zapping on TV."*

Instead of focusing on technological solutions, the other half of the participants used the co-design & sketching exercise to confirm their reluctance to use a DSCT to control their behavior (Figure 4). According to P20, in particular, technology overuse is mainly due to negative feelings like stress and anxiety: *"when I make positive choices in my life, when I am happy, these things don't happen to me, so it all starts with myself."* Also P9 uncovered a personal and introspective vision of the problem, as demonstrated by his sketching (Figure 4(a)). According to him, *"people have to find their own balance: what helps me not to get distracted while I'm studying, for instance, is to have a tidy desk, with a place where I can physically 'hide' my smartphone."*.

According to the participants, another important factor to reach digital wellbeing in a multi-device world is to learn how to properly use technology, since *"it's a matter of awareness: if someone told me certain things better, maybe I'd do them"* (P11). Such an awareness cannot come by itself, but it can be obtained with the help of competent figures:

> *"I think human figures can help me more than apps. If a competent person explains to me what I can do, what are the risks, how to behave, I would listen to him, I would trust him. Kind of like when you go to the psychologist."* (P8)

As such, participants agreed on the importance of learning how to find a balance with technology use since childhood, e.g., through a digital education course (P3, Figure 4(b)). Topics like digital wellbeing, indeed, *"are not currently covered in schools"* (P7). P15 explicitly said that *"education should be the major focus"*, and that *"we should tell young people 'you are doing this, do this': there's no point in doing 3 things at once if you do all the 3 things badly."* That was the reason why, in the co-design & sketching exercise, he sketched a school book entitled *"An analogue life - Compendium of digital*



(a) (b) (c) (d)

Fig. 4. Instead of focusing on technological solutions, some participants agreed on the importance of self-awareness (a), education (b and c), and social norms and political choices (d).

education for primary schools" (Figure 4(c)). According to the same participant, education might foster the development of new social norms, e.g., not to use the smartphone while you're talking to someone. Finally, novel political choices could help society to consolidate such norms, as mentioned by P12 (Figure 4(d)):

> *"Something at a government level might be useful. I'm thinking about the law on smoking in public places, something like that."* (P12)

5 DISCUSSION

Our investigation found different gaps in the single-device conceptualization characterizing the contemporary "race towards digital wellbeing." Regardless of whether they were students or workers, participants of our user study declared to regularly use several devices for various tasks. They acknowledged, in particular, that even smartwatches can become a potential source of distraction, and they stated that different factors, ranging from convenience to unconscious habits, shape positive and negative multi-device experiences that can influence digital wellbeing.

Stemming from the results of the presented work, we here discuss a design agenda for multi-device digital wellbeing, encompassing (1) data integration, (2) cross-device interventions, and (3) learning.

5.1 A Design Agenda for Multi-Device Digital Wellbeing

5.1.1 Data Integration. As highlighted in Section 3, only a limited number of contemporary DSCTs are able to collect data coming from different technological sources. A large part of these tools, moreover, are designed as parental control applications for mobile devices, only, or they force the user to be part of a single technological ecosystem, e.g., as happens for Apple Screen Time. Furthermore, they mainly track screen time, an information that by itself cannot capture all the nuances of multi-device experiences. Users, indeed, are more interested in understanding the usage details of certain devices rather than quantifying their overall screen time [72]. In addition, visualizing screen time can produce negative users' reactions [31], with feelings like anxiety and stress. As pointed out by some participants in our study, these feelings induce users to stop using the DSCT.

This demonstrates the need for researchers and practitioners to take into account *data-integration*, by implementing DSCTs able to make sense of raw data coming from different technological sources, e.g., screen time and contextual information, with the aim of providing users with a clear, high-level overview of their technological habits. This was explicitly requested by the participants of our user study, who envisioned DSCTs able to deliver *"intelligent analysis"* regarding the usage of different technological sources, with an *"exchange of information"* between the exploited devices. The variety of devices we have today, in particular, opens up new possibilities, especially if we consider the now-established Internet of Things paradigm. Since everything is nowadays interconnected, DSCTs could exploit devices like cameras and smartphone sensors in a sensible and privacy-preserving way to enrich usage data with contextual information, e.g., *"to figure out where you're looking at"*. As one of our participant correctly identified, indeed,*"sometimes I have a document opened on my desktop computer, but my attention is on the video playing on the nearby laptop."* Understanding what the user is currently doing with her devices would be extremely important: as reported in Section 4.2.2, the user's underlying task is one of the discriminant factors to differentiate between positive and negative multi-device experiences.

5.1.2 Cross-device Interventions. Our review of existing DSCTs shows that contemporary tools for digital wellbeing can sometimes be used to synchronize the same intervention to different devices, e.g., to block the Facebook website on the PC while blocking the same app on the smartphone. Such a synchronization, however, is not sufficient to influence, at least significantly, multi-device experiences. Indeed, each device has its own type of usage, and significant differences in how users use their devices exist even in mobile devices: smartphones, for example, are used almost thrice as often as tablet devices, but usage sessions on tablets are three times longer [36].

This suggests the need of novel DSCTs providing *cross-device interventions* that can adapt themselves to the characteristics of the target device. The intervention implemented by RescueTime [71], a popular DSCT with which websites can be blocked on the PC and the smartphone can put in do-not-disturb mode, is an interesting example. Participants of our user study, indeed, mentioned similar interventions, by envisioning *"cross-device tools"* to allow them to control different device-specific behaviors, ranging from controlling smartphone notifications to avoiding excessive zapping on the smart TV. Furthermore, data integration could allow to activate interventions on the basis of the current user's activity, e.g., to block smartphone distraction while working on the PC.

5.1.3 Learning. Given their simple implementation, contemporary DSCTs and several research studies in the smartphone context, e.g., [35, 45, 46], primarily focus on using lock-out mechanisms to reduce device use. While lock-out mechanisms are the shortest path to avoid unwanted behaviors, e.g., compulsive phone checking, they may not be the most effective solutions. Indeed, while users often declare their desire for interventions that cannot be bypassed (as reported by some of our participants and in [62]), the reality is that restrictive solutions often cause frustration and high abandon rate [23].

Thanks to our user study, we support the need of moving beyond lock-out mechanisms, by highlighting the importance of *learning* how to properly use technology. Instead of blocking a "bad" user's behavior, for instance, a novel DSCT could be used as a *learning* support, e.g., by suggesting desirable alternatives, or it might help the user to think about the negative aspects of her choice. That was the exact point of one of our participants, who said *"I would like an app to tell me what I missed with my distraction. Something like 'you wasted 30 minutes on Instagram, you could have written 4 pages of your Word document'."* Some of our participants, however, also shared a common sense of reluctance towards technological solutions, claiming that understanding how to use technology is often a path of personal growth that is more influenced by other human figures rather than any system or app. In our multi-device world, this suggests the need of pursuing digital wellbeing also outside DSCTs., e.g., by planning digital education courses for children and teenager.

Learning how to properly use technology also means learning when to *not use* technology. The HCI community recently investigated the benefits and the drawbacks of the intentional non-use of technology [35, 75]. HCI, however, mainly studies "use" rather than "non-use [75]", and the business model of the tech industry fights with the impelling need of the users to improve their relationship with technology. How to design technology that is also able to disincentive itself is, at the same time, an open challenge and an ethical responsibility that HCI researcher should explore to counter problems like technology unwanted (over)use. As called for by recent works in the digital wellbeing context [57, 62], a practical starting point could be the investigation of novel DSCTs able to scaffold new and desirable habits, e.g., taking a walk instead of checking social networks in the evening.

5.2 Limitations and Future Works

There are some limitations to be considered in our work. We conducted our user study with a small sample of 20 participants. While we balanced our population by recruiting both students and workers, our participants were more or less the same age, between 21 and 31 years. Given their extensive use of technology, however, young people are one of the most used populations in digital wellbeing related studies (see [45, 54], for example). Furthermore, our participants came from the same geographical area, and they had the same cultural background. We have to acknowledge that results may vary for different cultural settings. Nevertheless, although the reported findings may not generalize, our work provides rich, qualitative design insights that we expect to be transferable [48].

Future work would need to further explore multi-device digital wellbeing across a larger population. Researchers could also use the present study as a starting point to implement and evaluate novel DSCTs able to deal with the complex digital ecosystems that are today experienced by the majority of people.

6 CONCLUSIONS

The last few years have seen a growing research attention on analyzing the negative aspects of overusing technology. Although users interact with a plethora of smart devices every day, however, contemporary efforts to promote digital wellbeing target single technological sources at a time, mainly, with a major focus on smartphones [62]. In this paper, we took a step towards multi-device digital wellbeing through a review of more than 300 tools for digital self-control and a two-part qualitative study with 20 participants. With the first analysis, we showed that contemporary solutions for achieving digital wellbeing rarely include features for multi-device settings, e.g., cross-device notifications. Rather, they are often designed as tools to influence the usage of single devices, only. The user study confirmed the need of overcoming such a single-device conceptualization: participants acknowledged that every device can potentially become a source of distraction, and they shared several personal multi-device experiences negatively correlated with their digital wellbeing, e.g., seamlessly switching between devices to perform uncorrelated tasks.

On the one hand, we call for a design agenda to implement digital self-control tools that can make sense of data collected from a variety of sources, with the aim of adapting interventions to the used device and activity. On the other hand, we show the need of supporting technological solutions with social, educational, and political factors: a "digital education" school course, for instance, may contribute to the digital wellbeing of future generations, and may be more effective than any lock-out mechanism.

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