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Technology Supported Behavior Restriction for Mitigating Self-Interruptions in Multi-device Environments

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The interruptions people experience may be initiated from digital devices but also from oneself, an action which is termed "self-interruption." Prior work mostly focused on understanding work-related self-interruptions and designing tools for mitigating them in work contexts. However, self-interruption to off-tasks (e.g., viewing social networking sites, and playing mobile games) has received little attention in the HCI community thus far. We conducted a formative study about self-interruptions to off-tasks and coping strategies in multi-device working environments. Off-task usage was considered a serious roadblock to productivity, and yet, the habitual usage and negative triggers made it challenging to manage off-task usage. To mitigate these concerns, we developed "PomodoLock," a self-interruption management tool that allows users voluntarily to set a timer for a fixed period, during which it selectively blocks interruption sources across multiple devices. To understand the effect of restricting access to self-interruptive sources such as applications and websites, we conducted a three-week field trial (n=40) where participants were asked to identify disrupting apps and sites to be blocked, but the multi-device blocking feature was only provided to the experimental group. Our study results showed the perceived coercion and the stress of the experimental group were lower despite its behavioral restriction with multi-device blocking. Qualitative study results from interviews and surveys confirm that multi-device blocking significantly reduced participants' mental effort for managing self-interruptions, thereby leading to a reduction in the overall stress level. The findings suggest that when the coerciveness of behavioral restriction is appropriately controlled, coercive design can positively assist users in achieving their goals.

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

Additional Key Words and Phrases: Self-interruption, Interruption management, Behavior restriction, Technological coercion

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1 INTRODUCTION

The majority of knowledge workers are bound to digital devices such as PCs and smartphones in their workplaces. The number of digital devices and the application services we engage have increased, and multitasking is prevalent in everyday office scenarios [9]. We are exposed to greater odds of being interrupted by such devices.

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Prior studies in the human-computer interaction (HCI) domain explored the negative impacts of interruptions and suggested several approaches to mitigate interruptions from external sources, such as phone calls [12, 50], smartphone notifications [36], and the use of context-aware technology [22]. Recent studies have shown that self-interruptions are as prevalent as external interruptions [15, 19, 38]. Here, self-interruptions are defined as discretionary interleaving tasks [45]. Some studies claim self-interruptions are more disruptive than external interruptions [4], particularly when it leads to off-task media usage such as checking Facebook and playing games [18, 33]

However, a relatively small body of work exists on the topic of self-interruptions to off-tasks, particularly in what context such device usage occurs and how to provide technical support to mitigate them. Most behavior change literature take the approach of "persuasion" by quantifying user activities and "nudging" them into more desired behavior [16]. Persuasive technology is defined by Fogg as "technology that is designed to change attitudes or behaviors of the users through persuasion and social influence, but not coercion" [17]. Little is known about the impact of the "coercive" nature of technology that directly limits undesired behavior (e.g., off-task multitasking) until a certain goal is achieved. Such an approach contradicts the persuasive technology research that leverages self-regulation and autonomy.

Here, we initially conducted a formative study in search for identifying self-interruption sources and knowledge workers' management strategies. Based on the results of this formative study, we designed and implemented a self-interruption management tool, termed PomodoLock, leveraging two coercive behavior restriction mechanisms: (1) a behavior restriction mechanism for blocking self-interruptive sources on muiltiple personal devices ranging from webpages to smartphone applications, and (2) a timeboxing technique which allows the user to focus on the primary task within a user-defined time frame.

We conducted a three-week in-situ study with PomodoLock. The main research questions of this study were to understand (1) in what context PomodoLock was used, (2) how effective PomodoLock was in mitigating interruptions, and (3) if participants experienced any negative emotions (e.g., stress or coercion) with coercive behavior restriction mechanisms.

Our study results show that the experimental group who used the blocking feature had 41.5% more usage over the control group, who only had the baseline feature of a timer. The qualitative results from user interviews and self-assessment surveys show that the perceived levels of coercion and stress were lower in the experimental group with the multi-device blocking feature. We also present the statistics of the PomodoLock usage context and discuss the value of each feature, including the timer, app/website blocker and the multi-device synchronization capability implemented in our tool.

2 RELATED WORK

We review related work in the following areas: (1) multitasking and self-interruption in various situations, (2) problematic usage of digital technologies such as cyberloafing and overuse, and (3) and HCI work on promoting productive technology use.

2.1 Multitasking and Self-Interruption

Workers tend to organize their working spheres into related tasks and frequently to switch between different spheres [19]. Czerwinski et al. [15] showed that 40% of task switching was self-initiated, while the rest was mainly caused by external interruptions such as phone calls and emails. An interruption is disruptive if it does not occur at a natural break point or requires the shifting of one's working sphere. However, in reality, work is likely to be fragmented, and a typical work fragment lasts only about 11 minutes [38]. Jin and Dabbish [23] identified the typology of self-interruptions at work, such as adjustments, breaks due to frustration/fatigue, inquiries, recalling unrelated tasks, habitual routines, triggers/stimuli, and waiting to fill time. Adler et al. [4] stated that self-interruptions are initiated to maintain the flow state of work; i.e., individuals may seek more challenging tasks for stimulation and stay away from challenging tasks due to frustration, exhaustion, and obstruction. Mark et al. [39] defined the following attentional states based on engagement and challenge: rote (highly engaged, not challenged), focus (highly engaged, and challenged), bored (low engagement, not challenged), and frustrated (low engagement, high challenge). They also showed that attentional states are related to various contextual factors such as online activities (emailing vs. Facebook), the time of day (morning vs. afternoon), and day of the week (e.g., 'blue Monday'). While prior studies have detailed multitasking behaviors and the nature of self-interruption, little is known about how self-interruption leads to counter-productive usage and under which working contexts, how multi-device environments affect counter-productive usage, and what coping strategies knowledge workers use.

2.2 Problematic Usage: Cyberloafing and Overuse

Cyber-loafing refers to the voluntarily use of digital technologies for non-work purposes during working hours, such as off-task web browsing, using social networking sites, playing games, and engaging in online gambling [18, 33]. Digital technologies include company-provided computers (e.g., desktop or laptop PCs) as well as personal devices that employees bring with them to work (e.g., smartphones). Prior studies have shown that cyber-loafing is prevalent in the workplace; e.g., a 2006 survey showed that American employees spend 24% of working hours engaged in cyber-loafing [34]. Various mechanisms can be used to curtail cyber-loafing, such as Internet use policy/training and filtering/monitoring software [37]. Researchers have found some positive effects of cyber-loafing. Anandarajan and Simmers [6] found that personal web usage provide several benefits, such as increases in productivity, the ability to manage the work/life balance, increases in skills, and stress reductions. Cyber-loafing is linked to both situational factors such as organization justice as well as individual factors such as the internal locus of control and self-control [11, 20].

Media usage, such as the use of social networking sites and mobile games, provides emotional gratification to users, which reinforces their continual usage. Oulasvirta et al. [42] showed that due to the accessibility of smartphones, mobile usage can become habitual. Users of Facebook exhibit complicated behavioral patterns, such as resisting, leaving, relapsing, and limiting [8]. Furthermore, there are diverse behavior-change goals for social networking sites, ranging from reducing usage amounts to improving site engagement levels [49]. Our work complements prior studies on cyber-loafing and overuse by providing detailed accounts of digital interruptions among graduate student researchers in multi-device environments while also suggesting a technical approach toward multi-device blocking to maintain self-regulated usage behaviors.

2.3 Promoting Productive Technology Use

There are many products and research prototypes that aim to promote the productive use of various digital technologies and services. Intervention techniques can be classified into the following categories: usage tracking/reflection, goal setting, and blocking. Usage tracking and reflection approaches, such as RescueTime [2], ManicTime [1], and SLife [3], allow users to understand their usage behaviors such that they can attempt to change their behaviors [43]. In addition to usage visualization, prior studies employed various methods to help users to better reflect their behaviors. Lottridge et al. [37] built a Firefox plugin that highlights non-work-related sites in a tab and displays a productivity ratio (e.g., 70% work vs. 30% non-work) in the status bar, which significantly lowers non-work related web usage. When informed of productivity levels, Kim et al. [27] found that desktop widgets improved user engagement and negative framing when delivering unproductivity information was effective for improving productivity. Rooksby et al. [48] experimented with ScreenLife, a multi-device usage tracking service, finding that ScreenLife facilitated a better understanding of the overall usage and the balancing/managing of multi-device use.

Several have studies examined goal setting and reinforcement approaches. MyTime [21] allows users to set daily usage goals for specific mobile apps and intervenes in cases of over-usage by consistently sending timeout messages if usage goals are violated. Award badges helps to reinforce behavior maintenance [41]. Given that lapses are quite common during goal-based behavior change, Agapie et al. [5] experimented on a means of managing lapses in counter-productive web usage with "cheat points," in which badges are still awarded even with a slight deviation from the goal. Voluntarily usage blocking is also a commonly used method in both mobile and desktop environments [26, 28–30]. NUGU offers temporarily usage blocking, where a user can freely set the block mode for a limited period of time and share limiting activities with friends for social learning [30]. Let's FOCUS supports location-based reminders and social sharing to facilitate voluntarily usage blocking in college classrooms [26]. AppDetox [35] allows users to set more complex rules pertaining to limiting, such as time/activity-based blocking. Likewise, FocusMe supports desktop usage blocking, and Freedom cuts off desktop Internet connectivity.

These studies considered either smartphone or desktop usage only, but in the work context, multi-device usage is fairly common [24] and smartphone usage is often interleaved with PC usage [25]. Recently, Freedom added a feature that blocks Internet connectivity over multiple devices. However, Freedom lacks a systematic way to block specific apps and does not support time management. Our system not only blocks specific apps and websites but also incorporates timeboxing to assist with time management, thereby helping users to maintain their focus against various self-interruptions.

3 PRELIMINARY STUDY

We interviewed sixteen key informants who were recruited through a posting on the campus portal. Participation was limited to graduate students who considered themselves as being unproductive at work and who were willing to become more productive. They were a well-suited population, since their primary work was either studying or doing research within a similar physical environment. Also, we were able to conveniently recruit them within the campus and conduct a face to face interview with each one of them. Additional participation criteria were those who had a problem with interruptions and who had at least thought of ways to be more productive. To explore their interruptions from digital devices and that take them off task and lead to counter-productivity, we aimed to explore (1) the types of devices and their uses in participants' working environments; (2) what are the types of distractions, created by different devices, that lead to degrading daily productivity; and (3) if any coping strategies are employed to manage the interruptions.

3.1 Digital Devices and Their Uses in the Workplace

All of the participants indicated that they used a personal computer (PC) and a smartphone in their workplace, but only one of them used a tablet and not one used a smartwatch. We also asked whether any Internet of Things (IoT) devices existed in their working environments (e.g., smart lamps and smart plugs), but they reported none.

PCs were used for the participants'main tasks, such as searching for information online and organizing research data. They were also used chiefly for communication, such as through instant messaging and e-mail. Entertainment activities on PCs ranged from browsing websites such as Facebook and YouTube to playing games. All participants in particular mentioned web browsing as a most frequent activity during work. Web browsing was considered as a source of information as well as entertainment; therefore, it was perceived as both a productive and a counter-productive activity.

Smartphones on the other hand were used for more minor tasks at work, such as checking emails or for the quick browsing of information. They were reported as more frequently used for entertainment purposes among students. Examples included playing mobile games or using SNSs, as well as watching online videos. Their off-task usage in their workplace was very frequent, and most of the participants agreed that they are counter-productive devices as opposed to being used for productive activities.

3.2 Interruption Types and Their Management Strategies

Participants were asked how they managed external and internal interruptions as well as which interruptions posed the greatest challenges.

For PCs, there were few external interruptions, except for those from instant messenger applications. External interruptions mainly occurred on smartphones. Most participants said that they managed smartphone interruptions by configuring different types of apps, putting them in either silent mode or light vibration mode. They mentioned the necessity of maintaining a communication channel with others even during intensive tasks, reporting a certain level of anxiety if an alert is totally disabled or if the device is turned off. Overall, external interruptions were perceived as "easily managed" and "not very distracting," as the majority of notifications were perceived as a part of productive work. Even notifications that are irrelevant to productive work were described by participants as being "ignorable" and as "not taking away much time."

In contrast, self-interruptions were perceived very negatively. All participants reported that self-interruptions were more distracting than external interruptions. The two main reasons behind this were that (1) self-interruptions were more difficult to resist, and (2) recovery to the main task took too much time once they started engaging with the self-interrupting content.

We asked the interviewees to detail their experiences with self-interruption management strategies. Most of the participants reported that they knew that self-interruptions degrade their daily productivity and that they wanted to reduce them. Many did not have strategies for managing self-interruptions, except for being mindful. However, such mindfulness does not endure, and a participant found that she interrupted herself as frequently as every five minutes, telling herself, *"I am not the type of person who can concentrate well, so I go to this online shopping site every five minutes"(P7).* Some attempted to delete counter-productive smartphone apps that were too frequently used. Although some turned off their smartphones and moved them away from the desk, many worried about the inability to be contacted by their friends and collaborators. With regard to managing self-interruptions arising from PC use, some printed digital documents on paper and then turned off their PC. However, this was only a temporary solution given that the PC was necessary for their main work.

Self-interruptions were said to be more distracting because they are more time consuming. One participant reported, *"I planned to watch a short YouTube video, but once the next recommended video appeared, I continued to watch related videos"(P11).* Many suffered from a lack of self-control to stop at the point where they initially planned, finding themselves continuing in the off-task activities. Such repeated behavior may lead to a downward spiral that consumes much more time than expected.

3.3 Design Implications

Based on the interview results, we derived three main design implications regarding our intervention application to mitigate self-interruptions. The first of these is to create a temporal period for focusing on completing work. Many of the participants mentioned they *"make up their mind to concentrate from a certain point on to get things done."* Such an approach is similar to the personal "timeboxing" technique for time management, in which individuals allocate fixed time slots and use self-pressure to complete a task [44]. One of the best known timeboxing methods is the Pomodoro Technique, where a 25-minute timer is defined as a period for focused work, and a short, five-minute break follows [13]. During the working sessions, users should try to avoid any interruptions, including both external and internal types.

The second strategy is technically to isolate the user from interruption sources. As the participants noted, they delete certain applications that hinders their productive work. Some temporally move the smartphone away from their workplaces or even turn it off. These trials of eliminating possible interruption sources were found to be a common practice. However, PCs and smartphones are used for main tasks, and they cannot be simply turned off. This implies that an interruption management application must selectively disable or block interruption sources at a fine-grained level for a user-defined period. Such an approach toward restraining human behavior with technology is one of our research questions related to understanding people's acceptance of such an approach. To do this, we discuss the design and evaluation of this feature in relation to our implemented application.

The third strategy is related to how the isolation of interruption sources from different device platforms should be synchronously managed. Recent applications and services are available on different device platforms. For example, instant messaging and e-mail applications are accessible on both PCs and smartphones. Facebook and YouTube (SNS/online video) applications are also available in both device types. Therefore, when starting a period of quality "focus time" on a certain task, all interruption sources should be managed simultaneously. Unlike previous studies, we explore a synchronous, multi-device management solution which completely blocks user-defined interruption sources.

4 SELF-INTERRUPTION MANAGEMENT TOOL DESIGN

Based on the design implications, we implemented the self-interruption management tool PomodoLock. PomodoLock consists of three main features: a timer, an app/website blocker, and multi-device synchronization.

First, the timer is built on the foundation of the Pomodoro Technique. It leverages the timeboxing strategy, in which the user starts a 25-minute timer and focuses on one task until the timer rings. Successful completion of the 25-minute period is referred to as a "Pomodoro" or a "Pomodoro session." As the Pomodoro Technique emphasizes, user should endeavor to avoid any type of distraction. In our current design, we do not provide users any daily feedback on their successful completion, but the users were able to look up their daily achievements on the web dashboard.

Second, the app/website blocker temporarily limits access to smartphone apps as well as websites on the PC web browser. Our interview results from the preliminary study show that, in general, it is not easy to stay away from the interruption sources solely relying on one's ability to utilize self-control. Thereby, we introduce a means of technically eliminating interruption sources, in this case smartphone applications and websites. We hypothesize that by technically blocking interruptive apps and websites during the 25-minute period, the user would be less interrupted and could focus more on their main task(s).

Third, a multi-device synchronization feature enables the starting of the timer on all connected devices at once. This also implies that interruptive app/websites across devices are blocked with a single interaction. This is important, as the number of personal devices continues to grow. We describe each feature in detail with the implementation specifications in the following sections.

4.1 Multi-Device Synchronous Timer Design

The basic feature of the Pomodoro Technique is the 25-minute timer. However, according to our preliminary study, more than two devices exist in workplaces in a user's possession, and that they need to be synchronously operated. This allows the user to view the time as well as the start or end the timer on the device that is currently being used.

In order to minimize the interruption from the timer alert, we assigned weights to sound, vibration, and screen blinking. We enabled user customization of the alert sound and vibration style. For PCs, the PomodoLock timer can also be "always on top" to let the user see the timer. It can be minimized to the status bar, but once the timer activates the alert, it will pop up with a sound. For smartphones, the PomodoLock icon is shown in the status bar at all times, and the running timer can be seen in the notification bar. Once the alert is to be activated, PomodoLock pops up a message for the user to confirm.

An "Auto-Start Next Session" button is incorporated into the timer to minimize the burden of restarting the timer after the five-minute break (Figure 1). We considered that a user who repeatedly operates the timer could cause additional interruptions. Moreover, we considered that an auto-start button could prevent the user from prolonging the break time and thus maintain the 25-minute work, five-minute break cycle. The auto-start button

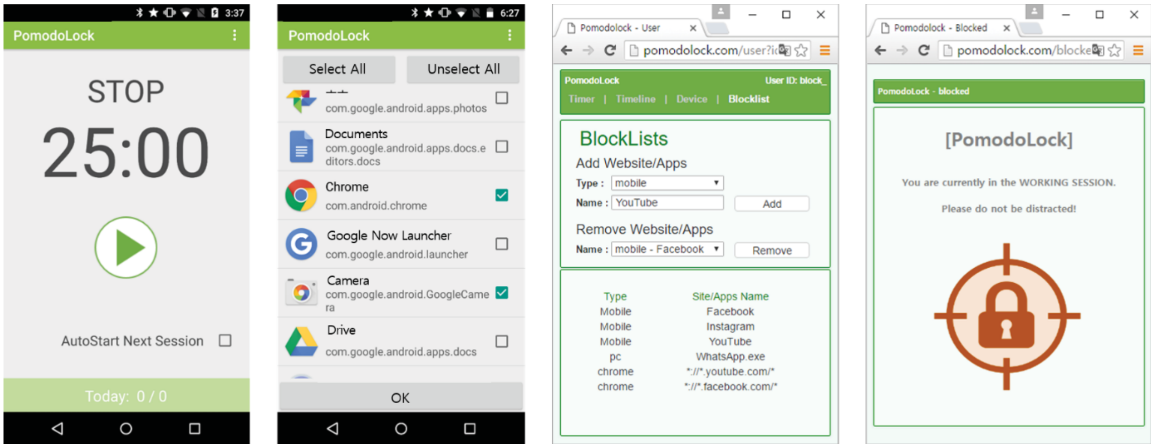

Fig. 1. PomodoLock user interface: (from left) Timer; Mobile blocklist selection UI; PC and webpage blocklist registration page, and redirection page when the user visits a webpage on the blocklist.

is deactivated once the timer goes to the next session. If the user wants to continue to the next session after the break, this feature must be reactivated. This was done so that the user's intention to go to next session would be logged accurately. If the button is activated at all times, the timer may activate even if the user is not working.

4.2 App/Website Blocker Design

We designed a web dashboard on which one may add or delete applications and websites on the "blocklist." PC applications are added to the blocklist by the filename and websites by their URL. Smartphone apps can only be added on the Android application. However, added smartphone apps are viewable on the web dashboard.

The blocking feature only works during the Pomodoro session, when the timer is running. This is to ensure that one can "eliminate interruption sources" when one decides to do so.The underlying mechanism is based on the Pomodoro Technique, which encourages users to resist or ignore any types of interruptions during the 25-minute session. Note that the user can always stop the timer at any time if the user needs to use or visit blocked apps/sites. In this case, the blocker will enable access to any app/website.

Any PC application on the blocklist is terminated from the time when the timer is started. For the Chrome browser, the Chrome Extension forbids the user to connect to a website which is on the blocklist by redirecting to the PomodoLock website, showing the message *"You are currently in the working session. Please do not be distracted!"* The Android application runs in the background, and once the user attempts to run an app on the blocklist, PomodoLock returns to the home menu and prevents the user from using the app.

The blocking feature allows the user to mitigate both external and self-interruptions simply by adding interruption sources to the blocklist. For smartphones, it automatically changes the notification mode to silent once the timer starts.

4.3 Technical Implementation

The PomodoLock system consists of three different client applications (the Chrome browser, Windows, and Android) for blocking apps/websites and a server for the synchronous timer that binds the three clients together. A web dashboard was implemented to add or delete websites and PC applications. For Android applications, the blocklist was managed on the smartphone for greater convenience to the user.

The Windows client application was developed with Microsoft MFC and node.js. The MFC application communicates with the server using HTTP requests and responds periodically to check for the timer and for updated blocklists. It also periodically scans all of the running processes in real time. Once the timer starts, any Windows application that is on the blocklist is immediately terminated.

The Android client app runs in the background as an Android service and overrides any applications that are on the blocklist. Upon installation, it requires permission to enact control over other applications. When the user starts the timer on the application or on any other platform, the apps registered on the blocklist are not executable. If the user attempts to execute any app on the blocklist, a warning message appears.

To control web access, we develop Chrome browser extension. Similar to RescueTime [2], we block access to the websites registered by the user on the blocklist. When the user attempts to visit a website on the blocklist during the working session, it redirects the user to the PomodoLock webpage while reminding the user to focus on their work (Figure 1).

All three platform (i.e., Windows, Android, Chrome) are synchronized by Google Firebase, which is a real-time database service. Timer synchronization across platforms had a maximum delay of less than one second depending on the application settings and the network condition. In addition, the total timer usage for each user is logged as a timestamp for analysis purposes.

5 EXPERIMENT

We conducted a three-week in-situ study of PomodoLock with forty university graduate students. The main concerns of our evaluation were to understand (RQ1) in what context PomodoLock was used, (RQ2) how effective PomodoLock was in mitigating interruptions and the impact of each feature, and (RQ3) if participants experienced any negative emotions (e.g., stress or coercion) due to the behavior-restraining mechanisms embedded in PomodoLock.

5.1 Methods

In order to observe the effect of the app/website blocker, we designed a between-group experiment by dividing the participants into control and experimental groups. The control group was given the PomodoLock application with the timer and multi-device synchronization feature, but not the app/website blocker. The experimental group's application additionally included the app/website blocker. We ensured that all other features and experimental guidelines were identical between the two groups except the blocking feature. Throughout the experiment, we collected three surveys: the first upon enrollment in the experiment, the second before the intervention, and the third after the intervention weeks had passed.

5.2 Participants

Forty university graduate students were recruited through an online posting. Participation was limited to those who (1) used a PC for their main tasks, and (2) were willing to improve their productivity. We also had to limit the participants to those who used Windows, the Chrome web browser and the Android OS for their smartphones. Participants' ages ranged from 22 to 35 (m = 26.5; sd = 2.9). Thirty-one were male and nine were female. All were daily users of computers and smartphones, reporting 3 to 12 hours of computer usage (m = 8.5, sd = 2.8) and 1 to 11 hours of smartphone usage (m = 3.7, sd = 2.3) per day. 82.5% of them had never heard of the Pomodoro Technique prior to this experiment. 12.5% had less than one month of experience with the Pomodoro Technique, and 5% had one to six months of experience. Each was given approximately $30 for the three-week commitment.

5.3 Procedure

Once the participants applied for the experiment, they were invited to take an online survey which asked about the context of their workplace and the devices they use; self-efficacy and motivation levels were measured as well. Among the participants, only two had used the Pomodoro Technique prior to the experiment; the rest had either never heard of the technique or, if they knew what it was, had never used it. We created education material consisting of textual and video information describing how to employ the Pomodoro Technique. All participants read this material before the experiment.

The three-week experimental process was divided into two periods. The first week was a period of adapting to the use of the Pomodoro Technique, and the next two weeks were the intervention period. The adaptation period was important for two reasons. The first was to minimize the effect of the technique itself. The second was to collect the number of Pomodoro session completions to be used as a pivot for dividing participants into control and experimental groups. Because we could not control every conceivable variable in this study, we hypothesized that the number of session completions would be a typical measure of such inherent factors, as fluency with the Pomodoro Technique, the working style/context, and the motivation to use the tool. After collecting the number of session completions from the first week, we used a matched subjects design to balance the two groups' total Pomodoro session completions. Since we did not have a large number of subjects, matched subject design allowed us to observe the effect of the blocker feature without the influence of the confounding variable of Pomodoro session completions.

The second and third weeks were the intervention period. We distributed two versions of the PomodoLock application – the blocking feature enabled version to the experimental group, and the disabled version to the control group. We introduced the "blocklist" page on the web dashboard and asked participants to add the distracting applications and websites that they want to mitigate. The control group understood this blocklist as a part of the experimental procedure for them to self-reflect and be mindful of distracting sources from different devices. We fully explained to the experimental group that the applications and websites they register on the blocklist will be blocked during the Pomodoro session. The participants were allowed to add or delete apps and websites anytime during the experiment period.

Both groups were asked to complete at least one Pomodoro session per day, giving them a minimum level of participation. Moreover, PomodoLock, once installed, was designed to remain logged in unless the user intentionally logged out or exited the application. After the intervention period, we conducted a semi-structured interview with each participant to assess their overall experience with using PomodoLock.

At the end of the study, we had to discard the data from four out of forty participants. Two of them reported that they were out of the office for a week and thus unable to use PomodoLock. The other two expressed they were previously Internet Explorer users and was unable to adapt to the Chrome browser. They happened to be two from the control group and two from the experimental group, making the two groups number eighteen each.

We collected the PomodoLock usage data of working days only, even if some participants worked during the weekend. The data was archived on the server for analysis. We interviewed all 36 individuals for approximately 20-25 minutes per person. All conversations were recorded and transcribed for analysis purposes. The semi-structured interviews were constructed based on the following themes: i.e., the context of PomodoLock use, whether it was supportive for managing interruptions, the benefits of multi-device synchronized support, and whether they experienced any negative emotions. We undertook a thematic analysis to identify, analyze and report themes; after generating the initial codes, two of the authors searched for themes and collaboratively review the themes

6 RESULTS

6.1 RQ1:Understanding the Context of PomodoLock Usage

6.1.1 Temporal Usage. In order to observe the participants' daily usage patterns, we mapped each participant's number of Pomodoro session completions during the second and third weeks to 24-hour time slots (Figure 2). A box-plot of the data usage of the two groups showed similar patterns, with usage starting at 9AM, peaking between 3PM and 4PM, and then gradually decreasing towards 6PM. The results show that not a small ratio still used PomodoLock after 6PM, continuing until midnight. This pattern differs from that of a general workplace, as the graduate students study or work after dinner. Scarcely any user used PomodoLock after midnight.

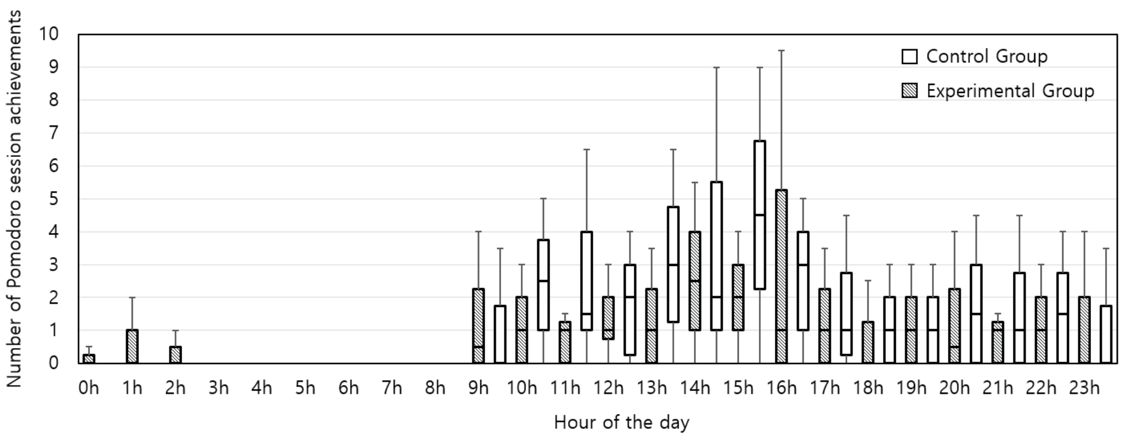

Fig. 2. Hourly distribution of Pomodoro session completions during the 10 working days.

6.1.2 Context of Usage. In our post-interview, we particularly asked about certain tasks and environments for which PomodoLock was well used. We derived three context themes pertaining to why PomodoLock was used, and why not.

The first theme of usage was "in a relaxed state without time pressure" (control group participants C3, C8, and C16; experimental group participants E3, E16, and E17). The participants reported that when relaxed and not under severe time pressure, they were prone to react to both external and self-interruptions. One participant from the control group stated '"I opened the browser to search for some information, but started surfing off-task websites" (C3). Another participant from the experimental group reported, '"I found myself shopping online when I was working on a loose deadline" (E3).

In contrast, when they were pressed for time to complete a task, their focus and concentration levels appeared to be high enough to avoid self-interruptions. One participant noted that opening and starting the application is burdensome and disturbed working with a tight deadline. A group of participants reported that they were not easily self-interrupted when they were busy working and did not feel the need to use additional support means to focus.

The second theme of usage was when "working with non-PC materials" (C1, C5, E1, E8, E9, and E13). Given that the PC and electronic devices are not needed for their work, they wanted to move away from these devices. However, because PC and smartphones are physically available in their workspace and because they have no choice but to work in close proximity to these devices, the ability to block apps and websites was greatly appreciated. *"When I was reading a textbook or a printed document, I continued to browse the web for irrelevant information. Then, I turned on PomodoLock" (E9).* In addition, participant E8 shared his past experience of putting away his smartphone, reporting, *"I was in the library reading books. I used to turn my smartphone off and put it deep in my bag. However, because I am using PomodoLock, I added all smartphone applications to the blocklist and therefore do not need to turn it off; only starting the application is enough."* In contrast, some responded that they did not need to use PomodoLock during non-PC work. *"When I am on a PC searching for information, I tend to go on surfing for irrelevant things…However, I did not use PomodoLock when reading books or doing non-PC work because I did not even use the web browser" (E13).* This leads to the understanding that people may or may not be self-interrupted by digital devices during non-PC work. It may depend on one's level of self-control.

The third theme of usage was "during personal tasks" or "non-collaborative work" (C2, E7, E8, E10, and E15). Many participants reported that PomodoLock was used in the office when they were engaged in a personal task. Once the task involved someone other than themselves, interruptions from interactions with peers, both from digital communication sources or non-digital types (e.g., face-to-face meetings), could occur frequently. Therefore, many stated that PomodoLock had to be stopped in order to use the communication applications. *"I was using PomodoLock to concentrate on making a poster, but I needed to contact my co-worker to change a design. We had to exchange feedback iteratively. Therefore (to stop PomodoLock from blocking the application), I stopped the PomodoLock timer. Eventually, given my concern over an inability to communicate with my peers, I deleted my instant messenger from the blocklist" (E15).* Previous work explains how digital interruptions at work (e.g., email alerts) are associated with the emotions of stress and anxiety [31, 40], but deactivating the alert may also cause anxiety over missing important information as well as the more frequent checking of one's smartphone [32, 46]. The participants here also showed similar reactions with regard to blocking communication applications.

6.1.3 Blocked Apps/Websites. PomodoLock provides functions for blocking applications on mobile and PC as well as specific websites on the Chrome browser.

	Mean (SD)		
	Web Browser	Smartphone	PC
Control	0.9 (1.0)	1.0 (1.5)	0.3 (0.6)
Experimental	2.7 (2.8)	8.1 (19.3)	0.6 (0.7)

Table 1. Number of apps/websites registered in each platform

As shown in Table 1, the experimental group added more apps and websites to the blocklists than the control group. The average number of registered apps/websites on web browsers was 2.7, on smartphones there were 8.1, and on PCs there were 0.6 in the experimental group (Table 3). Such a large difference likely stems from the fact that the control group's blocklist was only for self-reflection and did not function as a blocker, whereas the experimental group perceived it as an important feature because it actually blocked what they registered. It is notable that two participants (E1, E8) in the experimental group added 57 and 67 apps to be blocked on their mobile devices. In our post-interview, these two participants reported that they did not want to use a smartphone at all and thus added all of the apps to the blocklist.

6.2 RQ2:Understanding the effectiveness of PomodoLock

6.2.1 Overall Pomodoro Session Completions. We cannot be certain that all Pomodoro sessions were productive. However, we can infer that the more Pomodoro sessions achieved, the more effort one put into the productive task. Overall, the 36 participants achieved 907 Pomodoro sessions, which is equivalent to 22,675 minutes in total. The experimental group completed an average of 2.96 pomodoro sessions per day (sd = 1.35), which is 41.5% higher than the control group's 2.09 (sd = 1.36). We conducted a two-sample t-test on the total number of

Pomodoro session completions between the control and experimental groups. The effect size Cohen's d was 0.54, which is a moderate size [14]. However, two weeks of data on the whole was not statistically significant (p = 0.1). When we separately observed the pomodoro session completions of the first and second intervention weeks, the results showed that there was a significant difference for the first intervention week ($p < 0.05$, Cohen's d = 0.7), but not for the second week (p = 0.26, Cohen's d = 0.4).

We conducted an additional in-depth analysis by dividing the participants within each group into "high" and "low" achievers using the baseline week's Pomodoro session completion results. We hypothesized that the app/website blocker could be of greater assistance for the low achievers during the baseline week than for the high achievers who already employed good self-determination and self-control. We considered people who achieved more than an average of five Pomodoro sessions per day as legitimate "high" achievers. The high achievers in both the control and experimental groups numbered 3 out of 18 participants (16.7%). We again conducted a two-sample t-test to determine if there was a difference in the number of pomodoro session completions between the high and low achievers in the control and experimental groups.

The results show that there was no significant difference (p = 0.962) between the high achievers in each group. However, the low achievers showed a significant difference (p = 0.033) in pomodoro session completion numbers. The effect size was measured using Cohen's d (d = 0.78), showing that there was a strong effect of the app/website blocking feature.

	Mean (SD)		*Cohen's d*	*t*	*Sig.*
	Timer	Timer+Blocker			
High Achievers	4.7 (1.19)	4.8 (1.93)	0.06	-0.051	0.962
Low Achievers	1.7 (0.90)	2.6 (1.34)	0.78	-2.239	0.033

Table 2. The effect of blocking on high and low achievers; the app/website blocking feature had a greater effect with the low achievers.

6.2.2 Self-interruptions during Pomodoro Sessions. Another metric when evaluating productivity is to analyze the app/website usage logs during the Pomodoro sessions. Due to technical issues, we were only able to log web browser usage. First, ten people in the control group accessed websites on the blocklist (55.6%), whereas for the experimental group this number was eleven (61.1%). The experimental group was not able to visit any websites due to the blocking feature, but the control group users were occasionally tempted to visit sites during the Pomodoro sessions. To be precise, the control group's average time spent visiting websites on the blocklist was 110.6 seconds (sd=184.4) and the average webpage views numbered 3.33 (sd=5.89) per one pomodoro session.

These usage statistics imply that despite the timer and the app/website blocker feature, more than half of the participants from both groups experienced self-interruptions because they attempted to visit the counter-productive websites they had registered beforehand. However, the control group actually visited the counter-productive sties and spent approximately 110.6 seconds in the middle of a 25-minute session on what they considered unproductive activities. This usage behavior contrasts with the experimental group's reactions where there were only 0.6 attempts per Pomodoro session on average. It is apparent that the experimental group was not able to spend any time on the blocked website due to the blocking feature–if they want to access the website, they should exit the ongoing Pomodoro session.

Another observation was the success rate of the experimental group (74%) was lower than the control group (83%). The reason behind this difference likely have resulted from the fact that the experimental group had to stop PomodoLock to access the blocked apps/websites, whereas the control group did not need to do so. Therefore,

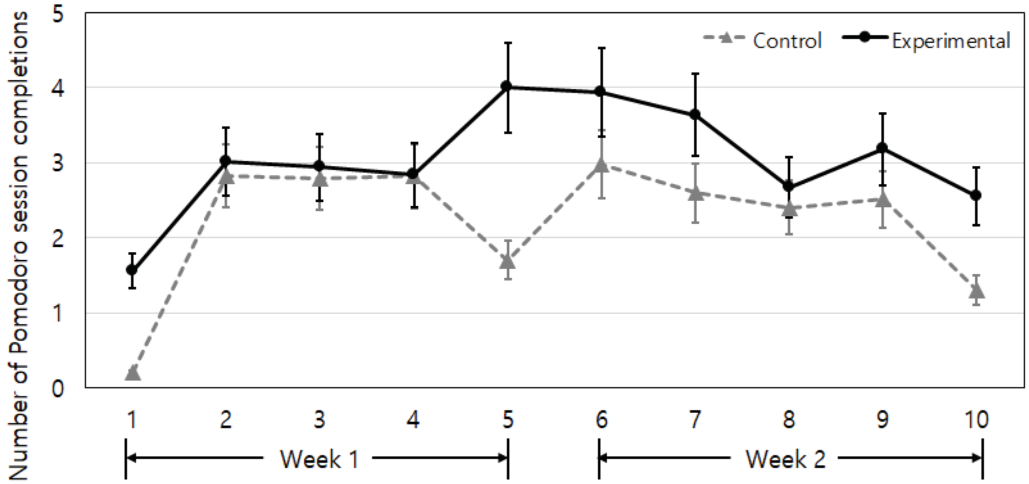

Fig. 3. Number of pomodoro session completions of each group during the intervention weeks

these numbers cannot be used to compare the control and experimental group's tendency of self-interruptions during the Pomodoro sessions.

From the interviews with the two groups on this topic, we found that the control group visited counter-productive websites both intentionally and unintentionally. Their intentional use was due to the fatigue and boredom from their main task. In addition, when they completed part of the main task, they wanted to reward themselves with off-task website visit, such as entertainment news or YouTube videos. The unintentional visit was due to habitual use. One participant from the control group reported, *"I visited Facebook unconsciously. Then, I saw the timer ticking and realized I am in the Pomodoro session. However, I saw an interesting video clip on which I had to click." (C6).*

The cause of the experimental group's attempt to visit blocked websites was primarily due to unconscious, habitual use [32, 42]. However, unlike the control group, the website blocker restricted the content from being shown to the user. The participants perceived such behavioral restriction both positively and negatively. They commented that the feeling of "being blocked by the application" left them with slight discomfort. This negative feeling kept them from visiting the blocked website during the Pomodoro session. Some viewed this positively, reporting, *"It introduced peace into my mind. I know it is useless to make any attempt to visit the blocked websites and therefore I simply did not think about it." (E11).*

6.2.3 Mitigating External- and Self-interruptions. Given that PomodoLock is based on the Pomodoro Technique, the technique itself was responsible for a large percentage of mitigating interruptions. A participant from the control group stated that *"PomodoLock helped me to build a certain level of pressure with which to focus" (C4).* A participant from the experimental group reported this reason as well, i.e., that the timer helped him to mitigate interruptions. However, there was a major difference in the level of difficulty when managing interruptions between external and self-interruptions. All participants agreed that self-interruptions are more problematic and more difficult to mitigate because, unlike self-interruptions, external interruptions are "ignorable," "deferrable," and "recoverable in a short time." This aligns with our formative study findings. External interruptions as "noticeable" and "deferrable" clearly contrast with self-interruptions. The participants noted that self-interruptions often occurred, but they were less conscious about such interruptions as they were naturally doing what they considered counter-productive *(C3, C16, E6, E9, E12, and E13)*. This occurred very frequently in various situations, such as "when doing a tedious task," or "when the task is overwhelming." E6 stated, *"When I successfully finish a part of the task, I watch a short video on YouTube...However, I fall into a downward spiral and keep watching one video clip after another."*

PomodoLock's software-based blocking feature was greatly appreciated by participants who experience serious self-interruptions. *"I was freed from habitual counter-productive behavior simply by thinking that the interruption sources are not accessible."* Another reported, *"When I unconsciously clicked the 'favorites' shortcut in the browser, the PomodoLock block message came up. Then, I noticed that I have to concentrate and went back to the task I was doing" (C3, C12, E1, E3, E4, E8, E9, and E10).*

The blocking feature was very much appreciated by the experimental group. In contrast, control group participants complained that it would have been much better if the apps and websites registered on the blocklist had actually been blocked (C1, C3, C6, C8, C11, and C14). They were never told that the blocking feature on their PomodoLock application was purposely disabled. However, throughout the experiment period, they noted that if the PomodoLock actually blocked, it would be more valuable to them.

Many recognized or have actually faced the problem of blocking neutral apps/websites, such as instant messaging applications or the browser itself. Most of them considered that while those applications were distracting, the necessity to keep in touch with collaborators was more important, causing them to exclude them from the blocklist.

Two of the sixteen participants in the experimental group added all the apps in the smartphone to the blocklist. Those two stated, *"I didn't want to use it during the working session,"* and added *"I don't have many friends or co-workers, so I don't care who wants to contact me" (E2 and E14).*

6.2.4 Synchronous Multi-Device Support. From our formative study, we found that recent applications work across multiple devices, exposing the vulnerability of previous approaches that were mainly intended to block or limit a single device. We wanted to understand how our actual implementation of multi-device synchronous operations supported the participants. Several participants from the control group mentioned that the synchronous operation of the timer was very useful, as once the PomodoLock timer was started on the PC, the timer ticking down could be seen on the smartphone as well, reminding them of the Pomodoro session and that they needed to focus on the main task. *"There was synergy. While working on the PC, I habitually turned on my smartphone screen to check for any new message or to check the time, but the timer displayed on the screen reminded me to keep working" (E5) "Wherever I lay my eyes on it, PomodoLock reminded me of my working status and was very helpful" (E4).*

In addition, the synchronous multi-device blocking feature was much more appreciated by the experimental group. Many participants stated that the *"complete block of interruption sources"* helped them to stay away from all possible interruptions. Some shared their experience prior to the experiment participation, stating, *"I turned off the PC to stay away from off-task web browsing, but I started browsing using my smartphone" (E15). "Facebook is a problem. It is available on both the PC and smartphone. If Facebook is blocked on only one device, I may use it on the other device" (E4).* The latent interruptive sources were completely blocked by the participants, which was appreciated. *"I can say that all interruptive applications and websites are gone. It was a bit frustrating in the beginning, but it was only for 25 minutes. Hence, I went back to my work" (E9). "It helped greatly. There are many applications that I often use which are available on both the PC and smartphone. Blocking both cut off my temptation to use them' (E13).*

6.3 RQ3:Understanding Negative Emotions with Restricting User Interactions

6.3.1 Perceived Coercion and Stress. One of our main concerns was how much negativity in terms of coerciveness and stress would be perceived during the use of PomodoLock. Because it technically restrains user interactions of accessing interruption sources, we hypothesized that the perceived coercion and stress of the experimental group would be greater than that in the control group. From our exit survey after the third week, we measured perceived coercion by asking, “How much coerciveness did you perceive during the use of PomodoLock?” We also asked, “How much stress did you feel during the use of PomodoLock?” The responses were collected using a five-point scale, scaling from 1 (not at all) to 5 (very much). The results are shown in Table 3.

	Mean (SD)		*t*	*Sig.*
	Control	Experimental		
Perceived Coercion	3.22 (1.11)	2.44 (1.04)	2.16	0.038
Perceived Stress	2.83 (0.70)	2.28 (0.83)	1.77	0.037

Table 3. Self-assessment scores of perceived coercion and stress from the two groups (score range: 1 to 5)

Both perceived coercion and stress levels were higher in the control group. This result contradicts our hypothesis that the app/website blocker will create a greater sense of coercion and stress on the users. We interviewed the participants in both groups in search for explanations. Our analysis revealed that coercion has two dimensions: external coercion from the app features (i.e., coercive behavioral restriction mechanisms such as timeboxing and blocking features), and internal coercion by oneself or self-coercion (i.e., effortful resistance for self-control under coercive behavioral restriction contexts).

Here, self-coercion denotes an action of exerting one’s mental efforts to restrain one’s behaviors by explicitly *setting up coercive behavioral restriction mechanisms* as *commitment devices* towards achieving behavioral goals. In other words, PomodoLock provides a contextual environment of coercive behavioral restriction (i.e., external coercion) with timeboxing and blocking. Once users commit to perform a Pomodoro session, internal coercion takes effect such that they must self-control interruption sources by effortfully resisting the temptation of accessing disruptive sources.

For this reason, it is likely that the amount of perceived coercion differs depending on what kinds of behavioral restriction mechanisms are employed. That is, the external coercion features influence the amount of perceived coercion depending on whether such a feature is actually helpful for mitigating their mental efforts to resitst from accessing tempting sources. This is particularly true when behavioral restriction is directly related with the behavioral goals. Thus, by separating internal and external coercion, as well as the two conditions of (1) the timer only and (2) the timer and blocker together, we could derive the self-assessment scores as shown in Table 4. Stress was also separated into the types of stress related to external and internal coercion.

These self-assessment questionnaire were given after week 3, only to the experimental group, who experienced both the timer only (week 1) and the timer+blocker conditions (weeks 2 and 3). Perceived coercion from the timer+blocker (m=3.3, sd=1.68) was slightly higher than that in the timer-only condition (m=3.7, sd=1.49); however, the paired sample t-test did not show a significant difference.

Perceived internal coercion showed a clear difference both in the mean value between the timer (m=5.1, sd=1.08) and the timer+blocker scenarios (m=3.3, sd=1.27). The effect size was large (d=1.52), indicating that the app/website blocker enabled the participants to reduce the “self-coercion” that was needed to focus on their tasks. We collected a number of interview responses stating that the blocking feature relieved them from maintaining the effort not to self-interrupt.

Perceived stress was also divided into two types. The first is stress from external coercion with the features. As expected, the level of stress in the timer-only condition (m=2.4, sd=0.78) was relatively low compared to that in the timer+blocker condition (m=3.2, sd=1.40) due to the presence of fewer restrictions. Despite this difference, we observed that the absolute value of the timer+blocker condition was only 3.2, indicating that it is not a stressful

		Mean (SD)	*Cohen's d*	*t*	*Sig.*
Perceived external coercion (e.g., inability to access blocked app/websites)	Timer	3.3 (1.68)	0.25	-0.735	0.467
	Timer + Blocker	3.7 (1.49)			
Perceived internal coercion (e.g., effortful resistance under behavioral restriction)	Timer	5.1 (1.08)	1.52	4.659	0.00
	Timer + Blocker	3.3 (1.27)			
Perceived stress due to external coercion	Timer	2.4 (0.78)	0.70	-2.213	0.048
	Timer + Blocker	3.2 (1.40)			
Perceived stress due to internal coercion	Timer	3.6 (1.29)	1.62	4.779	0.00
	Timer + Blocker	1.9 (0.73)			

Table 4. Experimental group's self-assessments of perceived coercion and stress from the timer and blocker (score range: 1 to 7)

coercion because it is below 4 (neutral) on a seven-point Likert scale. Thus, users do not consider this as distress, which is a negative form of stress. This result may stem from the fact that users can always exit the blocking feature at will.

Perceived stress from internal coercion of restricting one's access to blocked app/websites when using the timer (m=3.6, sd=1.29) was significantly higher than in the timer+blocker condition (m=1.9, sd=0.73). The user interview regarding this topic suggested that there exists a certain type of stress from restraining oneself from being self-interrupted by counter-productive app/websites. It is evident that the blocker lessened this stress.

6.3.2 Negative Experience with PomodoLock. From our quantitative results, the perceived internal coercion of the experimental group was significantly lower. To understand the reason behind this, we interviewed the top five raters who answered "very coercive" with regard to the timer-only PomodoLock and lowest five raters who perceived the block version of PomodoLock as "not coercive."

First the participants in the control group reported together that the Pomodoro Technique itself gave them (external) pressure to focus on their tasks. Once such external pressure is induced (by making a commitment), they had to fight against the continuous temptation to use counter-productive applications and websites. This fact led them evaluate the PomodoLock (without blocker) as coercive. On the other hand, participants in the experimental group noted that *"PomodoLock helps me resist the temptation of using counter-productive applications and websites" (E18)* and *"I can unblock any application or website any time. It is fully under my discretion; why should I feel coerced" (E11)?*

We asked both groups, "What would it be like if we disabled the stop button and you then have to maintain the blocked state until the timer ends?" Not surprisingly, all in the control group would not have minded, as the timer itself did not place any interactional restrictions on their tasks. However, 16 out of 18 (88.9%) individuals of the experimental group stated that it would be too coercive, and they would leave all communication apps and informative websites out of the blocklist to avoid unexpected situations when they need to access them.

7 DISCUSSION

7.1 Technological Coercion as Positive Support

Our quantitative results show that the control group experienced greater coerciveness and stress than the experimental group. Through extensive interviews with participants who experienced the technological coercion of blocking self-interruptions sources, we found intriguing evidence that providing technological support to limit one's behavior could result in lowering the effort for self-coercion of maintaining intended behaviors. In other words, the effort required to control self-interruption from diverse digital channels such as SNSs and games was high such that many of the control group participants had to spend more effort so as not to be self-interrupted. This kind of self-coercion can be considered as a special form of self-control in that a person needs to control their behaviors with effortful resistance under coercive behavioral restriction contexts (i.e., timeboxing and blocking). Baumeister's strength model of self-control [7] explains that a person's strength (or willpower) for self-control is a limited resource, and repeated exertions may deplete one's strength. In other words, we can say that any self-control task (e.g., resisting the temptation of self-interruption) requires a person to spend a certain amount of strength. Technology-supported behavioral restraints actually reduce the required amount of strength for resistance as they alter self-control tasks with coercive behavioral restraints (e.g., blocking self-interruption sources). We observed multiple cases from the experimental group that they did not have to utilize use such self-regulating control efforts and could focus on their tasks. One of the participant noted, *"I was able to free my mind from using the app because I knew that it was no use trying to execute the apps I had added to the blocklist anyway." (E2)* This contrasts with the participant in the control group reporting, *"I had to refrain from using the counter-productive apps I habitually use, so it was quite stressful" (C13).* Therefore, this discloses an evidence that technology can either "share" one's burden of self-control or "empower" one's total energy source for self-regulation.

Temporal restriction was another valued design element. PomodoLock locked the user into a behavior only during a 25-minute timebox, not whole day. This value point noted by the participants concurs with the design guidelines of Benford's Uncomfortable User Experience [10] and Rekimoto's Inconvenient Interactions [47]. Both researchers emphasized that the inconvenience should be temporary.

Another factor contributing to the fact that the blocking of interruption sources was perceived less coercive was due to the appropriate level of blocking. The fact that we allowed the participants to stop the timer during its use gave them authority over time (or full autonomy). Moreover, the blocklist could be modified at the user's discretion. The control over both time and the sources gave them a sense of freedom, as mentioned by a participant, *"I added many apps that I believe to be interruptive, but I deleted some apps from the blocklist, such as the instant messenger, after a few days, as I noticed that I needed to keep in touch with my colleagues during work..." (E18).*

There are many situations in which we enforce ourselves with regard to certain behavior. We do so because we know that it would be beneficial to perform intended behaviors. Recent studies present various persuasive systems to "persuade," "influence," and "nudge," such that people can be safe and healthy. However, occasionally we need a greater push from an external source to guide us more steadily toward a goal. This notion aligns fairly well with the inconvenient interaction [47], which is defined as an "interactions that would encourage, require or force a user to perform some actions that would benefit the user." In our case, we introduce user interaction restraints of blocking to force a user not to perform disruptive interactions with computing devices to benefit the user. In general, we find that as long as external coercion mechanisms contribute to achieving the overarching goal (e.g., blocking to mitigate self-interruptions), users are likely positively to accept such behavioral constraints as assistive tools for maintaining intended behaviors.

7.2 Beyond Synchronous Interruption Management

External interruptions such as email notifications occur on both PCs and smartphone at the same time due to the synchronous service. This trend is growing as more devices are being connected to networks, and need for such synchronous interruption management is increasing. This is clearly a problem to be considered. However, a more complex interruption problem resides in a multi-device environment. Unlike the external interruptions which can be configured in the system settings, self-interruptions cannot be managed on the device side.

Our approach to tackle this problem was synchronously to eliminate the possible self-interruption sources at once, and our results show that this method is promising. We did not conduct a single device blocking experiment in parallel, but we our interview revealed that if either the PC or the smartphone was blocked, the user would have used the other unblocked device, as most of the offending services are available on multiple devices. One of the most valued point of PomodoLock was that it was able to block “all” interruption sources one personally has.

Given that the number of digital devices are increasing over time (e.g., smartwatches, tablets, and IoT devices), there will be novel design opportunities to manage interruptions in multi-device environments. Prior studies have shown that multi-device usage is nuanced and contextual. For example, Jokela et al. [24] showed that multi-device interactions may involve parallel and sequential usage, and Weber et al. [51] found that a user’s preferences for interactions may differ across multi-device types. Beyond simple synchronous locking, this observations calls for fine-grained, flexible multi-device interruption management strategies.

7.3 Prioritizing Interruption Sources: Not Disruptive Interruptions

It was interesting to note that not many people registered instant messengers on the blocklist, despite the fact that this type of application is the major source of both external and self-interruptions. Our observation was that the types of applications and websites registered for self-limiting purpose were similar to those associated with MyTime [21] in that the percentage of people who decided to monitor messengers was significantly lower than those who listed SNSs. Many of the participants perceived an instant messenger as an external interruption source and noted it is not very interruptive or disruptive because the messages are ignorable, deferrable and recoverable. They also refused to include instant messengers on the blocklist due to the anxiety of being disconnected from others-both for work and for personal relationships. Unlike apps and websites for entertainment, they were able to manage both external and self-interruptions from communication apps fairly well. This observation provided useful insights into prioritizing the interruption sources one wishes to manage. Systematic user studies to measure the interruptiveness of various sources are therefore needed. We then can evaluate their impact on a user’s productivity and deliver personalized self-interruption management strategies in multi-device environments.

7.4 Supporting External Triggers for Improved Engagement

The participants completed two to three Pomodoro sessions per day. This is equal to one to one and a half hours of work time. Considering the daily working hours, it is likely a small portion. From our in-depth interviews with the participants, we learned that triggers are an important factor to consider, as a number of participants reported that they simply forgot to use PomodoLock despite the fact that they considered it to be helpful.

In our current design, we fully rely on internal triggers of self-necessity. If we incorporate a nudging method as an external trigger, it could boost the use of PomodoLock. For example, with a periodic alert or a context-aware alert when the user is sitting at a table, the user can then decide whether it can increase their focus on their tasks.

8 LIMITATIONS

There are several limitations of this work. The first is related to the diverse contexts and lifestyle of the subjects. Unlike employees in a company, graduate students’ activities are more diverse, and do not have strict working hours. Therefore, some work from noon to midnight, and some work only until 6pm. Moreover, some may decide to relax and some may be close to a deadline for a conference paper. We considered that this may influence the number of PomodoLock session completions and therefore divided the subjects into two groups based on their session completions during the first week of the experiment.

The second limitation relates to difficulty when attempting to evaluate productivity accurately. We collected usage logs from web browsers, PCs and smartphones to determine user’s productivity levels. However, the ambiguity between productive and counter-productive engagement with app/websites limited our assessment of productivity. The neutral nature of the interacted applications (i.e. watching YouTube can either be for entertainment or for educational purposes) was difficult to classify whether it was a productive activities or non-productive activities. We used the number of Pomodoro session completions as one of the metrics for assessing productivity. Moreover, the number of accesses to counter-productive apps/websites during the Pomodoro sessions provided additional evidence with which to judge productivity.

The main experiment was conducted for two weeks, which may not be long enough to observe behavioral changes. As described in the results section, we did find meaningful differences and assessed the participants' experience during their use of our multiple-device limiting application. However, we need to conduct a study for a longer period of time to understand not only the short-term but also the long-term effects of such an application-limiting application.

Another limitation as well as a future work of this work is regarding users working around technology restrictions. During our initial design iteration of PomodoLock, we have observed users using the web browsers that our blocking feature did not function, such as Internet Explorer. It was problematic because it was not only a loophole for accessing any blocked websites during the Pomodoro session, but it also hindered us from logging their activities. So in our final prototype, all browsers except for Chrome were blocked during the Pomodoro session.

Current version of PomodoLock was not "absolutely" coercive, meaning the user always had a chance to legally quit the blocked state. However, as the user has less autonomy and control over the interaction, it is more likely that the users will try to work around technology restrictions. It will be important to consider the issue of working around the technology restrictions in the future implementation.

9 CONCLUSION

We designed and implemented the interruption management tool PomodoLock, which helps users mitigate interruptions from multiple digital devices. Our three-week in-situ study with 40 graduate students demonstrated contrasting results between a control and experimental group. The results revealed that what appears to be a coercive means of restricting behavior in the experimental group is in fact less coercive and stressful than in the control group. The method was also more frequently used by the experimental group as compared to the control group, suggesting that technological coercion can work in a more positive way to help people achieve their behavioral goals as opposed to solely relying on one's self-regulation skills. We believe that the proposed approach introduces a new perspective for technology based behavior intervention researchers.

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