Let's FOCUS: Mitigating Mobile Phone Use in College Classrooms

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With the increasingly frequent appearance of mobile phones in college classrooms, there have been growing concerns regarding their negative aspects including distractive off-task multitasking. In this work, we design and evaluate Let's FOCUS, a software-based intervention service that assists college students in self-regulating their mobile phone use in classrooms. Our preliminary survey study (with 47 professors and 283 students) reveals that it is critical to encourage voluntary participation by framing intervention as a learning tool and to raise awareness regarding appropriate mobile phone usage by establishing social norms in colleges. Let's FOCUS introduces a virtual limiting space for each class (or a virtual classroom) where the students can explicitly restrict their mobile phone use voluntarily. Furthermore, it promotes students' willing participation by leveraging social facilitation and context-aware reminders associated with virtual classrooms. We conducted a campus-wide campaign for approximately six weeks to evaluate the feasibility of the proposed approach. The results confirm that 379 students used the app to limit 9,335 hours of mobile phone usage over 233 classrooms. Let's FOCUS was used in diverse learning contexts and for different purposes and its social learning and context-awareness features significantly motivated prolonged participation. We present the design considerations of software-based intervention.

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

General Terms: Persuasive technology, mobile application

Additional Key Words and Phrases: Software-based intervention, mobile phone usage, college students, context awareness, off-task multitasking

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1 INTRODUCTION

Mobile phones have become one of life's essentials owing to their convenience and helpfulness. Their prevalence has made it natural for students to use their mobile phones at schools, which can promote autonomy, improve interpersonal relationships, and expand knowledge sharing [44]. However, mobile phone usage can become habitual because of its accessibility and convenience. Instant access to stimulating content such as social networking sites and mobile games provides emotional gratification to users, which reinforces habitual usage [26,

40]. Hence, students regularly use personal digital technologies for non-study purposes such as off-task web browsing, social networking sites, game playing, and online gambling [29] during studying hours.

In this work, we consider personal digital technology usage such as mobile phones in a classroom setting. Although mobile phones are frequently regarded as useful learning tools, they are also considered as major sources of distraction owing to frequent off-task multitasking. Cognitive psychology studies have documented that multitasking is considered harmful; for example, heavy multitaskers are inferior in cognitive control such as filtering irrelevant information and task switching [39]. This means that there are many negative consequences to learning. Prior studies have demonstrated that off-task multitasking during a class negatively influences not only reading and writing performance [4, 22], but also exam scores and grade point average (GPA) [12]. Junco and Cotton discovered that students using off-task multitasking such as Facebook and texting had reduced grades compared to other students without off-task multitasking [15]. Off-task multitasking can also distract nearby students [46]; in particular, those students having difficulties understanding course material, or those experiencing illness or drowsiness are prone to off-task multitasking [52].

How do instructors regulate off-task multitasking in college classrooms? Prior studies have indicated that instructors use both restrictive and permissive rules [6, 23, 28] and employ various policy enforcement strategies such as issuing verbal warnings, levying a penalty score, or confiscating mobile devices during class. However, instructors tend to be lenient regarding enforcing rules because enforcement requires considerable effort for monitoring, which can disturb the lecture flow. A recent study has indicated that students use mobile phones more frequently when there is a lack of usage policy and proper supervision (e.g., teacher not circulating, large/crowded lecture halls). Under these circumstances, it could be desirable to consider employing software-based intervention with filtering and blocking features, as with parental control software for children's media usage. In this case, however, prior studies have demonstrated that considering a student's autonomy preference is critical for the adoption of intervention software [38].

In this work, we aim to explore how software-based intervention can be designed and deployed in colleges. Our work builds upon prior studies on filtering and blocking apps for controlling smart device usage (e.g., AppDetox [32], NUGU [20], Lock n' LoL [19], SCAN [42]). However, applying such approaches in college settings is challenging because we must consider the autonomy of students and address the perception differences between students and instructors; instructors are more likely than students to believe that technology use will significantly disrupt the learning process. None of the prior studies has attempted to design and deploy software-based intervention methods in a college setting.

We present the design of Let's FOCUS, a software-based intervention that assists college students in self-regulating off-task multitasking with their mobile phones. Towards this goal, we first conducted an online survey study (with 47 professors and 283 students) to understand the current policies of instructors and mobile phone usage behaviors of college students, and to identify the guidelines for designing a software-based intervention. From this, we identified the following design objectives: encourage voluntarily participation, frame intervention software as an assisting tool for learning, and raise awareness regarding appropriate mobile phone usage to establish social norms in college classrooms.

In this paper, we introduce the concept of virtual limiting spaces for classrooms: for each class, we have a corresponding virtual limiting room (or a virtual classroom). When a student enters a virtual classroom, mobile phone use becomes restricted; for example, only five minutes of use is permitted. Because supporting the autonomy of students is critical, we allow students to voluntarily join and leave the virtual classroom. Furthermore, we encourage user participation by leveraging social facilitation and context-aware reminders associated with virtual classrooms.

We evaluate the feasibility of software-based intervention by conducting a campus-wide campaign. Our evaluation aims to answer the following questions: (1) What were the general usage statistics of Let's FOCUS during the campaign? (2) How did Let's FOCUS help students stay focused? (3) How did social learning in Let's

FOCUS facilitate maintaining self-regulation? (4) After the campaign period, how did campaign participation influence attitudes towards in-class mobile phone usage and how did participants use the app after the campaign period? (5) How was overall usability of Let's FOCUS and were there notable user experience differences across heterogeneous platforms (Android vs. iOS)?

The campaign was conducted in a large technical university in Korea for approximately six weeks in the Fall semester of 2016. We deployed the proposed app on both Android and iOS platforms. During the campaign period, 528 users downloaded the app and 379 students used the app to limit 9,335 hours of mobile phone usage over 233 classrooms. The major contributions of this paper are the following:

- We performed a preliminary user study to identify design guidelines for software-based intervention. From this, we proposed a software-based intervention called Let's FOCUS by introducing virtual limiting spaces for classrooms to support location-based mobile phone locking and to leverage social facilitation.
- We released the proposed system on both Android and iOS platforms and conducted a campaign at a large university in Korea for approximately six weeks; this was the first implementation of its kind.
- We identified how Let's FOCUS usage encouraged students to learn by examining the user experiences of key features including their usefulness across diverse class contexts and under generic usage scenarios. We presented how social comparison facilitates limiting behaviors by examining various factors such as interpersonal relationships, online/offline presence, level difference, and shared activities.
- After the campaign period, we determined that the participants gained awareness of the negative aspects of in-class mobile phone use and that a majority of the users wanted to continue to use the app. Despite several technical restrictions in the iOS platform, there was no significant difference in overall usage behaviors across platforms; however, these resulted in lower usability scores.
- Finally, we discuss different design implications based on our findings: (1) autonomy support, (2) framing intervention as a campaign, (3) social facilitation, (4) addressing context-aware notifications, and (5) consideration of future learning environments.

The remainder of the paper is organized as follows. In Section 2, we provide background on off-task multitasking in class and review the related studies on software-based intervention. In Section 3, we present our preliminary user study results regarding mobile phone use and regulation in a college setting. In Section 4, we present the detailed design of the proposed software-based intervention tool. In Section 5, we evaluate the system and summarize the major findings. After discussing several design implications in Section 6, we conclude the paper in Section 7.

2 BACKGROUND AND RELATED WORK

We begin with an overview of human information processing models to illustrate why off-task multitasking is problematic. We then demonstrate how off-task multitasking influences students' learning performances. After reviewing recent studies addressing off-task multitasking, we illustrate the typologies of software-based intervention techniques.

2.1 Information Processing and Multitasking

Cognitive theory of multimedia learning indicates that human information processing for learning involves multiple channels such as auditory/verbal and visual/pictorial [36]. Information processing for learning follows the selection, organization, and integration steps; i.e., information from each channel is selected and organized to form verbal/pictorial representation in the working memory (e.g., clusters of selected words/images), which are then integrated into existing knowledge in the long-term memory. This theory assumes that each channel has limited processing capacity as in the multiple resource theory [60] and learning requires considerable cognitive processing over these channels.

A learner can perform multiple tasks simultaneously, however, attending to an additional task requires cognitive processing, which may cause cognitive overload. For example, in off-task multitasking with personal technologies (e.g., texting, browsing), a learner may require constantly attending to stimuli of interests (e.g., waiting for a text message from friends). Further, when an interruption occurs, the learner may interrupt the current task (e.g., by looking at a mobile phone instead of listening to a lecturer) and switch to the intruding task (e.g., replying to the message). Off-task multitasking with personal technologies may overload the overall information processing. Thus, multitasking can negatively influence unit-learning tasks such as reading, note taking, and recalling. Bowman et al. [4] studied the effect of texting while reading an article. They determined that texting significantly decreased reading speed, with those who used texting requiring 22–59% more time than those who did not use texting. Kuznekoff and Titsworth [22] investigated if off-task multitasking of texting while watching a video lecture influenced note taking and recall performance. They determined that students who did not perform any off-tasks were able to write down 62% more information and had improved recall scores compared to the other students who had off-tasks. Ophir et al. [39] determined that there are inherent limitations of multitasking: contrary to our intuition, heavy multitaskers had difficulty filtering irrelevant information and were slower in switching tasks than light multitaskers.

2.2 Distractions in classrooms

Tesch et al. studied potential sources of distraction in classrooms by considering different internal and external distractors including both technical and non-technical sources (e.g., cell phones vs. whispering) [52]. External distractors include difficulty of understanding content, chattering noise, and technology use of other students (e.g., phone ringing, laptop noise). There are also well-known internal distractors such as illness, drowsiness, and personal technology use (e.g., phone ringing, gaming, music, texting, email checking). When students are distracted, they can redirect their attention to mobile phones as a coping strategy (e.g., avoiding boring lectures by checking Facebook updates). Wei and Wang illustrated that distractive technology use such as texting in class is related to usage habits and media gratifications (e.g., pleasure, escape, affection, inclusion, relaxation) [58]. For example, college students habitually use text messaging to chat with their friends to cultivate their interpersonal relationships.

Off-task use of personal technologies negatively influences overall learning performance such as exam scores and grade point average (GPA). When texting is considered, controlled experiments by Gingerich and Lineweaver determined that a lecture-only group had higher scores on a quiz and felt more confident in predicting their performance [12]. Similarly, Wood et al. [62] conducted a controlled experiment to study if off-task multitasking, such as Facebook and text messaging during classroom lectures, leads to a negative influence on learning performance. Junco and Cotton [15] conducted a large-scale survey (n = 1,774) to investigate the influence of off-task multitasking on GPA while studying. They determined that Facebook and texting were negatively associated with GPA, whereas emailing and talking on the phone were not significantly related.

Prior studies of in-class laptop use indicated that laptop use is a significant distractor to both users and fellow students [10], and recent studies demonstrated that the level of laptop use was negatively associated with learning performance [11, 45]. The groups with off-task multitasking had reduced grades compared to the other groups without off-task multitasking (i.e., pen-and-pencil group vs. word processing group) [62]. Note that personal technologies were not only significant distractors to the users but also to fellow students. Sana et al. empirically demonstrated the secondhand smoking phenomenon with laptop use in that those students in direct view of a laptop user had reduced scores on a test than those who were not [46]. Furthermore, we posit that personal technology use can be contagious, in that one student's use may trigger use by other nearby students.

2.3 Policies to mitigate classroom distractions

There are two opposing opinions regarding personal technology policies in the classroom [3]. The banning group claims that personal technologies should be prohibited because interruptive off-task usage such as texting and social media negatively affects academic performance [6, 28]. Conversely, the other group argues that personal technologies should be leveraged as useful learning tools for facilitating engagement and learning such as note-taking, online discussion/Q&A, and information search [16]. In practice, instructors also employ permissive rules [23]; e.g., allowing mobile usage as long as others are not disturbed or devices are used only for class-related purposes such as mobile information seeking [24, 25, 43]. For policy enforcement, instructors use various methods, e.g., issuing verbal warnings, levying a penalty score, or confiscating mobile devices during class. However, instructors tend to be lenient when enforcing rules because enforcement requires considerable effort for monitoring, which itself can disturb a lecture flow. A recent survey demonstrated that many instructors included personal technology policies in the syllabus and acceptable usage was announced before a semester began [3]. Hopke identified that although a syllabus contains a policy, students' usage can be regulated only if it is actually enforced by the instructors [7]. Tindell and Bohlander indicated that students use cell phones more particularly when (1) instructors do not have a policy and are not concerned regarding texting behaviors in class and (2) instructors cannot monitor students' cell phone use (e.g., turned back, not circulating, large/crowded lecture halls) [54].

2.4 Software-based intervention

There are many products and research prototypes that aim to promote the productive use of digital technologies and services. Intervention techniques can be classified into the following categories: usage tracking/reflection, goal setting, and blocking. Building upon these prior studies on intervention software design, the proposed work focuses on the design and deployment of software-based interventions for self-regulating mobile phone use in college classroom contexts.

Usage tracking and reflection applications such as RescueTime, ManicTime, and SLife allow users to understand their usage behaviors such that they can attempt to change their behaviors [41]. In addition to usage visualization, prior studies have employed different methods to allow users to better reflect their behavior. Lottridge et al. [33] developed a Firefox plugin that highlights non-work-related sites in the tab and displays a productivity ratio in the status bar, which significantly reduces non-work-related web usage. For highlighting productivity levels, Kim et al. determined that desktop widgets improved user engagement and only negative framing of indicating how an individual's lack of productivity was effective in improving that user's productivity [18].

Goal setting has also been used in prior studies. MyTime [13] allows users to set daily usage goals for specific mobile apps and intervenes by consistently alerting timeout messages if usage goals are violated. Because lapses are common in goal-based behavior change, Agapie et al. experimented with methods of managing lapses in unproductive web usage with "cheat points," where badges were awarded even with slight deviation from the goal as long as these fell within fixed cheat points [1].

Voluntarily usage blocking is also a commonly used technique in both mobile and desktop environments. AppDetox [32] allows users to set more complex rules regarding limiting usage, ranging from time-based blocking to activity-based blocking. NUGU [20] offers temporary usage blocking where a user can freely set the block mode for a limited time period and allows users to share the usage limiting activities with other friends for social learning. Lock n' LoL [19] was designed to mitigate mobile phone distractions in the context of group activities. Kim et al. [17] studied negative aspects of off-task multitasking in multi-device environments and proposed an intervention system that supports time-boxing and multi-device blocking. They found that blocking software as a commitment device was *positively* perceived among participants, because it helped them to exert less willpower

to self-control. None of these studies investigated how software-based intervention could be designed in the context of college classrooms.

In addition to controlling personal technology use, there have been other mobile phone applications designed for recovery from different forms of addictions. Savic et al. [47] studied the efficacy of mobile applications for addiction recovery (e.g., recovery from general addiction, alcoholism, drugs, gambling) available in the Google Play store and the users' perception of these applications. These applications offer functions such as providing information, enhancing motivation, facilitating social support, and providing feedback to assist users. Several studies have demonstrated that software-based intervention can be appropriately applied within different domains. The proposed work contributes to the body of work in the software-based intervention field by designing and deploying a mobile software app.

3 PRELIMINARY STUDY

As a preliminary study, we conducted an online survey to better understand the mobile phone usage behavior of college students during class and to identify design guidelines for a software-based intervention that helps students focus on lectures. The survey allowed the researchers to collect a broad range of data (e.g., behaviors, opinions, attitudes) in a cost-effective manner. Therefore, we decided to conduct a survey to collect experiences with mobile phone usage and opinions regarding software-based intervention from a large sample of stakeholders in the classroom (i.e., students and professors).

We prepared common questions for students and professors on how they perceive students' mobile phone usage in the classroom (e.g., "In general, I think that mobile phone usage during the class distracts from learning," "In general, I think that mobile phone usage during the class helps learning") and how they perceive the adoption of software-based intervention to regulate students' mobile phone use (e.g., "I agree that using an application that limits students' mobile phone usage during the class for the flow of the class and learning"). The survey consisted of 5-point Likert scale questions and we required respondents to write detailed reasons for their answers to open-ended questions (e.g., "Please explain why you answered in that manner"). We also prepared further open-ended questions for students and professors separately. For students, we added questions on why and how they use a mobile phone during lectures; for professors, we asked how they mitigate students' mobile phone usage during the lectures.

We posted a survey link to the bulletin board of a popular online community in a large university to collect responses from many students. We used snowball sampling to recruit participants. We sent survey invitation emails to 56 professors, including those affiliated with the authors' department. We also asked professors to forward the survey link to the students in their classes. Consequently, 283 students (101 females; mean age: 23.5) and 47 professors (six females; mean age: 42.7) completed the survey. We sent survey invitations to each professor with different greetings and their name by email, which resulted in a high response rate (83.9%).

3.1 Mobile phone usage in classrooms

As indicated in Table 1, many students (79.2%) responded that they use a mobile phone during class, some students always (11.0%), some frequently (31.1%). By coding students' responses, we identified the major themes of mobile phone usage as follows (multiple responses were allowed): students use their mobile phones (1) as a learning tool (47.3%) (e.g., information search), (2) when they found it difficult to concentrate on a lecture (41.7%), (3) to contact people (41.0%), (4) to shake off sleepiness (8.1%), and (5) to check the time or their schedules (5.0%). Many students (74.9%) responded that mobile phone activities irrelevant to class are problematic (e.g., social networking services (SNS), text, messages, games, webtoons, videos); yet, they also stated that there are situations where they require a mobile phone (e.g., searching for information, writing memos, recording). The majority of the students and professors agreed that mobile phones disrupt the flow of the class (students: 74.8%, professors: 89.4%), students should abstain from mobile phone use (students: 69.4%, professors: 83.0%), and mobile phones

Table 1. Results of each online survey question in number of respondents (ratio)

	(Never) Strongly Disagree		(Rarely) Disagree		(Sometimes) Undecided		(Frequently) Agree		(Always) Strongly Agree	
	Students	Professors	Students	Professors	Students	Professors	Students	Professors	Students	Professors
How often do you use your mobile phone during the class?	11 (3.9%)		48 (17.0%)		105 (37.1%)		88 (31.1%)		31 (11.0%)	
In general, I think that mobile phone usage during the class distracts from learning.	4 (1.4%)	0 (0%)	25 (8.8%)	2 (4.3%)	42 (14.8%)	3 (6.4%)	150 (53.0%)	23 (48.9%)	62 (21.9%)	19 (40.4%)
I think students should abstain from mobile phone use during the class.	12 (4.3%)	0 (0%)	34 (12.3%)	3 (6.4%)	51 (18.5%)	5 (10.6%)	131 (47.5%)	20 (42.6%)	48 (17.4%)	19 (40.4%)
In general, I think that mobile phone usage during the class helps learning.	49 (17.3%)	16 (34.0%)	118 (41.7%)	21 (44.7%)	83 (29.3%)	7 (14.9%)	29 (10.2%)	3 (6.4%)	4 (1.4%)	0 (0%)
I agree with using an application which limits students' mobile phone usage during the class for the flow of the class and learning.	5 (18.7%)	13 (27.7%)	80 (28.3%)	12 (25.5%)	82 (29.0%)	13 (27.7%)	57 (20.1%)	6 (12.8%)	11 (3.9%)	3 (6.4%)

distract students' learning (students: 88.4%, professors: 93.6%). Interestingly, students already had a negative view of using mobile phones during class; professors were more negative than the students.

3.2 Perception of technological intervention

Many professors (42.8%) responded that they did not intervene in students' mobile phone usage. Some professors mediated during class, yet also acknowledged difficulties controlling mobile phone usage because (1) they may not be aware of what students are doing with a mobile phone (36.4%), (2) relationships with students could be worsened (27.3%), and (3) the class could be interrupted if they were required to enforce their rules (9.1%). Regarding the adoption of software-based intervention to regulate mobile phone use, a majority of students and professors were negative towards this option (student: 47.0%, professor: 53.2%). In particular, students were more negative (59.7%) because of (1) the infringement of students' autonomy and freedom (69.9%, and (2) usage demands in certain situations (21.8%) (e.g., information search, urgent contact).

Interestingly, giving additional points as a reward for behaving well was perceived negatively by students (62.3%) because a majority thought that rewarding "normative behavior" is less appropriate. Furthermore, enforcing the rules could be difficult. Professors were also negative regarding forcing students to use intervention software because they regarded students as adults who should self-regulate their own behavior (80.9%).

However, some students and professors (student: 24.0%, professor: 19.1%) were positive regarding software-based interventions because they could help students regulate their behavior and focus during class. Students who had a neutral attitude toward software-based interventions (29.0%) responded that such interventions are useful if selective mobile phone use for learning was allowed. Regarding restriction methods, both students and professors preferred allowing partial mobile phone use (e.g., allowing selected applications or allowing limited time) instead of a complete block (87.2% vs. 12.8%, respectively). 48 students additionally gave comments that interventions would be effective there provides reminder automatically based on the context of mobile phone use (25.0%) (e.g., time and location) and if classmates or friends participated in the process (16.6%).

3.3 Summary and design guideline for technological intervention

Our survey results indicated that students were already aware that mobile phone usage during class should be avoided or minimized; however, they frequently used their phones for different reasons (e.g., SNS, text messenger). Both students and professors had negative thoughts regarding adopting software-based intervention to regulate

mobile phone use in the class for reason of infringement of students' autonomy and freedom, and usage demands in specific situations. However, there were opinions that software-based intervention could help students regulate mobile phone use and focus on the class. Finally, allowing the partial use of mobile phones, social support, and automatic reminders based on context were suggested as intervention methods.

On the basis of these results, we propose the following design objectives for software-based intervention: (1) *encourage voluntary participation in software-based intervention instead of strict enforcement by professors,* (2) *frame intervention software as an auxiliary tool to help students focus in class rather than a tool to monitor students' usage behavior,* (3) *increase awareness regarding appropriate mobile phone usage to establish social norms.*

To meet such design objectives, we must carefully consider the functional and motivational aspects of software-based intervention design. The functional aspect is related to how to support the features that assist students self-regulate mobile phone usage in class. The primary function is to block mobile phone usage. For example, a block/white list can be maintained or usage can be temporarily enabled (for example, up to five minutes per hour). This permissive approach results from the fact that mobile phones can be used as a learning tool and, in some cases, students must attend to urgent necessities. Another functional requirement is to encourage students to voluntarily use such blocking features. One method to do this is to leverage context-aware reminders such as alerting students to use the software when they arrive at the classroom or automatically enabling the software.

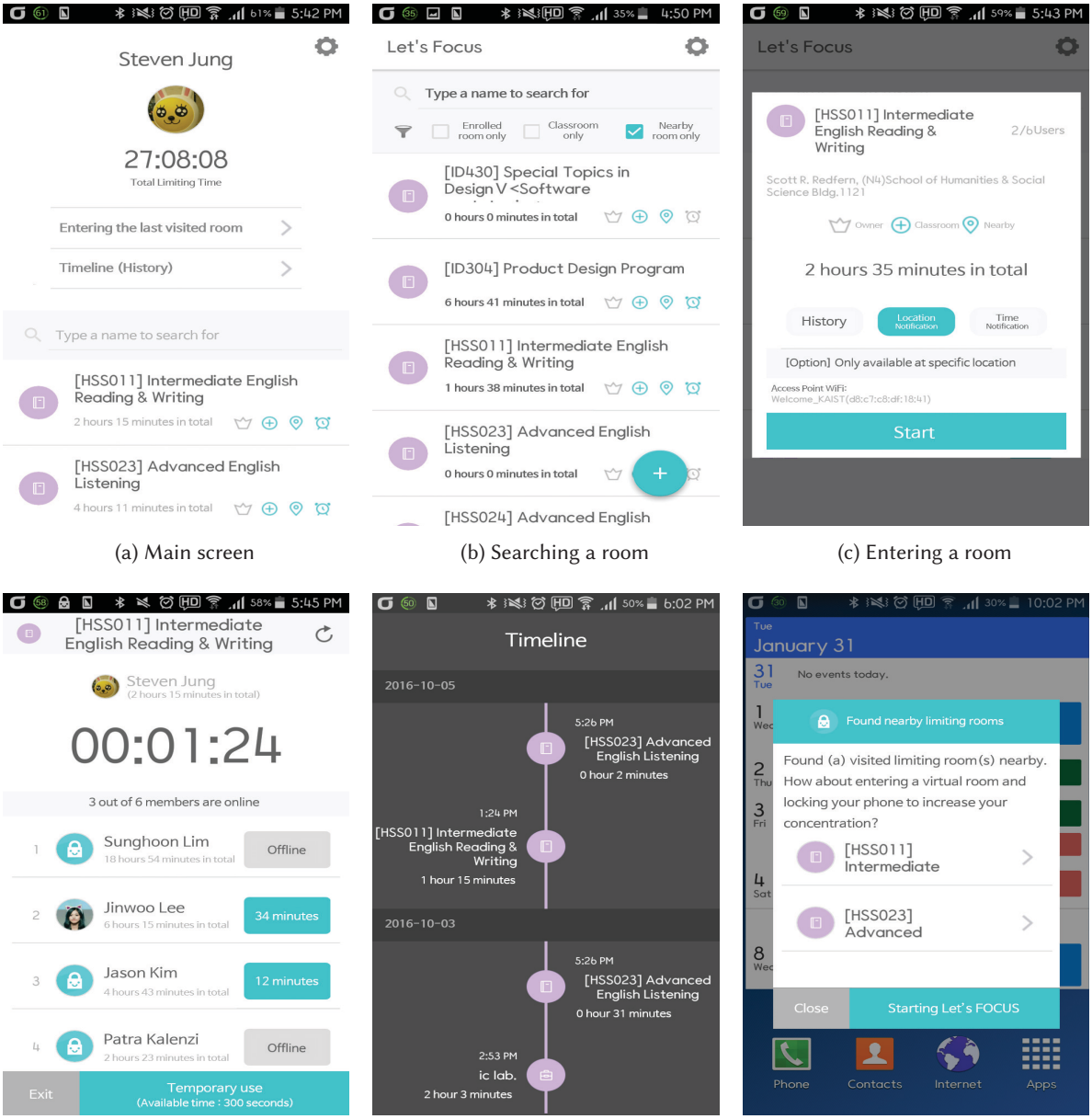
Beyond functional support, software-based intervention must carefully consider the motivational aspect; i.e., how to reinforce students' continued use of the software. Software-based intervention can be equipped with various motivational mechanisms such as points and badges. When users attain certain goals (e.g., hours of limited usage), external rewards can be provided (e.g., coffee coupons). For a given class, students can be encouraged to work together by sharing usage information with one another. This type of peer support is known to be effective in reinforcing target behavior [56].

4 APPLICATION DESIGN

In this section, we introduce Let's FOCUS, a mobile application that helps college students to focus on the class. The key idea of Let's FOCUS is to help students self-regulate their mobile phone use and guide them to use a mobile phone as an auxiliary tool for mitigating smartphone distraction while learning.

4.1 Design Methods

We used a rapid iterative prototyping that included several rounds of low-fidelity prototype tests (n = 4), high-fidelity prototype pilot tests (n = 5), and one round of a high-fidelity prototype field test (n = 10). During the several rounds of low-fidelity prototype development, we focused mainly on improving usability of the software. For high-fidelity prototype development, we considered both Android and iOS platforms. After building the high-fidelity prototypes, we performed a real-world pilot test to evaluate the design choices and understand preliminary user experiences. We recruited ten undergraduate students from a large university in January 2016 (8 males; age: M: 24.6, SD: 2.87). Each participant was compensated with a gift certificate worth approximately 10 USD. We instructed them to install and use the prototype for a week. The participants were allowed to use the prototype at any time; however, they were specifically requested to select a small number of places where they spent time regularly for study or work (e.g., libraries, labs) and to use the prototype therein. After the pilot test, we conducted an interview, which was recorded and transcribed for content analysis. Two authors performed affinity diagramming to identify and prioritize the major issues. We addressed those major issues and developed the second high-fidelity prototype, which was used for our main campaign. In the following, we explain three main features of Let's FOCUS: (1) virtual limiting room, (2) timeline and summary of limiting behavior, and (3) context-based notification. Owing to its high adoption rate among college students in Korea, we illustrate the features based on the Android platform. We also discuss various compatibility issues and technical challenges when we attempted to realize similar features in the iOS platform.



(a) Main screen (b) Searching a room (c) Entering a room

(d) Focus mode (e) Timeline (f) Context-aware reminder

Fig. 1. User Interfaces of Let's FOCUS

4.2 Virtual Limiting Room

Defining a virtual limiting room: Let's FOCUS provides virtual limiting spaces that help users avoid mobile phone distraction by locking their phones while they reside in those spaces. There are two types of virtual limiting spaces

depending on if the virtual limiting space is associated with a physical space. For example, a classroom can have a virtual limiting space that corresponds to the physical limits of the classroom. As illustrated later, Let's FOCUS supports context-awareness. For a given place, the physical presence of a user can be detected with periodic scanning of Wi-Fi fingerprints (i.e., unique MAC addresses of Wi-Fi APs near the classroom). We leverage this location awareness not only to provide location-based reminders but also to verify the physical presence of a user if a virtual limiting room has its corresponding physical space. A virtual room has the following information: title (e.g., class name), creator's user name (e.g., instructor), location, schedule, and Wi-Fi fingerprints. Conversely, a virtual limiting room that is not associated with a physical space does not have location information and therefore does not support physical location-related functionalities.

Creating a virtual limiting room: A user can create a new virtual limiting room by tapping a create room button that resembles a plus sign (See Fig. 1 (b)). The creator of a new room can set two options: (1) a location restriction if physical presence is required for joining a virtual room as in typical classes and (2) a password if a virtual limiting room is private. In creating a virtual limiting room, any combination of options are possible. When the first option is enabled, virtual rooms are associated with physical spaces (e.g., classrooms) and users can enter the rooms only if they are near the corresponding classrooms. Virtual rooms without this option can be joined at any place. When the second option is enabled, the room is searchable, however, only users who know the password can enter the room.

Searching for a virtual limiting room: The screen for searching for a room is presented in Fig. 1 (b). Initially, we only allowed students to search for named classes through the search interface. Following the pilot study, the participants emphasized that the app should support filtering options of existing virtual rooms. Furthermore, the filtered results should be readily accessible through a list view; in that manner, users could find a list of virtual rooms of interest with only a small number of touches. Thus, we added three checkbox UIs below the search interface to allow users to easily filter virtual rooms by listing only (1) virtual rooms previously participated in and enrolled (or simply a visit history), (2) virtual rooms for courses (known as virtual limiting classrooms), and (3) virtual rooms located nearby. These options are conjunctive; for example, if option (1) and option (2) are checked, then only the virtual ficlassroomsfi where a user has participated earlier will be listed in the list view. The first option is checked by default to support easy access to previously visited virtual rooms; the rooms are ordered based on the time spent in each room (rooms where more time has been spent are listed first). When all filters are unchecked, the virtual rooms are sorted based on popularity, which is measured by the total sum of users who have ever visited a given virtual room. After implementing these options, we did not receive any further usability issues associated with virtual room search.

User interactions for a virtual limiting room: If a user enters a virtual room, a mobile phone's mode is changed to the focus mode where mobile phone usage is blocked such that users cannot execute applications and all notifications (e.g., messenger, SNS, games) are muted. Fig. 1 (d) illustrates the focus mode. From the top, the screen displays the title of the virtual room (e.g., [HSS011] Intermediate English Reading & Writing), user's screen name, accumulated hours of limiting, amount of time spent in a given focus mode, number of active participants, and a list of participants in the virtual room who have previously logged into the virtual room. The list presents each user's screen name, current mode (i.e., focus mode, temporary use mode, not logged in), and limiting record (i.e., cumulative hours of usage limiting within a given room). To facilitate social comparison, participants are ranked based on their cumulative hours (See Fig. 1 (d)). This ranking allows users to know who the active participants are and if their friends are checked in.

As illustrated in our preliminary study, students use mobile phones as a learning tool (e.g., information search) and to contact people. In Let's FOCUS, we allow users to receive incoming calls even if they are currently in the focus mode. Furthermore, we implemented a five-minute allowance to permit occasional use of mobile phones. This design choice is for the following reasons. In general, selecting and maintaining black/white lists of apps

requires users to expend a considerable effort compared to allowing limited time for occasional use. Furthermore, the iOS platform does not allow blocking other apps.

According to our prior study [19], a five-minute allowance was sufficient for occasional mobile phone use in socializing contexts. Our pilot study results confirmed that five minutes was also appropriate in the setting considered. By simply touching the temporary use button, users can leave the virtual room for a short time to use their phones. This action results in changing the current mode to the temporary use mode where a timer is automatically set. If the five-minute allowance expires, their phone's status is automatically changed to the focus mode, thereby re-entering the virtual room. Users can check the remaining time at the notification drawer. They can easily return to the virtual classroom by clicking the timer.

Leaving a virtual limiting room: In Let's FOCUS, users can leave a virtual room at any time by tapping the exit button located at the bottom left as indicated in Fig. 1 (d). When the exit button is pressed, users are asked if they really want to exit, to persuade users to remain in the room as long as possible. This permissive design is because autonomy and the agency of students are critical in software-based intervention, as demonstrated in our preliminary user study. Thus, we allow students to make decisions regarding whether to stay in the virtual rooms rather than forcing them to stay there until the class completes, which may negatively affect motivation for voluntarily participation. When a user exits, the time spent in the room is added to the total amount of time spent in that room by the user.

4.3 Timeline of Limiting Behaviors

Let's FOCUS records a user's limiting activities and displays them on a timeline (See Fig. 1 (e)). The timeline is a simple, yet useful interface to visualize usage histories in a time sequence. Our decision to use a timeline is because it enables a quick review of recent activities for reflection and recall. Users' activities in Let's FOCUS are event-driven (e.g., classes) and occur regularly. Thus, it reminds users of recent activities such as what rooms they entered, when they started the focus mode, and how long their focus mode lasted. They can check their accumulated limiting hours in the focus mode (See Fig. 1 (d)). As illustrated in our campus-wide campaign discussed later, we used the accumulated limiting hours in each virtual room to extrinsically motivate students. After accumulating 20 hours in virtual classrooms during the campaign period, a student is compensated with a mobile gift voucher worth approximately 5 USD and becomes eligible to win a prize such as a fitness tracker or USB stick.

4.4 Context-Aware Reminders

For a given room, Let's FOCUS allows users to set context-aware reminders, i.e., (1) a location-based reminder or (2) a time-based reminder. A user can set these reminders when joining a virtual room. As explained above, if location restriction is enabled, a Wi-Fi fingerprint (i.e., the unique MAC address of the Wi-Fi APs near a classroom) is automatically collected. When a student approaches a classroom, a reminder is pushed to the student in the form of a short vibration and a popup message that displays a list of nearby virtual classrooms (See Fig. 1 (f)). This location-based alarm is delivered whenever they use their phones near a classroom. In addition to this location-based reminder, users can set timers for when they would like to receive reminders (e.g., setting class start times). Therefore, students can be reminded in a timely manner that they should focus on the class by entering a virtual limiting room or locking their phones. We expect that context-aware reminders will encourage students to self-regulate mobile phone use during a class.

In our pilot study, however, some participants commented that the location-based alarm was disturbing, particularly when they did not want to join the virtual rooms, in situations when they wanted to use their phones longer in the classroom, or stay at a location near the classroom. In these cases, users encounter pop-up messages whenever they turn on their phones. To mitigate the disturbance, we revised the notification-sending rule as

follows. If users ignore location-based alarms (i.e., discarding the pop-up message), the alarm is disabled for an hour.

Building an accurate Wi-Fi fingerprint database is important to realize effective location-based reminders. As a location fingerprint, we initially used the MAC address of the campus Wi-Fi whose signal strength was the strongest in the classroom. However, if a classroom is large, there could be multiple Wi-Fi APs with strong signal strength. In our pilot study, some users expressed difficulty in entering a virtual room owing to fingerprint mismatch. For this reason, we decided to maintain a list of Wi-Fi APs whose signal strengths are above a certain threshold and let the users select the virtual room to join if any one of the APs matched with the list of APs in the fingerprint. This simplistic approach is to improve the discovery of a classroom (i.e., by trading precision for improved recall). For this reason, we display a list of nearby virtual classrooms and let the users select the class to join manually.

4.5 Considering Multi-Platform Support

The Android platform was mainly considered in the proposed work because of its high adoption among college students in Korea. While developing its iOS counterpart, we encountered several technical challenges: (1) Wi-Fi fingerprint gathering is limited, (2) blocking usage of other apps is not feasible, and (3) background operations are not permitted. The iOS platform's APIs do not allow an app to scan Wi-Fi APs; rather, it can only access a Wi-Fi AP that is associated at the time of app usage. As in the Android platform, this AP's MAC address is used to enable a location-based check-in and reminder. In our pilot study, we noticed that students enabled Wi-Fi interfaces to access campus Wi-Fi networks owing to their concern for costly LTE network usage. The most critical concern was related to the fact that unlike the Android platform, we can neither block app usage nor mute notifications in the iOS platform.

Although this blocking feature cannot be realized in the iOS platform, we can allow users to enter a virtual limiting room and allow them to remain there during the lecture. Because our app is not permitted to run in the background (e.g., switching to a different app or turning off the screen), we cannot properly support the temporary use mode. Temporary usage can be only tracked as long as they return within the time allowance. Because autonomy and agency are critical, we decided to trust the iOS users. We basically assume that users rarely fioverusefi in the temporary use mode. When a user is in a virtual room, the app enters the background (e.g., screen turn-off) and the user returns after a period of time. In this case, we fully acknowledge the limiting duration as long as the user returns to the app before a threshold time (e.g., two hours).

We decided to implement the iOS version despite such limitations for the following reasons. Let's FOCUS allows a group of classmates to participate in the campaign and social interactions among students is critical. The iOS adoption rate is fairly high among college students in Korea. Thus, it is important to allow the students who use the iOS platform to participate in the campaign; it was our desire to elicit an increased level of student participation. To our knowledge, prior studies on software-based intervention of smartphone use rarely considered multi-platform support. To realize inclusive intervention service design, we feel that it is important to accumulate our design knowledge across different platforms. For this reason, we investigate (1) what the functional limitations are across different platforms, (2) how intervention should be designed to address such limitations, and (3) the influence of the platform differences on the user experiences. In that respect, our campaign can be considered as a valid case study towards designing cross-platform intervention services.

5 EVALUATION

We performed a real-world campaign to evaluate the proposed software-based intervention approach for six weeks in the Fall semester of 2016 at a large technical university in Korea. This section consists of three parts. First, we briefly describe the evaluation goals and how we attempt to respond (Section 5.1).Then, we explain the campaign design in detail (See Section 5.2), such as creating the technical environments and designing

the campaign procedures. We collected data from participants during the campaign (e.g., log data) and after the campaign (i.e., surveys and interviews). Finally, we present analysis results for our research questions: (1) campaign statistics (RQ1, Section 5.3), (2) distraction management benefits (RQ2, Section 5.4), (3) social sharing effects (RQ3, Section 5.5), (4) attitude changes and after campaign usage (RQ4, Section 5.6), and (5) usability evaluation (RQ5, Section 5.7).

5.1 Evaluation goals

Our evaluation answers address the following research questions: (1) What were the general usage statistics of Let's FOCUS during the campaign? (2) How did Let's FOCUS help students minimize mobile phone distraction? (3) How did social sharing in Let's FOCUS help maintain limiting behaviors? (4) After the campaign period, how did campaign participation influence attitudes towards in-class mobile phone usage, and how did participants use the app after the campaign period? (5) What were the user experience differences across platforms?

First, we begin by analyzing the overall usage statistics of Let's FOCUS during the approximate six weeks of the campaign period. Then, we investigate how Let's FOCUS usage helps students to concentrate by examining user experiences of the key features, its usefulness in diverse class contexts, and generic usage scenarios. Next, we study how social comparison facilitates limiting behaviors by examining different factors such as interpersonal relationship, online/offline presence, level difference, and shared activities. We analyze possible attitude changes regarding in-class mobile phone usage and users' willingness to continue to use the app (why and why not continue using). Finally, we investigate how implementation differences due to platform restrictions (i.e., focus and temporary use modes) affect the overall user experience and usage behaviors.

5.2 Campaign design

5.2.1 Technical environment setup. Before beginning the large-scale real-world campaign, it was necessary to establish the technological environment for the campaign. Using the university computer system, we identified 137 classrooms and 1,003 lectures that were scheduled in the Fall semester of 2016 at the university. We collected the Wi-Fi fingerprints of all APs that were near the classrooms. All lectures information including class names, instructor names, locations, schedules, and Wi-Fi fingerprints of the APs near the classrooms were stored in our server. Then, we generated virtual limiting rooms for each lecture (i.e., 1,003 virtual classrooms). We verified that the application's services functioned correctly (i.e., location-based notification, allowing entrance a virtual classroom at a designated place).

5.2.2 Campaign procedure. After establishing the technological environment of the campaign, we began to promote the campaign under the slogan"*Let's focus in the classroom with Let's FOCUS!*" to encourage students to participate voluntarily in the campaign and to highlight concentrating on the class rather than enforcing limiting behavior. We produced two types of promotional posters (See Fig. 2). The first poster described the information of the campaign (e.g., the purpose of the campaign, campaign period, how to join the campaign, giveaways) and the second poster emphasized normative behaviors in classrooms (e.g., focus on the class), with amusing cartoons and phrases to attract students' attention (e.g., "*If you turn off the mobile phone, your knowledge will be turned on!*"). In the case of the second poster, we designed ten different cartoons and distributed these throughout the campus. Because of university policies, we could post advertisements inside classrooms; however, we did post them on public boards near classrooms. Further, we posted advertising articles on a university online community and erected large banners around the university. Before beginning the campaign, we uploaded the Let's FOCUS app to both the Google Play store and Apple App Store to allow any student to install and use Let's FOCUS without platform restriction. The campaign period was 41 days (approximately six weeks), from September 19 (which is immediately after Korean Thanksgiving) to October 28, 2016 (the end of the midterm exam period).

Fig. 2. Promotional posters: Main poster (left) and Cartoon posters (right)

For bootstrapping, we prepared three promotional events: (1) *I am a master of concentration*: Every student who achieved 20 hours in the focus mode was compensated with a mobile gift voucher worth approximately 5 USD and is eligible to win a prize (i.e., fitness trackers, wireless keyboard/mouse combos, USB sticks, Bluetooth speakers). (2) *Best classroom of concentration*: We selected two virtual classrooms where room members actively used the application and their aggregated limiting durations were ranked, first and second. Every student received a mobile coffee gift voucher worth approximately 3 USD as a reward. (3) *Here is my story*: Students submitted their stories regarding their experiences using Let's FOCUS via email. We offered winners giveaways including mobile gift vouchers based on their limiting duration accumulated during the campaign period (i.e., 41 days). For the third event, we selected stories and distributed similar giveaways to the winners.

5.2.3 Data collection. We collected usage data with timestamps for all students (e.g., what room students entered, when students started focus mode, how long the focus mode lasted). During the campaign period, we regularly checked the database logging students' usage data and discovered that a small number of the students were using the application abnormally. For example, one student continued a focus mode for several days. We removed these unnatural behaviors from the analysis (i.e., residing in the virtual classrooms and study rooms for more than 12 hours and six hours, respectively). We required students to report via email or campaign homepage if they experienced discomfort or encountered problems with Let's FOCUS during the campaign. After the campaign, we conducted an exit survey to understand students' general experiences of Let's FOCUS use. To measure the usability of the application, we prepared a list of questions based on the USE questionnaire with the following subscales, usefulness, satisfaction, and ease of use [34]. 177 students completed the survey (112 males,

65 females). We sent emails requesting an interview to understand in detail the user experience regarding our intervention and 19 students granted our request (15 males and 4 females). Our interview was semi-structured: we questioned why and how they used the application and what features were effective to focus on the lecture or individual study. The interview required between 30 minutes and 45 minutes. We assumed that interviewees' responses were reliable because every interviewee used the application more than 20 hours. Each interviewee was compensated with approximately 20 USD. All of the interviews were audio recorded, transcribed, and separated by sentence. The interviewee answers for each question were classified with similar themes. Three different researchers iteratively analyzed the sentences with affinity diagramming; this was repeated until all researchers reached an agreement for the final themes.

Lastly, we conducted an additional survey to investigate how students recognized our promotional posters. We posted the survey link on the online bulletin board of the university. Forty students responded to the survey (22 males, 18 females). 27 of the 40 students were aware of our campaign; 13 of them downloaded the Let's FOCUS application. In our survey, we presented two types of posters that we used for the campaign promotion (i.e., main poster and cartoon poster). For each poster, we asked students if they had seen the poster and if they decided to join the campaign after seeing the poster. For the second question, we required students to describe the reasons why they answered in that manner. Before presenting the results, we explain the notation of a participant. P(ID) and P'(ID) denote quotations from the interview and the survey, respectively. ID is a participant's identification number. For example, P'03 means that a quotation comes from participant ID=3 on the survey.

5.3 RQ1: Campaign statistics

Over the campaign period, 528 students downloaded the application and 379 students limited their mobile phones at least once. 194 students entered virtual classrooms during the class. The majority of the participants were either undergraduate (77.4%) or graduate students (21.5%). A small number of university employees also participated in the campaign. Among participants, 37.7% were females; this reflects the skewed gender ratio of the university (approximately 20% female). As indicated in Table 2, 379 students used the Let's FOCUS application for 9,335 hours: 2,082 hours in virtual classrooms and 7,253 hours in virtual study rooms over the campaign period. The difference between virtual classrooms and study rooms was considerably large. It seemed that the students involved in the campaign included not only undergraduate students but also graduate students who typically attend fewer classes and expend more time on their individual study or research; lecture hours are limited in time, however, individual study hours do not have a time restriction. Professors did not participate in the campaign; however, two staff members did participate. It appears that the staff members used Let's FOCUS to concentrate on their tasks for productivity reasons. They visited only a small number of virtual limiting rooms and their total usage was 2.5 hours and 16 hours, respectively.

Fig. 3 (a) illustrates how limiting hours were accumulated during the campaign period. The last week was a midterm exam period. Therefore, we identified that limiting time in the virtual classrooms did not increase significantly during this period; however, limiting time in the virtual study rooms increased steadily. The university classes were typically of 75 minutes duration and thus, in a virtual classroom, students limited a mobile phone usage on average 64.2 minutes (SD = 149.6) for a given focus mode. In a virtual study room, students limited on average 80.7 minutes (SD = 175.2) for a given focus mode. Note that before the beginning of the campaign, we generated 1003 virtual classrooms. Students entered 233 of these virtual classrooms and they created 375 new virtual study rooms. Thus, the total number of active limiting rooms was 608 during the campaign. The largest virtual classroom and study room in terms of the number of participants were rooms with 32 and 43 students, respectively. Students were engaged in 3.07 virtual classrooms and 2.07 virtual study rooms on average. Each classroom was visited 8.3 times on average (SD = 10.9) whereas each study room 11.9 times (SD = 42.0). The top virtual classrooms involving many students were related to freshmen courses. These included "Calculus," "General Physics," "Probability and Statistics," and similar courses. Because these courses are mandatory for

Table 2. Overall results of using two different types of virtual rooms in Let's FOCUS during the campaign period

	Mean (SD)	
	Classroom	Studyroom
Total usage from all the users (hours)	2,082	7,253
Duration of staying in the virtual room per each entrance (minutes)	64.2 (149.6)	80.7 (175.2)
Number of virtual rooms which were used by at least one user (number of rooms)	233	375
Number of visits per each virtual room (times)	8.3 (10.9)	11.9 (42.0)

freshmen, it seems that the numbers of the students who attended these courses were greater than any other classes resulting in the largest virtual classrooms. The top five rooms had 20 students on average.

Fig. 3 (b) displays the overall trend of the application use over the campaign period. The solid line represents the number of users who limited their mobile phone use with the application at least once on that day. The dash line indicates students' average limit duration for that day. We identified that students consistently used the application over the campaign. There was a repeating pattern at the solid line: the number of users decreased on the weekends because there were no classes and increased again on weekdays. Interestingly, during the midterm exam period (e.g., final week), the limiting time per one student rapidly increased. This indicates that students used the application to limit their mobile phone use for their individual study. After the midterm exam, the number of users sharply decreased, which is partly because students wanted a break, and the campaign was officially ended.

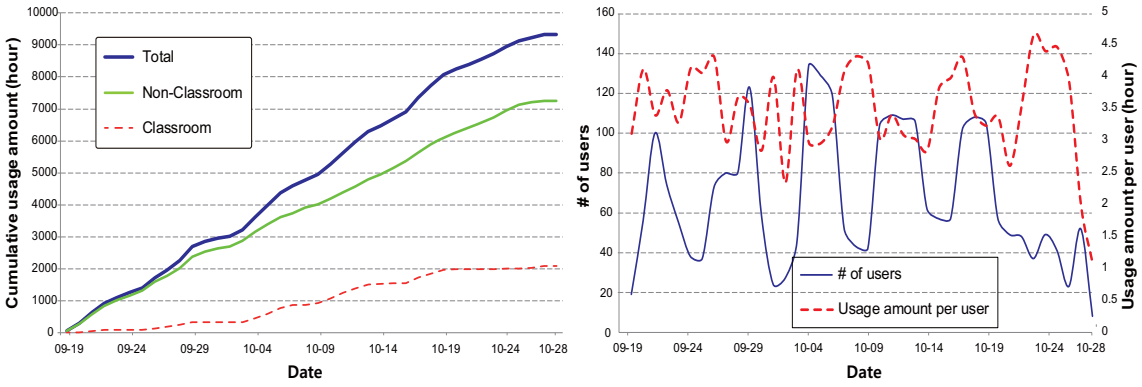
Our follow-up survey demonstrated the effectiveness of our extensive advertisement. 70% and 75% of students saw the main and cartoon poster, respectively. Our participants reported that the amusing cartoon posters attracted more attention from students and induced more campaign participation than the main poster. The number of students who were inclined to join the campaign after seeing the main and cartoon poster was 39.3% (11 out of 28) and 53.3% (16 out of 30), respectively. Students responded that they were motivated to join the campaign because the cartoon poster was interesting, novel, and empathic. The cartoon posters were amusing and attractive; however, they provided insufficient information regarding the campaign. Hence, participants commented that they did not participate in the campaign even after seeing the cartoon posters. There was concern regarding information overload in the main poster. Some students responded that it was difficult to identify the message of the main poster at a glance. Finally, other students said that they were not motivated to participate in the campaign even after looking at the posters.

5.4 RQ2: Assisting students in staying away from mobile phone distraction

We investigate how Let's FOCUS helped students avoid mobile phone distraction. We present its effect on focusing by examining the key features in Let's FOCUS (e.g., focus mode, temporary use mode, context-aware notification), its usefulness in diverse in-class contexts, and various usage contexts other than classes (e.g., group studies, work).

5.4.1 User experiences of the key features. We investigated how these features helped students to concentrate on the class. The key features of Let's FOCUS are the focus mode, temporary use mode, and context-aware notification.

Focus mode: Many students (71.9%) reported that they could better focus on the class because of Let's FOCUS. Students generally agreed that the focus mode was useful for increasing concentration on the class by avoiding mobile phone distraction (63.3%). We determined that the focus mode prevented students from being interrupted from habitual mobile phone usage and external distraction (e.g., notification from messengers, SNSs, games) during the class. One student said, "*When I turned on the smartphone screen as usual during the class, the screen*



(a) Accumulated limiting hours

(b) Overall trend of app use

Fig. 3. Campaign statistics

indicated that it was in the lock mode. After seeing that screen, I turned it off and focused on the class again. Through this application I became aware of how frequently I check the smartphone." (P6). One students stated, "*While using Let's FOCUS in class, I could focus totally on the class and felt isolated from the outside world with its distractions. I had never before experienced concentrating on the class from the beginning to the end; however, this application allowed me to do that.*" (P4). Another student commented, "*I used Let's FOCUS to concentrate on my study without distraction from my mobile phone.*" (P6). Students also responded that they experienced the feeling of accomplishment when they left virtual classrooms after the class. One student mentioned, "*After the class, I could see the amount of time that had accumulated during the class. I was proud of myself because the time implied that I focused on the class successfully for 75 minutes without any smartphone use.*" (P9).

Temporary use mode: We could not implement a function that tracks students' use of the five-minute allowance. Rather, we asked students why and how they utilized the temporary use mode through the exit survey and interview. 96.3% students reported that they utilized the five-minute allowance. The main purposes were contact (54.3%) and information search (37.0%), whereas SNS and game were only 7.4% and 1.9%, respectively. Many students responded that the temporary use mode was useful and the five-minute allowance was sufficient. One student commented, "*Temporary use mode was good because I could focus again after dealing with a phone task within five minutes.*" Another student said, "*When I attended a class taught in English, I used the five-minute allowance and that was sufficient to search for English words. Sometimes I replied to important text messages.*" (P17). We determined that a limited short time prevented students from being distracted by locking the mobile phone again. One student commented, "*I used temporary use to search materials related to the class. However, sometimes after searching I was tempted to view amusing content, such as Facebook. In those situations, the five-minute allowance effectively prevented that kind of irrelevant use.*" (P14). We determined that students could easily be adapted to locking their mobile phones owing to the five-minute allowance. One student commented, "*I could enter virtual classrooms with less worry because this application provided a five-minute allowance instead of blocking the smartphone entirely without any allowance.*" (P6).

Context-aware notification: Note that Let's FOCUS sends a notification with a short vibration and a message, displaying a list of nearby virtual classrooms at a time specified by students or once a student approaches a classroom. Students reported that they primarily used location-based notification rather than time-based notification. Many students responded that location-based notifications were useful because it reminded them

that the classroom is the place where they should focus. We asked of their experiences of receiving the context-aware notification. One student commented, "*When I was off task at that time and I received the notification, I felt guilty.*" (P12). Another student said, "*When I received the notification near a classroom, I recognized that the class would begin soon and that I should focus on the lecture.*" (P7). However, students did not enter the virtual classroom immediately after receiving the notification. Students started limiting when they decide to focus on the class. One student said, "*The notification I received was somewhat delayed. It did not work at the exact time I entered the classroom; however, it did work a few minutes after I was seated in my chair. Because I knew that I could not use my smartphone after entering the virtual classroom, I didn't tap the notification message to start the limiting mode directly. Rather, I ran the application when the professor began his lecture and I was required to focus on the class.*" (P14).

5.4.2 Usefulness in diverse class contexts. We identified that there were several learning contexts where students used Let's FOCUS. First, students responded that they wanted to use Let's FOCUS because it was difficult for them to maintain concentration due to lack of interaction in a class. Students said that Let's FOCUS was particularly useful when they were in classes where professors delivered less interactive teaching. One student mentioned, "*Let's FOCUS was helpful to me when I attended a class where the professor only lectured and did not allow any discussion time; this type of class made it difficult for me to concentrate.*" (P6). Another student said, "*It seemed that Let's FOCUS was less effective in lecture classes where professors encouraged students to take a more active part in the class.*" (P3).

In classes that students considered important for them, the students utilized Let's FOCUS to listen to every word of the professors by blocking their mobile phones. One student said, "*There was a mandatory class where the professor lectured only; he lectured incessantly without any jokes. In that class, if I missed a point because of using my smartphone, I couldn't catch up. In this situation, Let's FOCUS was much more useful because it maintained my focus on the class, even when it was boring.*" (P3).

Students also responded that Let's FOCUS was more helpful when the professors did not mediate students' mobile phone use and/or intervention was difficult to enforce. One student said, "*In a situation where the professor did not mediate students' mobile phone use, I tended to use it more. In this case, Let's FOCUS helped me focus on the class.*" (P4). Another student commented, "*I think if the classrooms are large and there are many students, professors have difficulties in intervening in mobile phone use and Let's FOCUS is required.*" (P8).

Finally, we determined that Let's FOCUS was useful in boring classes. One student said, "*When I attend seminars, I always access Facebook because I feel sleepy and bored. Let's FOCUS was useful in these cases.*" (P11). Another student commented, "*There was one class that proceeded slowly compared to the other classes. In this situation, Let's FOCUS was helpful for me.*"

5.4.3 Diverse usage contexts other than classes. We designed Let's FOCUS to support different usage situations requiring concentration. Students can limit their mobile phones by creating a virtual limiting study room. 84.7% students reported that they entered a virtual study room to study alone without the distraction of a mobile phone. Among them, 58% responded that there were one or more other members in the virtual study room. 64.8% of students reported that they could focus better on different activities (e.g., individual, work) after the use of Let's FOCUS. The main purpose of using the application was for study concentration. One graduate student commented "*I usually executed Let's FOCUS to concentrate on my research without distraction by a mobile phone.*" (P6). One undergraduate student commented "*I created a new room and studied for midterm exams with my close friends.*" (P13). Many students also used the application in multiple situations. Interestingly, some students used the application before sleep. One student commented, "*When I stayed up late in the bed watching content such as comics and YouTube, it was difficult to quit. So, I locked my smartphone with Let's FOCUS and I could fall asleep after using the five-minute allowance.*" (P5). One student used Let's FOCUS when he chatted with friends: "*when I met*

friends at a café, I created a room and tried to focus on the conversation." (P8). Some students used the application when they exercised or took walks with friends.

5.5 RQ3: Social comparison and limiting behaviors

Based on our interview analysis, we determined that students maintained their limiting behaviors primarily owing to a sense of competition through social comparison, intrinsic usage motivations for self-regulation, and extrinsic rewards of promotional giveaways. Given that we explained intrinsic usage motivation with the focus mode and extrinsic rewards in the earlier sections, in the following, we focus on illustrating social facilitation in Let's FOCUS. We uncovered four factors that facilitate social comparison: (1) *intimacy level between members*, (2) *existence of active users*, (3) *limiting record differences*, and (4) *engagement of collocated activities*.

5.5.1 Intimacy level with members. Students said that they were motivated to use Let's FOCUS particularly when they limited their phones with close users. One student said, "*I enjoyed using Let's FOCUS as if playing a game with friends. When I saw my friends' records, I wanted to beat them as if we were in a competition. I thought that displaying others' limiting records was good for bringing a sense of competition. The records of my friends motivated me more than when the competitors were unknown users.*" (P7). Another student mentioned, "*I didn't need to compete with others who were complete strangers.*" (P15). Sometimes, students were encouraged to use Let's FOCUS even though their friends were not present in their virtual rooms. One student commented, "*At first, I used the application to accumulate a more (limiting) time record in the virtual classroom. However, after I created a new room to use with my friends, I found another purpose of using the application, beating my friends. When we met together, we talked about using Let's FOCUS and compared our records. Moreover, I tried to study harder after I found my record was much less than those of my friends.*" (P13).

5.5.2 Existence of active users. The active users represent all users who ever logged into a virtual limiting room and are currently on focus mode in that room. Any member can view the list of participants in the focus mode of a virtual limiting room. Recall that members can be either online or offline, and they are ranked based on the limiting hours accumulated in that room. One student said, "*When I tried to leave a virtual classroom to temporarily use a mobile phone, I could see a list of classmates who were in focus mode at that time. Hence, I decided to turn off the mobile phone screen and continued to focus on the class.*" (P8). Another student commented, "*When I entered a virtual classroom somewhat late, I saw the other classmates who were already in focus mode and I became aware that they had entered the room from the beginning of the class, yet I didn't. I felt that I should not be late next time.*" (P19). Some students were concerned regarding how they were perceived by their friends. One student said, "*I was stimulated by others' limiting records and that they could check my limiting status if I left a room.*" (P15).

5.5.3 Limiting record differences. Limiting records were the key factor facilitating social comparison. Students felt stimulated to use Let's FOCUS if they viewed their limiting records. One student said, "*A limiting time record displayed on the screen of the focus mode presents how long the user has studied and concentrated. This gave me stimulus to study and use Let's FOCUS.*" (P7). Interestingly, when record differences were large, students felt less motivated to limit usage. One student said, "*If other users' records were similar to me, I felt very encouraged to match them. However, if the record differences were excessively large, for example ten hours, I did not feel any sense of competition.*" (P17).

5.5.4 Engagement of collocated activities. We identified that social facilitation was more effective when members of a virtual limiting room were co-located and engaged in the same activities; for example, taking the same class, or participating in a group study. One student commented, "*In the case of the virtual classrooms, there is a shared purpose of concentrating on the class together and I was strongly motivated to use Let's FOCUS. However, in the case of a virtual study room, I did not care as much because I was unable to know what they were doing and where they were. Moreover, there was no common purpose for limiting.*" (P8).

5.6 RQ4: Attitudes changes and continued usage after campaign

We analyzed possible attitude changes regarding in-class mobile phone usage after the campaign. We also investigated the users' willingness to continue to use the app. We present how participants actually used the app through the end of the Fall semester. We determined that approximately 30% had gained awareness of the negative aspects of in-class mobile phone use after campaign participation and more than 70% of the users wanted to continue to use the app owing to its effectiveness; the remainder of the users expressed their concerns regarding software-based intervention and limited features of Let's FOCUS.

5.6.1 Attitude changes about in-class mobile phone usage. In our exit survey, we asked students how their initial attitudes had changed after participating in the campaign (5-point Likert scale response) and the reasons for such changes (free-text response). Further, we asked the interviewees of their reasons and opinions.

We identified that 31.7% of the survey participants responded that their attitudes toward in-class mobile phone usage changed after campaign participation. Surprisingly, a majority of those people (84.2%) became more negative regarding mobile phone use in classrooms than before the campaign. There are several reasons for these negative attitude changes. First, students realized that urgent matters for mobile phone usage did not occur frequently. Although urgent matters happen during a class, they learned that they could defer their responses until after the class by simply focusing on the current lectures. One student said, "*Before participating in the campaign, I thought that I had many urgent tasks relating to my smartphone. With Let's FOCUS, however, I found that there were not as many urgent tasks as I had expected. Instead, I frequently used my phone to do other activities. Hence, I should abstain from using my mobile phone in class.*" (P'095). Another student commented, "*Sometimes I was required to use my phone for programming. However, I realized that its usage was not necessary and I could focus on the lecture for 1.5 to 2 hours [by using Let's FOCUS].*" (P'099). Secondly, students learned that off-topic usage in class negatively influenced their concentration. One student said, "*I thought that mobile phone usage did not affect my learning during the class, however, after I forced myself to not use the phone [using Let's FOCUS], I found that I could better focus on the lectures.*" (P'163). Other students determined that class-related usage such as information search was possibly not required as long as they were fully focused on the lectures. One student said, "*When I was really focusing on the lecture, I tended to not do information search and I was still able to understand most lecture content.*" (P'121).

Conversely, 15.8% of those participants (i.e., 5% of the survey participants) responded that after campaign participation, they had become more positive regarding mobile phone use in classrooms than before. They stated that as long as students can use their mobile phones properly, mobile phone usage was not a distraction source for learning in the class. As one participant commented, "*It does not matter if students use mobile phones properly.*" (P'128). Let's FOCUS's focus mode helped them better manage usage time, which provided a positive influence. As one student stated, "*It was great that I could use my mobile phone only for searching, owing to Let's FOCUS.*" (P'6).

5.6.2 Let's FOCUS use after campaign. After the campaign ended, we rewarded the students who achieved certain levels of use (i.e., 20 hours of usage limiting) and selected a number of participants to provide promotional giveaways. After the official campaign period, we allowed the students to continue to use the app; however, we did not offer any rewards afterwards. We continued monitoring Let's FOCUS usage until the end of the Fall semester. We found that 117 active participants continued to use the app and were able to additionally limit 1,224 hours of mobile phone usage. There were 56 students who regularly used the app in their classrooms.

In our exit survey and interview, we asked the participants if they were willing to continue to use the app after the campaign period. Our survey results indicate that 74% of the participants wanted to continue to use Let's FOCUS after the campaign because they had positive experiences with it. First, Let's FOCUS helped them to better focus on the class and individual studies. One student complimented its usefulness by commenting, "*I would like to continue to use Let's FOCUS because I think that it is useful when I attend a class or must focus on something.*"

(P'39). Some students were able to manage their mobile phone usage behaviors, as one student commented, "*I will continue to use the app because I reduced my habitual unnecessary mobile phone usage.*" (P'79). Others wanted to continue to track their study hours, as one student responded, "*Let's FOCUS records my limiting behavior for study. The greater the amount of the accumulated limiting hours, the more I feel that I have accomplished.*" (P'167).

However, 27.3% of the participants said that they would discontinue using the app. The reasons behind such decisions were primarily due to their concerns regarding software-based intervention and the application specific features of Let's FOCUS. They argued that students should be able to self-regulate without intervention, as one student said, "*I think that it's better for students to voluntarily focus on the lectures and they should improve self-regulation by practicing self-control.*" (P'170). Some students wanted to seek alternative approaches, as one participant said, "*I think software-based intervention does not address the fundamental problem related to mobile phone usage regulation in class.*" (P'64).

In addition to these issues, we determined that the application specific features of Let's FOCUS were a further hindrance. Remarkably, our respondents wanted a stricter focus mode. One participant commented, "*This app was not helpful for me to limit my mobile phone use. While staying in the focus mode, I often left the virtual limiting room to use mobile phones longer than five minutes. Then I could easily return to the virtual room after that.*" (P'22). Another participant said, "*This app was much less restrictive than other locking apps.*" (P'42). Another issue is related to the lack of social facilitation. As illustrated earlier, social comparison was one of the major factors that encouraged maintaining limiting behaviors. If there were fewer members in the virtual limiting rooms, they were less motivated to join them. As one student commented, "*I would continue to use this app only when there were many other users in the rooms.*" (P'138).

5.7 RQ5: Usability evaluation and cross-platform differences

We evaluated the overall usability of Let's FOCUS and then investigated if there were any common usability issues across both platforms. For usability evaluation, we used the USE questionnaire [34] that was administered as part of the exit survey (n = 177). The questionnaire was composed of four sub-constructs including usefulness, ease of use, ease of learning, and satisfaction. Further, we explored such usability dimensions in the in-depth interviews. Note that using our survey data, we evaluated the reliability of the USE in terms of Cronbach's alpha. The Cronbach's alpha values were given as follows: overall (0.889), usefulness (0.863), ease of use (0.882), ease of learning (0.844), and satisfaction (0.827). It is widely accepted that when the Cronbach's alpha value is greater than 0.7, the results are assumed to be reliable.

Overall, our participants were positive with an average rating of 3.87 (SD = 0.62) in the USE questions. Note that all the exit survey questions, including the USE questionnaire, were given in 5-point Likert scales to avoid mapping confusion [21]. Our results demonstrate that it was easy for the participants to learn how to use and then actually use the application. We created a campaign web page with a tutorial blog and video, which provided an intuitive user guide. This user guide provided a quick overview of major tasks such as how to create/search virtual limiting rooms and how to use five-minute breaks. Furthermore, there was a FAQ section in the homepage and we allowed users to ask questions via email.

In addition to such tutorials and FAQs, our interview results indicate that the current user interfaces were easy to learn. Our participants highly appreciated the simple interface that provided only the necessary features. One participant commented, "*It was simple and easy to use even though it is an intervention app. Unlike Let's FOCUS, other similar applications were complicated to use because there were excessive options.*" (P5). Another participant said, "*It was easy to use because the interface was intuitive and there were no excessive, unnecessary features.*" (P11).

In our analysis of the interview data, we determined that the participants typically used the app according to our original intention. The most frequent method of locating virtual limiting rooms was to use the nearby filter that displayed only nearby virtual classrooms. Recall that once virtual classrooms were checked in, location-based notifications were then automatically sent whenever they were near the classrooms. We confirmed that for

Table 3. Results of two-tailed independent t-tests on limiting records and usability scales between Android and iOS users ($\alpha = 0.05$).

		Mean (SD)						
		All users (n=177)	Android (n=129)	iOS (n=48)	Cohen's d	t-value	df	p-value
Usability (range: 1~5)	Usefulness	3.88 (0.69)	3.93 (0.69)	3.73 (0.67)	0.29	1.63	79.19	0.106
	Ease of Use	3.85 (0.81)	4.02 (0.75)	3.40 (0.79)	0.81	4.55	74.74	**0.000**
	Ease of Learning	4.10 (0.76)	4.24 (0.68)	3.72 (0.83)	0.70	3.75	65.76	**0.000**
	Satisfaction	3.74 (0.76)	3.85 (0.65)	3.47 (0.95)	0.47	2.44	59.17	**0.018**
	Total	3.87 (0.62)	3.99 (0.56)	3.55 (0.66)	0.72	3.93	67.61	**0.000**
Limiting records (hours)		53.06 (62.20)	56.36 (49.27)	51.73 (103.85)	0.06	0.09	36.52	0.950

this reason, check-ins were guided primarily by this context-aware reminder. Our participants had a clear understanding of the concept of virtual limiting space, as one participant said, "*I don't attend classes because this is my last semester. When I searched for a virtual limiting room using the nearby filter, I found that there was no room around the location where I usually studied individually. So, I made a new one and shared it with my friend.*" (P2). As described earlier, participants effectively utilized the five-minute allowance to address their urgent calls or tasks while they were checked in a virtual limiting room. These results clearly demonstrate ease of use and high satisfaction in usability.

This next segment explains how the usability and usefulness of Let's FOCUS differed across the platforms (Android vs. iOS). Note that the iOS version of Let's FOCUS had limited blocking functions, unlike Android, because the iOS platform's APIs do not allow specific features (e.g., blocking use, background operations). In our system implementation, owing to technical limitations, we were not able to collect platform information in our server, and thus, we could not differentiate to which platform a user belonged. As an alternative, in our follow-up survey, we required participants to specify their email account (used for sign up) and the platform type (i.e., Android, iOS). This information allowed us to match their activity data in the server. Thus, we grouped the users based on the platform types. Among the 177 users who completed the survey, there were 129 (73%) and 48 (27%) users for the Android and iOS platforms, respectively. To investigate the differences in user experiences between the Android and iOS, we analyzed the following metrics: (1) usability, (2) subjective reports on usage patterns, and (3) objective usage log data.

Our results indicate that there was significant difference in usability ratings between Android and iOS users (Android: M = 3.99, SD = 0.56 vs. iOS: M = 3.55, SD = 0.66; $p < .001$, Cohen's d = 0.72). As presented in Table 3, there was no significant difference in the *usefulness* subscale ($p = .106$, Cohen's d = 0.29). For example, a representative item is "*Let's FOCUS helped me to concentrate.*" We hypothesize that our participants generally considered that Let's FOCUS was useful in that it helped them to self-regulate usage hours during class. However, the lack of the locking feature in the iOS platform had a negative influence on the overall satisfaction. One iOS user commented, "*I could still use the temporary use mode although the five-minute allowance expired. Actually, it would be better to provide exactly five minutes in a coercive way.*" (P1). Furthermore, user interactions in the temporary mode were deemed less satisfactory owing to the lack of timer features and automatic locking. This usage is less intuitive and involves additional user steps/interactions when compared with those of Android.

We then analyzed the log data to verify if there were any differences in limiting durations between the two platforms. Our results indicate that there was no significant difference in limiting hours (Android: M = 53.36 hours, SD = 49.27 vs. iOS: M = 51.73 hours, SD = 103.85; $p = .950$, Cohen's d = 0.06). Despite functional differences, we determined that students could continue to participate in the campaign and experience a similar level of engagement.

6 DISCUSSION

In this section, we discuss design implications based on our findings. We begin by discussing how to support autonomy of software-based intervention and to frame software-based intervention as a campaign. We then illustrate how software-based intervention can leverage social facilitation and context awareness. Further, we discuss how we should consider future learning environments.

6.1 Supporting autonomy in software-based intervention

Software-based intervention has been widely used in various domains such as education and mental health owing to its low delivery cost and interactive nature [5, 9, 14, 61]. However, there are critical design issues such as ethics [53] and autonomy [38]. In this work, we conducted a preliminary user study to explore design guidelines for software-based intervention. Although students agreed that off-task mobile phone usage is problematic, they felt that software-based intervention would infringe on their autonomy. This finding is consistent with prior studies on software-based intervention for parental control of children's media usage where a child's autonomy preference was found to be critical for software adoption. Moreover, software adoption by older youth was lower than that of younger youth [38]. Further, many professors wanted to respect students' autonomy and commented that the students should be able to properly self-regulate mobile phone use in classrooms. According to the literature, autonomy can be defined as a state of being independent or self-governing [51]. This means that to avoid infringement of the students' autonomy, their *ability* and *willingness* must be respected [30].

In Let's FOCUS, we introduced the concept of virtual limiting spaces for classrooms (or virtual classrooms) to support location-based mobile phone blocking and facilitate online interactions for social learning. Furthermore, we framed software-based intervention as an auxiliary tool for helping students to self-regulate usage. Thus, we supported their autonomy by suggesting that they enter virtual classrooms and allowing them leave if they desired, and to self-organize social support groups. Our field trial results validate the effectiveness of the proposed approach. To the best of our knowledge, the proposed work is the first attempt of software-based intervention in college classrooms.

6.2 Framing software-based intervention as campaign

General perception regarding new technology has an important role in whether it will be adopted [8]. Many studies have examined how framing affects attitude or behavior [8, 37]. In this work, one of the most challenging parts was how to frame the purposes and functions of Let's FOCUS. The key concept of Let's FOCUS is virtual limiting spaces for classrooms where a user's mobile phone use is limited. For a given physical classroom, there is a virtual limiting room (or virtual classroom), where mobile phone use is limited. This coercive approach was used to frame the situation to encourage students to self-regulate their mobile phone use in the classrooms. To solicit students' voluntary participation, we decided to conduct a campaign where we considered the proposed app as an auxiliary tool to allow students to self-regulate mobile phone usage (e.g., focus and temporary use modes). In our campaign, we deliberately excluded faculty involvement to prevent the use of the proposed app as a monitoring tool for student supervision and encouraged students to voluntarily participate in the campaign without enforcement. We also attempted to reinforce students' awareness regarding appropriate mobile phone use in the class (i.e., social norms) over the campaign period. Social norms for changing target users' behavior have been employed in many prior studies [49, 50]. The majority of students favored Let's FOCUS's coercive function, which temporarily blocks mobile phone use (if a student agrees to block), because it helped them focus on the classes and they felt a sense of accomplishment as they participated in the campaign. Furthermore, many students responded that they would continue to use the app after the campaign period, although there was no external reward. Thus, our framing approach had a positive influence on changing students' behaviors and attitudes towards mobile phone usage in classrooms.

6.3 Promotional Material Design for Intervention

From our post survey, we identified various opinions regarding the promotional poster design for software-based behavioral change intervention (e.g., attractiveness, information delivery, relatedness). From these opinions, we identified three design implications for promotional posters. First, poster design should be able to raise awareness of problematic situations in an effective manner. In our case, we used amusing cartoons with short statements of problematic situations with respect to mobile phone usage in classrooms. Secondly, it should clearly present detailed information in the form of actionable instructions; e.g., downloading an app and joining virtual limiting rooms. Lastly, when using different poster designs for promotion, the designers should provide clear linkage regarding how different posters are related with each other. We expect that when promoting a large-scale software-based intervention, our design guidelines would help lead to increased engagement.

6.4 Leveraging social comparison in software-based intervention

Social comparison is one of the most studied methods for behavior change [55]. Our campaign results indicate that social comparison and competition among students had a key role in facilitating the intended behavior in the class. In the proposed work, we identified several factors related to social comparison and competition. First, the limiting records shared with virtual classrooms were the key influencing factor because limiting records explicitly represented how well students focused in a given virtual room. However, if a user's limiting record was considerably less than those of other users in a virtual room, the user became demotivated. This result was consistent with prior studies where users who had similar physical conditions were most influential with one another in fitness tracking scenarios [27]. This highlights that direct competition may result in a negative outcome [57]. One method of mitigating this problem is abstracting limiting records rather than displaying exact limiting records. Alternatively, we can use badges/levels based on limiting records and we can periodically reset limiting records (e.g., once a month, two months) to restart the competition. In this regard, classrooms could be potential intervention environments to facilitate social comparison and motivate students to change behaviors because classmate have similar conditions (e.g., age, grade level, major), and thus, they could easily influence each other.

6.5 Providing context-aware intervention

Let's FOCUS sent students notifications based on the context of the class (i.e., location, schedule) as in traditional context-aware computing applications [48]. In the proposed work, many students commented that context-based reminders helped them think of normative behaviors during class and to engage in limiting behaviors, possibly before a lecture began. We determined that the majority of the students preferred location-based alarms rather than time-based alarms. This could mean that simply reminding users of the places where they are located was sufficient because it is likely that each course could occur in a different classroom. Furthermore, location-based reminders were essential to reinforcing students' awareness of normative behaviors during the class. As indicated by our design, the frequency of the reminder delivery must not disturb users; for example, a rejected reminder can be "snoozed" for an hour.

6.6 Towards smarter classrooms

We can expect that a future classroom will be fully equipped with various smart technologies such as table-top technology [35], wearable devices (e.g., glasses, smartwatches) [31], interactive augmented/virtual reality systems [63], and Internet of Things (IoT) [2]. In this ubiquitous learning environment, smart devices will be intimately connected and students will be fully surrounded by interactive technologies as envisioned by Mark Weiser [59]. Owing to the prevalence of smart technologies, however, in the future, people may interact with the technologies frequently, become more dependent upon them, and be exposed to distracting interaction

opportunities. A future classroom will be surrounded by complicated, pervasive, and life-essential technologies that make it almost impossible for students to study without their aid. The proposed work is currently focused on regulating single devices; however, future work should investigate how software-based intervention can manage multiple connected devices.

6.7 Limitations

Regarding the effectiveness of Let's FOCUS, our findings should be considered cautiously. First, the proposed work aimed to regulate only mobile phone usage. In practice, students could use other personal digital devices (e.g., tablets, laptops) in class while using Let's FOCUS. Based on the survey and interview, however, it is clear that Let's FOCUS effectively reminded students of normative behaviors in classrooms. Further, they felt a sense of competition, actively using Let's FOCUS with other co-located users and engaging in the same activities (e.g., focusing on the same class). Furthermore, many students continued to use Let's FOCUS after the end of the campaign, even without rewards. Hence, we can state that Let's FOCUS had positive effects as an auxiliary tool for learning. Nonetheless, we were not able to verify if Let's FOCUS actually helped improve students' academic performance (e.g., exam results, grades).

Our main target participants were undergraduate students whose primary daily routine is attending classes. The proportion of undergraduate students who downloaded Let's FOCUS during the campaign period was approximately 10.3%. This relatively low adoption rate could be attributed to a number of reasons. First, we were required to use students' voluntary participation. However, it seemed that, based on our preliminary study, many students (47.0%) had negative feelings towards adoption of software-based intervention to regulate mobile phone use during the class. As our post survey results indicate, there may have been many students who failed to notice that there was an ongoing campaign, despite extensive promotions with posters across the campaign.

Regarding the number of virtual classrooms engaged in the campaign period, we created 1,003 virtual classrooms; however, students entered only 233 virtual classrooms (23.2%). This level of participation can be explained as follows. First, there were a large number of small-sized classes (e.g., approximately five students enrolled) and student enrollment was skewed to large departments (e.g., electrical engineering, mechanical engineering, computer science). Probabilistically speaking, it would be difficult to locate Let's FOCUS users in small-sized classes. Furthermore, more than one third were graduate courses (38.1%); yet, we had a reduced level of graduate student participants (only 21.9%).

We prepared different giveaways to promote the campaign. Providing extrinsic rewards to drive students' participation could be effective for bootstrapping, however, it is probably not a sustainable method of continuing promotion owing to a limited budget. After bootstrapping, we determined that students were primarily motivated from other factors such as social comparison and intrinsic motivations for self-regulation to maintain their limiting behaviors. Furthermore, some students continued limiting behaviors using Let's FOCUS after the campaign, even though there were no extrinsic rewards. In the future, therefore, it would be interesting to perform an in-depth study that investigates how extrinsic rewards influence the behaviors of participants.

Owing to API differences supported in the different mobile platforms, limited functionality (e.g., blocking and background services) was supported for the iOS users. Our usage log data analysis did not indicate significant differences; however, we observed considerable differences in usability scores (except the usefulness sub-scale). Further investigation is required to better investigate what aspects of the features are related to the usability and user experiences via in-depth user interviews and controlled experiments.

We used the USE questionnaire for usability evaluation [34]. In the original questionnaire, items were supposed to be rated in a 7-point Likert scale. In our study, however, we used a 5-point Likert scale to avoid confusion, because all the other questions were given in 5-point Likert scales. According to Krosnick and Presser [21], survey participants must map their attitudes or thoughts into numeric scales and thus, we thought that heterogeneous mapping could confuse the answerers. Reliability or consistency of a measure typically becomes saturated when

Likert scales with five or more points were used [21]. Furthermore, our results indicate that Cronbach's alpha values of the USE scale and its sub-constructs were greater than 0.8, which generally means that the results can be assumed reliable.

The scope of our results is limited to Korean college students. For generalizability of our findings, follow-up studies in different technical and sociocultural backgrounds are required. Towards this goal, we have released our software to both the Google Play and Apple App Store and we plan to release the source code to GitHub. We believe that our intervention could also work effectively in other nations. For example, a number of studies regarding methods of behavior changes [57] and technology use (e.g., mobile phone) in the classroom [3, 58, 62] have been conducted in other nations. As discussed above, the results of our work aligned with the prior studies.

7 CONCLUSION

Our goal in this work was to explore how to design and deploy software-based intervention in a college classroom setting. Our preliminary survey study (with 47 professors and 283 students) revealed the key design guidelines for software-based intervention, i.e., encouraging voluntary participation and establishing social norms of proper usage in classrooms. Based on the design guidelines, we carefully designed Let's FOCUS, a software-based intervention tool for college classrooms that supports both the Android and iOS platforms. Let's FOCUS provides virtual limiting spaces for classrooms through which students can voluntarily block their mobile phone use, receive context-aware reminders, and recall normative behaviors. 379 students used the app to limit 9,335 hours of usage over 233 classrooms. Our deployment study revealed that Let's FOCUS was used in diverse learning contexts and purposes. Our work demonstrated that the autonomy of students must be carefully considered in software-based intervention, that location-based notifications were useful for reminding normative behaviors and encouraging participation, and that social comparison motivated students to maintain limiting behaviors. To our knowledge, the proposed work is the first large-scale trial regarding software-based intervention in a college. In an age of smart classrooms, we expect that off-task distractions and technology dependence will emerge as a serious social concern. Our trial has provided the stepping stones for addressing this issue through technology.

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