CampusWatch: Exploring Communitysourced Patrolling with Pervasive Mobile Technology

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Community policing to collaboratively maintain community safety and order in conjunction with law enforcement is becoming increasingly popular and efficient with the use of mobile technologies. Beyond sharing information about local problems such as crime via online discussion forums, there has been an increased focus on the impact of mobile, location-based systems on community policing. In this study, we designed a novel communitysourced patrolling campaign in which community members schedule their own patrol times and routes, then perform bike-based patrolling with video capturing and sharing using their smartphones. We conducted a four-week field study (n=20) on a university campus to verify the campaign's feasibility and observe users' behavior. Our results show key findings about users' task scheduling, event capturing and reporting behaviors, factors affecting task selection and execution, and user motivation and engagement. Finally, we discuss several practical design implications in building location-based systems for communitysourced patrolling.

CCS Concepts: • **Human-centered computing** → **Human computer interaction (HCI)**; **Collaborative and social computing systems and tools**; **Ubiquitous and mobile computing systems and tools**; • **Information systems** → *Crowdsourcing*; • **Social and professional topics** → *Corporate surveillance*;

KEYWORDS

Communitysourcing; Crowdsourcing; Crowdsensing; Community Policing; Mobile Sensing; Community

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1 INTRODUCTION

Community policing is a proactive approach that empowers residents to participate in preventing crime and maintaining order, enlisting them as partners with the police in activities such as neighborhood watch and community patrolling [7, 19, 54]. In recent years, information and communication technologies (ICT) have been increasingly adopted to foster community policing. Online communities and social media such as Twitter and Facebook, for example, have been used to share information, build relationships with the police, and take collective action [20, 22, 33].

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Mobile technology has enabled novel forms of community policing with crowdsourced sensing, allowing community members to collaboratively share local safety issues such as crime and suspicious activities with mobile sensing technologies such as GPS data and cameras [5, 25, 53, 56]. In addition, connected devices—home surveillance cameras and vehicle dashcams, for example—equip people to capture street videos as digital evidence and then share for collaborative neighborhood watch [8, 45]. These novel kinds of community policing activities with mobile devices generally belong to the body of research about mobile crowdsourcing and crowdsensing in the field of HCI [47, 59, 60].

Previous studies of mobile crowdsourcing and crowdsensing for community engagement have focused primarily on designing methods to effectively/accurately perform tasks online [29, 45, 59, 60], and on encouraging user contribution and motivation (for example, situated crowdsourcing and financial incentives) [27, 44, 47, 57]. Less attention has been given to designing and assigning tasks based on participants' spatio-temporal mobility patterns and contextual factors, and encouraging community members' participation beyond the well-known incentives in mobile crowdsourcing and crowdsensing.

In this paper, we consider communitysourcing [21]—an alternative crowdsourcing (or crowdsensing) approach requiring specific knowledge in a community—for community patrolling. Unlike the existing prior studies on mobile crowdsourced community engagement systems [28, 29, 45, 59, 60], communitysourced patrolling requires considerable physical efforts (i.e., walking/driving) and local knowledge/experience [44, 47] for collecting local issues with mobile devices and sharing the local issues with community members or security services.

Our goal is to design a communitysourced patrolling campaign that allows community members to schedule and execute their location-based tasks and that leverages social media to share local safety and public order issues. Towards this goal, we explore following three research questions:

(1) What are the implications in designing a communitysourced patrolling campaign?
(2) How to design a patrolling task for a communitysourced patrolling campaign?
(3) How do people perform patrolling tasks in a communitysourced patrolling campaign, and why?

To deploy communitysourced patrolling, we targeted a university campus because university students are digital natives and mature enough to participate in policing activities. A large university is also the proper community size to conduct a field trial of a community patrolling campaign. We first performed a user study to understand students' perceptions and experiences of local problems and their mobility patterns to assess possibilities for communitysourced patrolling. We then designed and built a CampusWatch campaign system that provides a suite of tools: task scheduling, task execution with mobile video capturing, and online sharing. Finally, we conducted a four-week field trial at a large university in South Korea. Our field trial aims to answer the following questions: 1) how do people set task schedules? 2) what events are captured and reported? 3) what factors affect their task selection and execution? and 4) what would affect participants' motivation and long-term engagement?

Our study results showed that, in communitysourced patrolling, participants have strong spatial-temporal preferences; task selection tended to be opportunistic. Task selection and execution were influenced by several factors, including uncertainty and busyness of work schedules, tiredness and fatigue, social contexts, and environmental conditions. Leveraging diverse motivations and the fostering an online community are required for proactive user engagement. Detailed guidelines and policing authority can enhance participant's engagement. We discuss how our findings can be leveraged in scheduling micro-tasks, sustaining user engagement, fostering online communities, establishing guidelines and authority, and addressing privacy concerns.

2 RELATED WORK

2.1 Community Policing Systems

Recent advances in smartphones and the Internet of Things (for example, intelligent connected cameras) make possible novel community policing services. Smartphones are widely used, not only to share local crime-related information but also to allow people to report any safety issues in real time (see, for example, SALUS [25], CrowdSafe [53], S4S [56], ComfortZones [5]). SALUS [25] visualizes crime related information (crime maps and safety tips) and allows users to report crimes in real time. CrowdSafe [53] recommends safe paths on a map by incorporating crime data into routing algorithms. To promote campus safety, S4S [56] supports text- and voice-based incident reporting and personalized notification delivery (for example, preferred paths and places). ComfortZones [5] is a mobile service designed to mitigate fear at night in urban locations by allowing users to capture and share location-based safety or comfort attributes and provide social support and interaction.

Brush et al. [8] explored the use of connected surveillance cameras with video sharing to realize the concept of digital neighborhood watches. They also considered potential privacy concerns related to video sharing. This kind of digital neighborhood watch can be extended to vehicular scenarios if vehicles are equipped with advanced sensors, including dashboard cameras [45, 46, 55].

Our work also focused on community policing where the public gets involved in various activities of prevention, problem-solving, and law enforcement, but differs from such prior studies in that we designed a novel form of communitysourced patrolling campaign with mobile technologies for safety and order. Communitysourced patrolling requires physical efforts such as walking/driving through the community and sharing suspicious activities with community members or security services. We then allowed community members to freely schedule their contributions based on their personal contexts or preferences to ensure effective, high spatio-temporal coverage. In addition, we enabled community members to actively collect video evidence (location tracking and video recording) for safety issues and public disorders using their smartphones, and provided opportunities while patrolling to deal with issues such as calling security staff or distributing guidance notes, not just sharing information online.

2.2 Mobile Crowdsourcing and Communitysourcing

Crowdsourcing with mobile technology enabled mobile crowdsensing [18], which is a technique where a group of individuals having mobile devices contribute to collect and share sensor data using the mobile devices. This mobile crowdsensing enabled to design various forms of civic engagement in addressing local issues and needs, including community policing [56], urban infrastructure maintenance [30], urban air quality monitoring [4], and disaster relief operations [36]. In addition, researchers explored a concept of communitysourcing [21, 51], an alternative crowdsourcing mechanism that requires specific knowledge or skill to perform tasks. For example, Heimerl et al. [21] proposed a communitysourced vending machine that crowdsources exam grading tasks to students and rewards them with snacks in a university. They showed that the system was able to attract students with right expertise levels, thereby achieving high level of accuracy.

In mobile sensing platforms, mobile workers perform various micro-tasks, generally divided into opportunistic sensing and participatory sensing. Opportunistic sensing sees mobile workers performing any kinds of sensing tasks using their phones, without requiring user interactions such as collecting traffic information using GPS data [59]. Participatory sensing, by contrast, requires that they proactively perform elaborate micro-tasks, such as taking photos [60] and collecting local knowledge/experience [44, 47]. The complexity of micro-tasks ranges from simple tasks of photo-taking [60] to more complex tasks of delivering packages [29] or cleaning houses [57].

In our work, we considered a novel communitysourced system for community policing, in which local community members freely schedule their time slots and routes and then perform bike-based patrolling with video capturing for surveillance. From the field trial, we wanted to understand task scheduling and execution patterns, so we investigated the factors that seem to affect task scheduling and execution.

2.3 Understanding User Behaviors in Micro-task Performing

Participation in crowdsourcing and communitysourcing is largely motivated by intrinsic, social, and monetary factors. Teodoro et al. [57] found that mobile workers in on-demand labor markets such as TaskRabbit were highly motivated by monetary rewards. Other micro-tasks, on the other hand, are driven by intrinsic and social motivations: knowledge sharing [47], community help services [31], or community policing [45]. Violio et al. [61], for example, showed that the key motivations for participation in online neighborhood watches are egoism (for my safety), altruism (for others' safety), collectivism (for our community safety), and principlism (for social justice). In their communitysourcing trial with a physical kiosk, Heimerl et al. [21] showed that when performing micro-tasks of exam grading, student participants preferred community/context-specific rewards (e.g., snacks) to monetary rewards.

Regarding factors affecting user participation, researchers found that users' contexts are important. Participants preferred to perform nearby tasks [3, 17, 29, 58]. Musthag et al. [39] showed that workers' physical locations affect their decisions about accepting task prices on mobile crowdsourcing. Kim et al. [29] explored package delivery crowdsourcing via those people who are on their way to a destination. They found that task acceptance depended on a person's current route, availability, personal situation (busyness and social contexts), and weather conditions. Ikeda et al. [24] examined micro-tasks of mobile network quality assessment, finding that a user's contextual factors, such as busyness, fatigue, and social situation affected task acceptance and performance. In citizen science, researchers found that personal interests and preferences about a task affected participation willingness in participatory citizen air quality monitoring [4].

In this work, we carefully designed a communitysourced patrolling campaign that allows community members to contribute to community safety and order. We then identified several motives that participants may consider as encouraging, along with various factors (for example, user's context and environmental restrictions) that affect task reservation and execution behavior through a four-week field study (n=20).

3 PRELIMINARY STUDY ON COMMUNITYSOURCED PATROLLING

Designing communitysourced patrolling campaigns requires us to carefully study the perceptions and experiences that participants have with local problems of safety issues and disorder in a community, as well as their major concerns and willingness to participate. Furthermore, we need to study participants' mobility patterns to improve the better design of communitysourced patrolling tasks. In this section, we report the key results of a preliminary study, which consists of two online surveys with university students and an interview with university campus security staff about their role and responsibility.

In the first online survey, we asked students to rate their perceptions about local problems on campus and their willingness to participate in campus community policing (in the seven-point Likert scale). We then posed open-ended questions that allowed them to report their recent experiences with local problems on campus, including their reactions and barriers to participation via Survey Monkey. In the second online survey, we asked respondents to report their daily mobility patterns such as commuting, going to the gym, or working part time jobs using Google Sheets. On Google Sheets, we asked them to fill out all of the information regarding their regular mobility patterns

Table 1. Summary of the two survey results

Perception	
What do you think of level of safety on campus?	M=5.22 (SD=1.29)
What do you think of level of public order on campus?	M=3.53 (SD=1.44)
Experience	
Do you have any experience of safety risks or public disorder on campus?	n=34 (56.7%)
- vehicle/traffic related issues(e.g., Illegal parking, speeding, disorderly bike parking) - daily life issues (e.g., loud noise near residential areas at night) - safety/security issues (e.g., thefts, damage to facilities, violence, harassment)	
How did you deal with the incidents?	
- called campus security (n=7) - directly attempted to resolve the incident (n=13) - ignored (n=14) - shared incidents with friends (n=15)	
Willingness	
I think students also need to participate in a campus policing campaign to promote safety and public order.	M=5.83 (SD=0.96)
I want financial rewards	M=5.07 (SD=1.49)
I do not need financial rewards	M=3.42 (SD=1.41)
Primary mobility on campus	
- on foot (n=11) - by bike (n=7) - by car (n=3) - on a kickboard (n=1)	

with departure times and locations, arrival times and locations, mode of transport, purposes for movement, and day of the week. Both surveys also collected demographic information. The two online survey forms were posted to a campus online community website as well as to Facebook in November 2016. The two survey results are summarized in Table 1.

In the first online survey, a total of 60 participants responded (39 males), with an average age of M=23.6 (SD=3.76). All respondents were students, either undergraduates (n=27) or graduates (n=33). In the second online survey, a total of 22 students responded (10 males), with an average age of M=26.3 (SD=2.6). In the two online surveys, three graduate students were duplicates. In the field study, two students were duplicates from the two online surveys (one of the three graduate students who responded to both surveys, and another undergraduate student who responded to the second survey) For each survey, we randomly selected five respondents and compensated them for their participation with a gift card worth 5,000 KRW (approximately 4.50 USD). In addition, to deepen understanding of how the campus security service works, one of authors accompanied a security staff member for one day (8 hours) as an assistant with permission of the security team. After this experience, the author interviewed two campus security staff employees.

3.1 Perception, Experiences, and Willingness

We initially asked respondents to describe their perceptions of current safety and public order on campus. In response to the question, *"What do you think of the level of safety on campus, and why do you feel this way?"* the respondents indicated their belief that the campus is safe from crime (M=5.22, SD=1.29). Many respondents commented that they felt safe due to the regular patrols of campus security service. For the question, *"What do you think of level of public order on campus and why do you feel this way?"* the respondents reported that the campus had a slightly lower level of public order (M=3.53, SD=1.44).

We asked respondents to report any incidents related to safety risks and public disorder that they had experienced on campus, and how they had dealt with them. We found that 56.7% of respondents (n=34) reported that they had experienced safety risks or public disorder, which can be categorized as vehicle/traffic related issues (e.g., illegal parking, speeding, unreported fender-benders, disorderly bike parking), daily life issues (e.g., loud noise near residential areas at night), and safety/security issues (e.g., thefts, damage to facilities, violence, harassment).

We then asked the respondents how they dealt with such incidents. Some reported that they at least reported the incidents to the campus safety team (n=7). There were quite a few students who attempted to resolve the incidents directly (n=13). Nonetheless, many students ignored the incidents, simply passing by the scenes (n=14) or only talking about these incidents with their friends (n=15). One of the major reasons cited was the desire of avoiding any trouble, as one respondent commented, *"It may cause some trouble if I ask a drunken person to be quiet."* Other major reasons were that they were not able to secure any evidence to report, or they did not know what to do.

We then asked the respondents about their willingness to participate in a campus community policing campaign to address potential safety risks and public disorder. In response to the statement, *"I think students also need to participate in a campus policing campaign to promote safety and public order,"* the respondents signaled strong agreement, stating that students need to participate in campus policing (M=5.83, SD=0.96). In response to the prompt, *"Please leave any opinions to improve safety risks and public order on campus,"* the respondents offered several possible suggestions for better safety and public order on campus. Many respondents noted that students strongly needed to improve their sense of public order (n=17). In addition, they also wished to have strict rules and punishment for violations (n=9). One respondent commented, *"Many students lack a sense of public order. We need to educate them and enforce punishments for rule violations."* Some respondents suggested that the campus should improve street lights and increase the number of surveillance cameras to ensure better safety (n=6).

We sought to determine what types of rewards students would expect by letting them rate each option. It was found that most students preferred a financial reward (M=5.07, SD=1.49), whereas participation without a reward was preferred the least (M=3.42, SD=1.41). This result is partly due to the fact that there are many on-campus part-time jobs available to students, including library work, pedestrian safety, and cafeteria serving.

3.2 Mobility Patterns and Modes of Transport

In response to the survey question on regular mobility patterns, we found that all respondents commuted between their home (typically a dormitory) and classrooms (for undergraduate students) or the laboratory (for graduate students). Commuting mostly takes place in the morning (9AM-1PM) and in the evening (8PM-2AM). Their average time for commuting was 8.3 minutes (SD=3.7). Respondents also reported that they had a couple of other regular mobility patterns as well such as going to cafeterias, coffee shops, gyms, and libraries. For the questions about primary mobility

on campus, students reported that they commuted on foot (n=11), by bike (n=7), car (n=3), or on a kickboard (n=1). As shown later, we consider bike-based patrolling due to the relatively fast mobility of patrolling, and the popularity of bike riding on campus. Our participants were very positive about patrolling the campus as part of their everyday routines, which can cover most of the spots in campus.

3.3 Campus Security Routines

The main activities of the campus security team include the controlling of traffic during rush and lunch hours, maintaining street parking and safety (e.g., bicycles, motorcycles, cars, and helmet wearing), and dealing with emergency calls on campus (e.g., chemical spills and traffic accidents). In addition, the security team reacts to various issues reported by students. We were told that the security staff does not have predetermined patrolling schedules and routes, mainly due to the rather varied service needs on campus. As time permits, the security staff patrols the campus by car and checks potential safety risks and public order (e.g., warning speeding vehicles and asking students to wear helmets). The security staff very much liked the idea of organizing a student campaign on campus community policing that could potentially improve the safety and public order. They provided their policing guidelines for us, but due to lack of human resources, they could not be involved in our work.

3.4 Design Implications

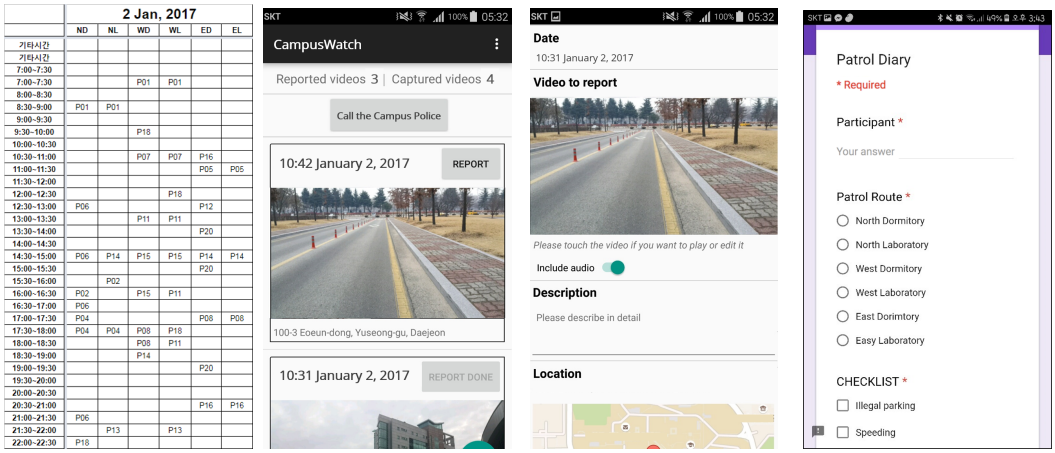
Our results showed that students were well aware of potential safety risks and public disorder on campus. They displayed high willingness to participate in campus policing activities to promote a safe and orderly campus. In addition, we studied students' regular mobility patterns in their daily routines, which can cover most of the spots on campus. Based on the results, we drew several design implications to build a mobile system that supports communitysourced patrolling.

First, we needed to build a system that could lower the burden of intervening in safety risks and public disorder situations on campus. We found that, in many cases, people did not actively try to resolve problems because they did not want to seek out trouble, such as by becoming involved in a quarrel. To ensure better engagement, it is important to secure some evidence, which is critical for resolving problematic situations such as illegal parking and loud singing near a dormitory at night. Such evidence will help campus security services or student organizations to deal with these situations more proactively. For example, in-vehicle or bike dashcams which are used widely in South Korea can be utilized for collecting objective evidence while being on the move [46].

We found that our participants were highly willing to participate in community policing, but sustained participation may require financial rewards similar to those given for part-time jobs on campus. Most were very positive about participating as part of their daily routines, which cover most of the important places on campus, such as dorms, libraries, cafeterias, and cafes. Thus, a communitysourced patrolling campaign design should carefully reflect students' motivations and daily routines; for example, it should be possible to do a micro-task when they are commuting, and rewards should be properly designed.

4 CAMPUSWATCH CAMPAIGN DESIGN

We describe our design of the communitysourced patrolling campaign by reflecting the results of the preliminary study. In our campaign, we consider communitysourced policing in a distributed manner. We recruit a group of students who are interested in promoting campus safety and let them perform the micro-tasks of bike-based patrolling (e.g., capturing videos and reporting events with their smartphones). Our campaign consists of three parts: (1) task design and scheduling, (2) capturing/reporting local problems, and (3) the creation of an online community.



(a) Task scheduling (b) Video browsing (c) Event reporting (d) Patrol Diary

Fig. 1. CampusWatch overview

4.1 Task Design and Scheduling Support

We divided the campus into six regions, related to its major geographical sectors (north, east, west), and home/work areas (dorms and labs). We then defined six patrol routes, comprising paths covering each region's circumference based on three criteria: 1) equal patrol time for each route (approximately 15 minutes by bike) to prevent participant bias in route selection (for example, taking only short routes); 2) balanced location of the routes (three from the dormitory area and three from the academic area); and 3) main roads instead of byways. We then named the six routes ND (North Dorm), NL (North Labs), ED (East Dorms), EL (East Labs), WD (West Dorms), and WL (West Labs). "Labs" denote major buildings representing each department, such as the School of Computing, and include the classrooms in each building. We carefully established boundaries. Two authors (one male, one female) tested many bike journeys to estimate the time and effort for each route, ensuring that each route would take about 15 minutes by bike (at a typical bike speed).

We created a Google Sheets displaying the patrol routes and time slots (see Figure 1a). Each sheet shows the day's patrol schedule. To make a patrol reservation, participants choose their preferred routes and times for the patrol, entering their names in slots on the Google Sheets to reserve the slot in consideration of their personal schedule. This real-time sharing prevented duplication with other participants. Because each patrol requires approximately 15 minutes, we set the duration of each time slot as 30 minutes so that the participants would have enough time to complete the patrol (e.g., including time to leave their building and prepare their equipment). We maintained scheduling sheets for two days: on the present and on the next day. At midnight, the previous schedule was replaced, and the participants could then schedule their tasks one day in advance. We let the participants freely change their schedules, but we informed them that every change would be tracked, and that no-shows would automatically be found by matching the schedule assignment to the patrol report records.

4.2 Capturing and Reporting Local Problems

To promote ease of participation in the communitysourced patrolling campaign, we iteratively developed CampusWatch, a mobile app that supports video capturing and event reporting of potential safety risks and public disorder on campus. In the mobile app design, for example, we

used an iterative development methodology to identify usability and functional issues based on a cyclic prototyping process. We conducted several rounds of low-fidelity prototype tests (n=4 or n=5) and a high-fidelity prototype pilot test (n=5), for a couple of days for each test, as well as one round of a high-fidelity prototype field test (n=14), for a week. All the prototype tests were conducted with university students on campus. By responding to feedback from these iterative prototype tests and interviews, we enhanced the mobile app, improving usability (for example, user interface) and correcting functional errors (for example, capturing and reporting bugs). We completed the final version of CampusWatch app for field study with this work. CampusWatch has four major components: continuous video recording, event capturing and reporting, patrol diary, and a function for calling campus security.

4.2.1 Continuous video recording. CampusWatch supports continuous recording and GPS location tracking as part of supporting distributed mobile surveillance with community members. Whenever a user starts a micro-task, the user is supposed to start video capturing with the app, which is similar to a security camera for bicycles. Furthermore, the user can capture an event and its video simply by touching a smartphone screen while the video record mode is on. The captured event video is 30 seconds long (i.e., 15 seconds before touching and 15 seconds after touching). In addition, CampusWatch records contextual information such as the date, time, and location trace (GPS).

4.2.2 Event reporting. As shown in Figure 1b, a user can browse all of the captured videos in the main list view. A captured video in the list can be replayed in the app. To send a report, the user must fill out a form that includes the target events (for example, the license plate number of a vehicle), a detailed explanation of related risks, and the precise capture location, as shown in Figure 1c. To deal with possible location errors and user mobility issues, we let the user adjust the reporting location. The app supports a few privacy preservation schemes, such as audio muting and video cropping. Users can remove audio by toggling the "include audio" option. When a video is selected for replay, the user can select the parts of interest and can crop the selected segment.

4.2.3 Patrol diary logging and security calling. At the end of each micro-task, a user is supposed to write a patrol diary (see Figure 1d). When a user selects this diary logging menu, it shows a Google form so that users can answer a set of questions to check which routes they took and to ensure that they followed a set of patrolling guidelines; e.g., *"I checked whether there were any strange people."* In addition, CampusWatch provided a button by which to direct phone calls to campus security (see Figure 1b). This helped the participants to call the campus security service directly if the need to do so was urgent.

4.3 Online Community for Community Policing

Unlike traditional group patrolling, our communitysourced patrolling occurred in a distributed manner. We created a virtual community among the campaign participants that allowed users to share typical videos and to receive and provide feedback. In our campaign, we created a private group on Facebook and invited all of the participants. During the field study, two authors acted as representatives for community policing and carefully selected reported events by considering their uniqueness and seriousness. The authors then shared the reports with the group, including videos and descriptions, so that the participants could understand the major issues that were occurring on campus. Participants could freely exchange feedback by leaving comments about the video feeds.

At the end of each week, we created a weekly activity report that included visualized participation statistics such as the number of patrols and reports of each participant, the types of reports, and patrol distributions across time and routes. We shared the weekly activity report so that the participants could understand the status of our communitysourced campus policing campaign.

4.4 Task Execution Overview

Participants were required to put their smartphone in a smartphone mount installed on their bicycles. After running the CampusWatch mobile app, they started to patrol the campus according to their schedule. CampusWatch continually records video while the user is patrolling. When observing a local problem such as a safety risk or a case of public disorder, a user can also capture the event by simply touching the smartphone screen. After patrolling, the user should turn off the video capturing option and make an entry in their patrol diary. If there are captured events, they can report these events along with the automatically generated contextual information and add manual descriptions of the events.

5 FIELD STUDY DESIGN

We designed a four-week field study to examine the feasibility of communitysourced patrolling and to understand user behaviors such as task scheduling/execution and factors that affects user behaviors. In December 2016, we recruited 20 participants from a large technical university (17 males; age: M=24.9, SD=4.0) who were interested in promoting a safe and clean campus. Ten participants were undergraduate students and the rest were graduate students. Each participant was paid 200,000 KRW (approximately 180 USD) for participating in the four-week field study. We carefully set the rewards by considering the typical salaries paid for on-campus part-time jobs and the workload required by the CampusWatch activities.

Before starting the field study, all of the participants were given an introductory session. First, we explained how to make a patrol reservation on the Google Sheets we had created. We taught the participants how to use the CampusWatch mobile app and asked them to use it for four weeks whenever they were patrolling. We allowed them to participate freely in the patrol activities, but asked them to patrol 20 times per week, which is approximately four times per day on weekdays (an hour of bike riding). We let them join in the Facebook CampusWatch community. To encourage participation in the communitysourced patrolling campaign, we distributed two types of half-letter-size guidance notes requesting safety cooperation: one for illegal parking (of a car or bike) and the other for unregistered motorcycles (20 guidance notes for each). At that time, there was a series of campus-wide announcements asking students to register motorcycles on campus. The participants were asked to distribute the guidance notes when they observed appropriate occasions. At the end of the introductory session, we provided them with smartphone bike mounts to be installed on their bicycles. We carefully chose the bike mounts such that they would not hide the front-facing cameras while also securely holding the phone.

We collected the following data to deepen our understanding of user behaviors. First, we crawled the task reservation editing history on the Google Sheets. Second, we collected the CampusWatch app usage data, including the timestamped on and off history and patrol videos with contextual information such as dates, times, and locations (GPS), which were automatically synced to our cloud server whenever a user connected to the campus WiFi. Third, we collected reporting data. The reporting data included 30-second-long captured videos with contextual information such as dates, times, locations (GPS) information, and descriptions, as well as information pertaining to the usage of our privacy preserving tool, i.e., whether audio was removed from the video and whether the video was clipped.

After the field study, we interviewed the participants to understand their overall user experiences. The interview included a set of questions about task scheduling/execution and details about what affected their scheduling and execution decisions. To analyze the interview data, we recorded the interviews and then transcribed everything, performing a thematic analysis by iteratively developing emerging themes [6]. The two authors independently coded the transcriptions and

Table 2. Summary of the results

Task scheduling preferences	
Patrol reservation	when ready to patrol or early reservation in advance
Day preference	on weekdays rather than on weekends
Time preference	during daytime rather than at night
Route preference	around their own main locations (a dormitory or a laboratory)
Patrol preference	tendency to patrol adjacent routes at once
Event capturing and reporting behaviors	
Illegal parking (n=105)	
Unregistered motorcycles (n=51)	
Requests for fixing safety facilities (n=12)	
Speeding (n=5)	
Lane violation (n=4)	
Motorcycle drivers with no helmet (n=4)	
Unpermitted motorcycle deliveries (n=2)	
Factors affecting task selection and execution	
Uncertainty and busyness	
Social pressure (being with people)	
Weather and environmental restrictions	
Tiredness and fatigue	
User motivation and engagement	
Motivations	financial rewards, physical activity, social good, and pastime
Online community	to share information such as patrol activities
Guidelines and authority	to encourage active participation

iteratively discussed the identified codes until they reached consensus on the codes using ATLAS.ti 7. In order to gain an in-depth understanding, we examined our coding schemes and analyzed relevant quotes to build rich descriptions and apposite examples of participants' behavioral patterns such as task scheduling and execution behaviors and the various factors affecting the task scheduling and execution in the field study.

6 RESULTS

This section presents the results from our field study by answering the following questions about communitysourced patrolling campaign:

(1) How did our participants set their task schedules?
(2) What events were captured and reported?
(3) What factors affected their task selection and execution?
(4) What would affect participants' motivation and long-term engagement?

First, we explored how the participants set their task schedules by examining their temporal and spatial preferences as well as their task-level selections. Because we allowed our participants to manage their patrol schedules by themselves, they were able to choose their time slots and routes freely before doing a patrol. Second, we studied which events were captured and how people reacted to these events. Third, we examined the factors that affected their task selection and execution by analyzing their patrol history and interview data. Lastly, we investigated what would affect people's motivation and long-term engagement with the communitysourced patrolling. The key results are summarized in Table 2

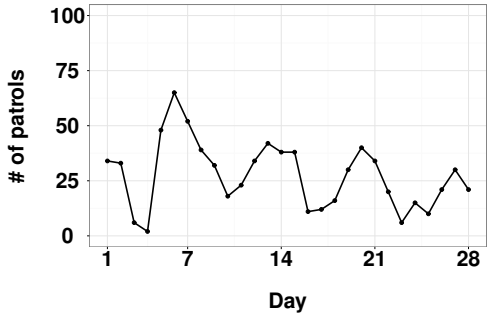


Fig. 2. The number of patrols across day

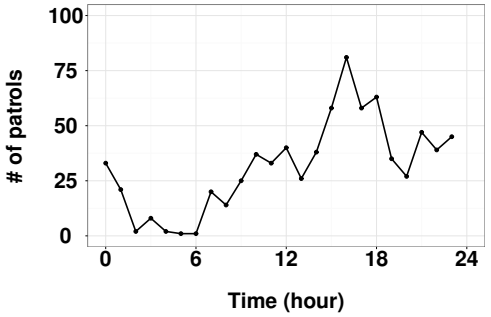


Fig. 3. The number of patrols across time

6.1 Task Scheduling Preferences

During the field study, a total of 770 patrols were performed by 20 participants, 27.5 times per day on average (SD=15.0). To deepen our understanding of the participation characteristics, we analyzed the participation logs (for example, scheduling logs on the Google Sheets and patrol logs on the CampusWatch mobile app) and interviewed participants. As a result, we discovered several participation patterns pertaining to task scheduling, including patrol reservation and spatio-temporal preferences.

6.1.1 Patrol reservation. Before the field study, we notified the participants that they could make patrol reservations whenever they wanted, but the patrol reservation should precede the patrol. In the interviews, we asked participants when they reserved the patrol schedule and found that there were two patrol reservation patterns: *Right before undertaking patrol* and *Reserving patrol in advance.*

Sixteen participants answered that they simply tended to check the patrol reservation sheet and select available routes immediately before undertaking patrol (that is, when they were ready to patrol). They then conducted the patrol. They did this because they were not sure in advance if they would be able to patrol due to unexpected events, such as a sudden meeting. The participants reported that it was difficult to predict when they would be able to go on patrol. For example, one participant reported, *"I did it right before patrolling because my schedule varied depending on the lab schedule. At the beginning of the field study, I reserved a patrol earlier, but sometimes I could not adhere to the schedule."* (P12) Another participant said, *"(I did this) five minutes before patrolling because I may not be able to patrol at that time if I made a reservation earlier due to an unexpected meeting."* (P20)

On the other hand, some participants reported that they generally made reservations in advance. They did this to book desired slots so that other participants could not patrol the routes at these times. This early reservation strategy was possible because they could be sure of their daily schedule. One participant commented, *"I made a reservation before going to bed. I worried that other participants would take the slots I wanted beforehand."* (P16) *"I was taking two classes and could therefore patrol between the two classes. I wanted to patrol at those times."* (P9)

6.1.2 Day preferences. We found that participants considered day and time conditions when they made patrol reservations. Participants engaged more actively in the communitysourced patrolling on weekdays (see Figure 2). Interestingly, the number of patrols on Fridays decreased to the level of weekends. Comparing the number of patrols from Monday through Thursday (weekday patrols) and from Friday through Sunday (weekend patrols), we found a significant difference ($p < .001$). The average number of patrols on weekdays was M=36.63 (SD=11.81), and the average number of

Table 3. Patrol distribution by route

	Route					
	ND	NL	WD	WL	ED	EL
# of patrols	103 (13.4%)	77 (10.0%)	130 (16.9%)	146 (19.0%)	168 (21.8%)	146 (19.0%)
Inter cover time (hour)	4.85 (SD=4.84)	5.79 (SD=5.26)	4.32 (SD=4.29)	3.94 (SD=3.99)	3.26 (SD=3.06)	3.61 (SD=3.03)

patrols on weekends was M=15.33 (SD=9.85). Our participants reported that they preferred not to patrol on the weekends, mainly because there was no regular weekend study schedule, such as classes or research work, and they wanted to rest at home rather than go out. Another reason was that they typically were not on campus due to other obligations on their schedules on weekends. As P2 noted, *"I used to patrol while going to work. I tended not to patrol on weekends because I did not need to go to my laboratory on the weekend."*

6.1.3 Time preferences. Figure 3 shows the number of patrol reservations against time of day. Most patrols were performed during the daytime rather than at night. During the exit interview, we asked about temporal preferences. From the responses, we noted that participants had two temporal patterns.

Many participants (n=15) tended to patrol by embedding the tasks into their daily routines. For example, they want to complete certain tasks while commuting, or wanted to go to some outdoor place. One participant responded, *"I had an on-campus part-time job related to pedestrian safety control. I used to patrol while going to that work."* (P17) *"I preferred to patrol on my way to some destination rather than intentionally making time to patrol to save time."* (P1) In some cases, participants (n=12) intentionally spared some time for a patrol as part of their daily routines, particularly when making transitions between tasks; these included work-related and non-work task switches as well. One participants noted, *"I mainly patrolled after lunch or dinner to help digest the food and to shake off sleepiness"* (P11).

6.1.4 Route preferences. We first analyzed participants' routes selection distribution to investigate whether the participants' selections were skewed. As shown in Table 3, we calculated the number of patrols for each route and found that the six routes were patrolled without any significant partiality during the field study. We also reported the average inter-cover time (ICT)—that is, the time elapsed between two consecutive patrols [63] for each route. This ICT value also showed that the six routes was patrolled relatively evenly, based on time. While mean ICT values are in the order of several hours, we can reduce the ICT by increasing the number of participants, or employing various incentive schemes, which will be discussed later.

Although the six routes were relatively evenly patrolled by 20 participants, we found that each participant had his/her own route preference. In Table 4, we present the participation rate, which refers to the number of patrols for each route of the entire sample of patrols, and an entropy measure (the lower the entropy, the higher the level of focus on the patrol). To deepen our understanding of route preferences, we asked participants about the routes on which their dormitories and laboratories were located during our exit interviews. As shown in Table 4, many participants tended to patrol routes around their own main locations (such as a dormitory or a laboratory) on campus. For example, P16 was the most active participant, but this participant only patrolled two routes, ED (60.24%) and EL (39.76%).

Table 4. Participants' route selection distribution

Participant	Route						Entropy
	ND	NL	WD	WL	ED	EL	
P01	0.20	0.21	0.18	0.25	0.07	0.09	2.46
P02	0.80	0.15	0.00	0.05	0.00	0.00	0.88
P03	0.32	0.27	0.11	0.08	0.11	0.11	2.37
P04	0.75	0.25	0.00	0.00	0.00	0.00	0.81
P05	0.00	0.01	0.00	0.04	0.46	0.48	1.30
P06	0.63	0.29	0.04	0.04	0.00	0.00	1.32
P07	0.15	0.13	0.35	0.38	0.00	0.00	1.84
P08	0.00	0.00	0.23	0.17	0.26	0.34	1.96
P09	0.38	0.21	0.21	0.13	0.04	0.04	2.23
P10	0.43	0.39	0.05	0.11	0.00	0.02	1.74
P11	0.00	0.00	0.22	0.35	0.20	0.22	1.97
P12	0.04	0.00	0.00	0.08	0.60	0.28	1.43
P13	0.00	0.50	0.00	0.10	0.00	0.40	1.36
P14	0.13	0.15	0.38	0.31	0.02	0.02	2.05
P15	0.04	0.06	0.44	0.44	0.00	0.02	1.58
P16	0.00	0.00	0.00	0.00	0.60	0.40	0.97
P17	0.13	0.06	0.38	0.00	0.31	0.13	2.06
P18	0.06	0.00	0.32	0.61	0.00	0.00	1.21
P19	0.00	0.00	0.14	0.14	0.34	0.37	1.87
P20	0.00	0.00	0.13	0.25	0.44	0.19	1.85

We then asked participants why they chose the routes they patrolled. We found that participants tended to patrol routes, which require less time and/or physical effort. Some participants preferred to patrol closer routes rather than those further away to save time. One participant stated, *"My laboratory is located in the east area, so I usually reserved and patrolled east routes. If someone already made a reservation for east routes at the time I wanted, I reserved the next time slot rather than patrolling other routes at that time."* (P8) On the other hand, some participants preferred to patrol easy routes. For example, each route had different characteristics, such as slopes and different road conditions. One participant commented, *"There are uphill roads in the north and west areas. Therefore, I liked to patrol the east area because it is only flatland."* (P16)

6.1.5 Tendency of grouping patrol routes. Along with the route preferences, we found that many participants tended to patrol adjacent routes simultaneously. The average number of routes simultaneously selected was 2.17 (SD=1.29). Participants attempted to group multiple adjacent routes and patrol them together in various ways. For example, some participants patrolled two routes in one time unit (30 minutes). In addition, some participants attempted to patrol more than three routes across two time units (an hour). Responding to the question asking about their patrol scheduling, one participant stated, *"I preferred to go on patrol four times at once from a laboratory when it became warm at daytime."* (P8) Another participant said, *"When I went to a part-time job, I patrolled two routes at once and when I came back from the part-time job, I patrolled these two routes again."* (P15)

6.2 Event Capturing and Reporting Behaviors

A total of 770 patrols were performed, and a total of 183 events were reported; four participants reported no events. Participants patrolled 1.38 times per day on average (SD=1.88), and patrols occurred 38.65 times (SD=25.17) per week during the field study. Participants reported 0.32 events on average (SD=1.16) per day.

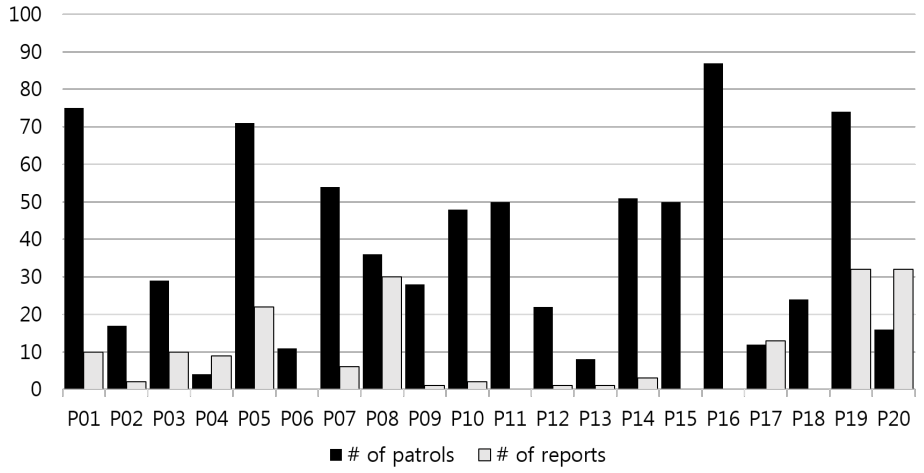


Fig. 4. Participation distribution

Two of the authors manually examined the 183 reported events using an affinity diagramming technique to develop a classification scheme iteratively for safety risks and incidences of public disorder. We found that these reports were mostly about traffic-related safety risks, such as illegal parking (n=105) and unregistered motorcycles (n=51). The remaining reports included requests for fixing safety facilities (n=12), speeding (n=5), lane violations (n=4), motorcycle drivers with no helmet (n=4), and unpermitted motorcycle deliveries (n=2).

However, we found that the number of patrols was not closely related to the number of reports, as shown in Figure 4. For example, P16 never created a report despite the fact that he was the most diligent participant. On the other hand, P20 reported 30 events while patrolling 16 times. To understand the causes of this report distribution, we asked participants what they focused on while patrolling. From these responses, we discovered that some participants had their own focuses based on their experiences, such as traffic risks and loud talking on the street at night—these are all included in our patrol diary checklist. For example, one participant said, *"I mostly focused on finding cars in car-free zones because it was annoying to people and cyclists."* (P9) Another participant said, *"In a west dormitory, people frequently made loud noises on the street at night. I really wanted to see these cases, but I could not find the cases while patrolling."* (P19)

6.3 Factors Affecting Task Selection and Execution

In the field study, we found that participants typically set their own patrol schedules not long before performing the patrol task (ranging from a few hours earlier to immediately before the patrol). They would therefore only select time slots and routes that were available at the time. Other participants scheduled their tasks a day in advance to secure what they perceived as good slots. Our analysis of scheduling sheets revealed that on average 2.6 reserved patrols per day were no-shows. In addition, some participants did not schedule any events for some period of time. In the following sections, we present the major reasons why patrolling tasks were not conducted. These were (1) uncertainty and busyness, (2) social pressure, (3) weather and environmental restrictions, and (4) tiredness and fatigue.

6.3.1 Uncertainty and busyness. Participants reported that unexpected work-related events hindered their patrol scheduling and performing; for example, a meeting request from a professor or a friend's visit. For these participants, the unexpected new event took priority over a patrol reservation if the new event was considered to be more important for them. For example, P1 complained that he could not patrol due to unexpected work-related events: *"Due to an unexpected meeting or a call from my advisor or sudden business travel, I could not patrol."* Another participant noted, *"My friend dropped by my office; therefore, I could not patrol even though I had a patrol reservation at that time."* (P14)

Another reason was that the participants failed to predict the ending time of what they were doing. Many participants tended to make a patrol reservation immediately after a daily routine, such as dinner. However, in reality, it was often difficult to predict the exact finishing time. If this occurred, they changed patrol time slots or, in some cases, they failed to show up. For example, P9 said he sometimes miss patrol time due to uncertainty of his schedule: *"Usually I patrolled after dinner but sometimes I missed the patrol times because I waited for a long time in line at the cafeteria."* P8 also pointed out uncertainty: *"I schedule my patrol based on my estimation when the meeting would be finished, but it lasted longer than I expected. I then changed my patrol reservation to a later time slot."*

We found that some participants did not mark patrol reservations on the reservation sheet for several days during the field study. We asked participants if there were any particular reasons why they did not patrol for a while. They answered that these absences were mainly due to full work schedules, with events such as research deadlines, business travel, and conferences, as well as personal activities. One participant stated, *"I had to participate in a conference and so could not patrol for a week."* (P16) Another participant said, *"It depends on the lab schedule. I could not even go home on time for a few days because I was too busy with work. I could not patrol during that period."* (P12)

6.3.2 Social pressure (being with people). In our daily routines, we spend a lot of time with other people. As far as being with people, participants tended not to patrol when they were in the company of their friends or when their routes differed from the patrol routes. They preferred to be with their friends rather than patrolling. They commented that they would feel regret if they left a companion alone due to patrolling. P10 felt that it might be rude leaving a friends due to patrolling: *"I occasionally had lunch with a friend. I thought I would feel bad if I say to my friend that I'll be leaving them alone only to patrol. Therefore, I delayed my patrolling and selected a later time slot."*

6.3.3 Weather and environmental restrictions. Since our communitysourced patrolling requires physical effort to perform patrols, weather and any other environmental conditions are critical. Our field study was conducted in the middle of winter. The weather was very cold, and there was sometimes snow on the streets. Many participants reported that the weather was too cold to finish their routes successfully. In addition, participants occasionally felt danger while patrolling on a bicycle, particularly when they were on icy roads (despite snow removal), or when it was snowing. One participant noted, *"When it was too cold, I felt that my hands were freezing without gloves. I gave up on patrolling when I forgot to bring my gloves."* (P7) In addition, some participants did not even reserve a patrol when the weather was too cold, especially when it was snowing.

6.3.4 Tiredness and fatigue. Our participants commented that there were tiring moments, such as the end of a week (i.e., Friday), and/or the end of a long work period. In such cases, they had difficulty in carrying out the reserved tasks. P7 commented, *"This occurred due to my experiments. If I finished work after midnight, I sometimes felt very tired, and I had difficulties in performing scheduled patrolling."*

6.4 User Motivation and Engagement

We report participants' major motives for participating in communitysourced patrolling campaign and then illustrate two major aspects that are closely related to long-term community policing engagement, namely online community and rules/authority.

6.4.1 Major motives. From our interview analysis, we found that our communitysourced patrolling campaign engaged the following motives: (1) intrinsic motives (like the activity itself, keeping good health, useful way of spending spare time), (2) social motives (socializing, social pressure, and social goods), and (3) financial motives (monetary rewards).

Overall, four participants commented that financial rewards were the sole reason (all low achievers, P9, P12, P18, P20) and five users were motivated only by non-financial reasons (P10, P11, P14, P15, P17). The rest of the users indicated a mixture of financial rewards and other motives. Interestingly, the top five achievers were all financially motivated (P1, P5, P7, P16, P19). At the same time, they liked biking (P1, P19), and/or thought that community policing was a socially good activity (P5, P7, P19), and/or was considered as good exercise (P5, P16). Some participants thought that community policing was a useful way of spending their spare time (P14, P15, P17). Some participants were motivated due to social pressure (via the online community) and socializing with friends; for example, there was a pair of participants who patrolled the routes together.

6.4.2 Online community and activity reports. Prior works showed that an online community can be used effectively to engage participants in crowdsourcing systems [14, 45]. To deepen understanding of how an online community engages participants in a communitysourced patrolling campaign, two authors manually selected typical event videos among the reported events and shared these events with detailed information, including the reported time, route, and the report's description with the Facebook group. A total of 31 reports were shared during the four-week field study. Participants reported that the posts helped them understand the types of issues that were occurring and why they were problems. They also said that this process prompted them to participate more actively. One participant stated, *"It stimulated me to patrol more diligently. I became more aware of the posted events and then started to focus on those types of issues while patrolling."* (P16) In addition, participants felt pleased when their reports were posted on the closed Facebook group. P4 noted, *"When my report was selected and posted on the group, I felt great because I thought my contribution was acknowledged,"* and P8 said, *"I felt pleased to see my report (on the Facebook group) because it looked like a compliment. My report was considered valuable enough to share with others."*

We also provided a weekly activity report that included visualized participation statistics, such as the number of patrols and reports by each participant, the types of reports, and the patrol distributions over time and routes. We found that, for several reasons, the weekly activity reports encouraged participants to continue to participate. Some noted, *"All participants could see the other participants' patrol statistics. I felt at that time that I should go on patrol as I had reserved because other participants were watching."* (P16); *"I could see exemplary participants. They made me participate more actively."* (P8) Nonetheless, some participants reported that they were comforted to find that there were other participants who had fewer patrols compared with others. On the other hand, P14 noted, *"I could see two participants who had low contributions. This demotivated me."*

6.4.3 Guidelines and authority. We put a call button in the mobile app so that participants could easily reach out to campus security. However, only two participants reported that they made such calls. The other participants noted that they thought it would have to be a very serious event to call the campus security service, and they did not witness problems that were serious enough while patrolling. Some participants thought their call could be considered a bother if the events were not serious. One participant noted, *"There was no serious situation such as an accident and a violent*

fight. I thought I could call the campus security service only for serious situations." (P17) Another participant stated, *"I thought I would be sorry to call the campus security service to ask them to deal with illegally parked cars late at night."* (P7)

In the introductory session of the field study, we distributed two types of guidance notes requesting safety cooperation with regard to illegal parking and unregistered motorcycles. Participants were worried that they would face the owner of an illegally parked car or an unregistered motorcycle and that the owner may complain about the guidance notes. Participants did not want to encounter these types of uncomfortable situations and felt that they did not have enough authority. One participant worried, *"Because this student campaign was not official policing [by campus security], I was concerned that people would argue with me. Thus, I hoped I would not run into them."* (P18) Indeed, the campus security staff had similar concerns about arguments with students, as they also have lack authority to issue real tickets for violations, and thus, tend to avoid proactive engagement unless it is really needed for safety reasons. Another participant was also concerned, *"It was just a student campaign, so I did not want to make other people uncomfortable. I would do it if I were an actual campus security employee."* (P20)

7 DISCUSSION

In this work, we designed a novel communitysourced patrolling campaign in a campus context, in which participants performed location-based micro-tasks with mobile devices. Our work belongs to a class of participatory mobile sensing because the collective patrolling task requires participants' proactive physical work, such as continuous video recording and event reporting using mobile devices. In particular, our work applied the concept of communitysourcing—an alternative crowdsourcing (or crowdsensing) approach requiring specific knowledge in a community—in our patrolling campaign design. Participants had local knowledge and experience, which can be effectively used while performing patrolling tasks to examine potential issues in a community. Participants could use their own focuses while patrolling based on their local knowledge and experience. This novel form of communitysourcing allows us to explore a new design space in developing other kinds of social-purpose physical collaborative activities for a community. In the following section, we discuss a number of key aspects of the communitysourced patrolling, including: consideration of user preferences and contextual factors for scheduling; sustaining user participation; fostering online communities; setting task execution guidelines; and responding with privacy concerns. Our findings will allow researchers and practitioners to explore better orchestration of community members by considering their preferences and contextual factors, leading to mobile tools that can achieve more effective community policing.

7.1 Personal Preferences and Contextual Factors

7.1.1 Spatio-temporal preferences. Our participants clearly showed their personal spatio-temporal preferences. Most of them had preferred time slots and routes, which were largely dependent on their daily routines and corresponding mobility patterns. This behavior matches the results of prior studies of crowdsourcing for physical tasks such as geographical task selection [57, 58], and location-aware task recommendation [49]. In communitysourced patrolling, spatio-temporal coverage (e.g., inter-cover time) may be critical to ensure high performance of community policing because long time gaps between two consecutive coverage periods might miss urgent safety issues. This finding can be used to leverage physical crowdsourcing campaign, for example, by recruiting an enough number of participants that can satisfy spatio-temporal coverage, with consideration of their schedules such as daily routines and corresponding mobility patterns.

7.1.2 Leveraging task reservation and execution. We found that the factors affecting task selection and execution included personal, social, and environmental aspects, that is, uncertainty and busyness of work schedules, tiredness and fatigue, presence of other people, and bad weather and environmental conditions. In task reservation, many participants tended to prefer opportunistic scheduling by signing up for available tasks whenever they were (or were soon to be) available; only a few users scheduled further in advance. In task execution, participants sometimes could not carry out their patrol reservations due to busyness or unexpected events, failure to predict ending times of current work, or being with a companion. Some participants mentioned that they were very mindful of current weather conditions (especially snow and rain), checking whether it was safe to do their work. By conducting a real-world four-week field deployment, our results significantly extended prior work on crowdsourcing that has investigated factors affecting a user's task selection and execution [24, 29].

Minimizing long-term empty patrol time and routes due to a lack of voluntary task scheduling and execution would be one of the ultimate goals to explore. In our current system design, a task selection is only "pull-based" in that users choose their preferred time slots/routes. Alternatively, we can incorporate "push-based task allocation" by leveraging context sensing and data mining [27, 29, 49]. By tracking users' mobility and task execution patterns, we can automatically assign or recommend a patrol task to the appropriate candidates. For example, the system can select a set of users who have a spatio-temporal preference for a given time slot and route, or those who are currently close to the route, as in on-the-go crowdsourcing [28, 28].

7.2 Sustained User Participation

Prior studies found that monetary motives are considered more important than intrinsic motives [13, 26, 32, 48]. In addition, research from psychology and behavioral economics shows that monetary incentives may crowd out intrinsic and social motivators [9]. Our results, however, showed that the participants had diverse user motives: a majority of the participants were motivated by the financial rewards, but there were other participants who had different motives, such as social goods and personal interest [2]. For example, when analyzing high performers' motives, we found that positive attitudes towards physical activities and social goods can be critical for successful communitysourced patrolling. This result concurs with Kobayashi et al.'s work in that social good or altruistic motivations are important factor in social-purpose crowdsourcing campaigns [31]. This finding can be considered to engage participants in sustained community patrolling; e.g., when recruiting participants, their motivation to participation could be considered to elicit better contributions.

An alternative way of enabling sustained user participation is to leverage gamification [12], or game with a purpose (GWAP) [62]. For example, we can introduce Pac-Man-like gamifiation such that for each unit distance, a user is awarded a certain number of points (a la eating pac-dots). The system can dynamically adjust points such that subareas requiring better coverage, or less preferred by users can be better explored; this concept is similar to steered crowdsensing [27]. Furthermore, it is possible to fully design an game with a purpose. In Human Pacman [10], a mobile user being part of a game world navigates a real-world to acquire special bonus (gifts) but avoid ghosts (enemies), whose positions can be controlled for spatio-temporal coverage. Similarly, in a Pokemon GO like game, virtual items can be distributed based on spatio-temporal coverage requirements.

7.3 Fostering Online Communities for Community Policing

Prior studies revealed that online communities can be used effectively to promote performance in crowdsourcing systems. For example, Erete et al. [14] showed that the interaction of community members in an online community affects their offline behavior in crowdsourced crime information

sharing. Park et al. [45] suggested that online communities help community members to build relationships, share information and advice, and regulate online and offline norms in mobile crowdsourced policing.

In our work, we created a private Facebook group and selectively shared participants' reports. We also allowed the participants to leave comments freely on any video posts. Participants mentioned that it helped them understand what kinds of safety risks and public disorders existed and why they were problematic. In addition, we shared a weekly activity report that included visualized participation statistics on the private Facebook group, and this helped them to appreciate their contributions with the other participants. These findings show that fostering an online community can be effectively applied to encourage participants' contributions toward communitysourced policing, as its purpose is to keep the community safe and healthy, not simply completing a given task to receive a reward.

In that sense, our system design should consider facilitating a sense of community [38]: participants matter to the community, and they should proactively fulfill the needs of community policing. From the urban social space perspective [35], communitysourced patrolling helps create a parochial space that provides a sense of commonality among local community members in their neighborhood areas—a parochial space is typically situated somewhere in between the public and private spaces. Furthermore, communitysourced patrolling spanning over physical and online spaces provides opportunities for facilitating prochialization, which is defined as 'the process of creating, sharing, and exchanging [locational, social] information to contribute to a sense of commonality among a group of people in public space' [23]. System design can specifically leverage a sense of community by facilitating prochialization; for example, visualizing community activities, promoting social norm invention, and reinforcing participation with badges and ranks [41, 44, 47].

7.4 Micro-Task Guidelines

We provided patrolling task guidelines in the introductory session and asked the participants to complete a patrol self-checklist at the end of each patrol. Furthermore, we illustrate how to reach out and collaborate with campus security services as part of community policing to resolve issues. Our design was based on prior studies; a lack of detailed guidelines may result in low task quality [1, 34]. Despite such guidelines and checklists, some participants still commented that they wanted to have more elaborated instructions; for example, they were not sure about what was the proper level of seriousness to capture/report an event or to call the campus security service. Fortunately, our online community helped the participants to learn from one another, thereby promoting social learning; i.e., participants can have better awareness of social norms via online interactions [11].

7.5 Lessening Privacy Concerns

The video evidence is critical in dealing with local issues. In our study, we allowed participants to capture video evidence while patrolling. The video evidence, however, may include private infringements, such as a person talking to himself/herself, having a conversation with someone, or bystander's privacy as documented in prior studies [16, 45, 46, 55]. In our study, we provided a privacy-preserving tool for audio muting and video cropping to lessen the burden of privacy concerns. We found that participants were concerned about their own speech, such as singing and talking to themselves, as in prior studies [45]. In addition, some participants worried that bystanders would be displeased if they became aware that they were being recorded—in practice, this is less likely given that most vehicles are equipped with dashcam videos in South Korea.

Regarding these privacy issues, we expect that providing privacy guidelines and privacy-law information, such as the Fair Information Practices (FIP) standards can help reduce the burden

of privacy concerns [40]. In addition, Park et al. [46] revealed that levels of trustworthiness in managing personal information of shared dashcam videos vary with who is responsible for the data management; people mostly trust the police. We believe that managing any privacy-sensitive data with the security authorities (e.g., campus security team or police) can lessen the privacy concerns in facilitating community policing.

7.6 Beyond Campus Contexts

Our work showed the feasibility of communitysourced policing using mobile devices in which a group of people can patrol an area of interest in a loosely coupled way and share their activities in online communities. The CampusWatch campaign design and associated tools (e.g., micro-task design, task scheduling, and mobile video capturing) can be applied to other kinds of social-purpose physical collaborative activities such as community policing in a city, disaster recovery/relief, and citizen science [4]. In a city, a local police department can complement a neighborhood watch program by organizing a group of users who contribute street videos using their vehicles such as bicycles and cars. Likewise, in a disaster recovery scenario, a group of users can easily coordinate themselves with local authorities to collect information and provide safety and public order services. Overall, our scheduling tool will help people to easily locate a micro-task that they can fulfill, and the mobile app will allow them to review their duties and capture information on the move.

7.7 Limitations and Future Work

The generalizability of this work is limited in that our work considered only a specific community policing activity in a campus setting in South Korea. Further studies are needed among other user populations over a longer period of time in order to generalize the results.

In our field study, the campus security service acknowledged and helped our campaign but were unable to actively participate due to their lack of human resources. In future work, the campus security could join in the communitysourced policing activity to further encourage participation. Our results showed that some participants considered not calling campus security, because they considered it a bother if the events were not serious; other participants felt that they did not have enough authority to deal with events directly, worrying that people would argue with them; some participants wanted more detailed guidelines. Collaboration with the campus security service would overcome this limitation and encourage participants' active engagement. For example, participants can ask campus security for detailed guidelines when they face safety and public order issues, or they can call to ask them to deal with an issue directly, without feeling that they are being a nuisance.

In our work, because of the university campus situation in which students prefer payment for long-term engagement, and in light of the many available part-time campus jobs, we paid our participants. Participants were paid in advance, to minimize the effects of financial reward. In future work, various other rewards can be considered to better motivate active participation. Our results showed, for example, that some students were demotivated because they found that other participants contributed less but were paid the same. To resolve this issue and foster greater participation, individual task-based incentives could be considered. As mentioned earlier,, gamification could also be used effectively to encourage participation and achievement (patrolling all routes, for example, or patrolling every day for a week) or rankings (best contributor on a route each week).

Our results showed that participants tended to check the patrol reservation sheet and select available routes immediately before undertaking a patrol, due to their uncertainty about their schedule. We could, then, reflect participants' contextual information and recommend proper timing and routes. For example, a system could read participants' schedules via Google Calendar and then

recommend possible tasks. An on-the-go approach could also be used to recommend a task to participants by notifying them of available situations they are likely able to contribute to tasks [28].

Our work made a first step towards exploring mobile, location-based community policing systems. Future work should deepen our understanding on how mobile, location-based community policing systems affect people's perceptions and behaviors related to interacting with everyday space and places. Several focusing lenses for user studies include Luke's concept of 'phoneur' [37], depicting a dystopian view of mobile phones that drive consumerism-centered urban lifestyles, and Saker's concept of 'playeur' [50], stating that people's intentional playful interactions with locative media facilitate co-construction of their relationship with space and place, including 'Image of place' [15] and 'self-identity' [52]. For example, recent studies identified that a location-based mobile game play can create novel perception and engagement with spaces and places [42], and there is relationship between self-identity and expressions of territoriality in mobile location-based social networks [43]. It would be interesting to perform in-depth user studies with such focusing lenses to understand how communitysourced patrolling influences community members' perception and engagement with neighborhood spaces and places.

8 CONCLUSION

Our goal is to design a communitysourced patrolling campaign that allows community members to schedule and execute their location-based tasks and that leverages social media to share local safety and public order issues. Towards the goal, we developed a supporting systems, including a task scheduling tool, a mobile capturing and reporting app, and an online community. Our four-week field study on a university campus clearly showed the feasibility of communitysourced patrolling. Our results revealed several key insights that are critical for system design: unique long-term user behaviors such as task scheduling preferences, event capturing/reporting behaviors, key factors affecting task selection and execution, and major user motives. Our findings can be applicable to designing other kinds of social-purpose physical collaborative activities, including citizen science and disaster recovery.

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