Investigating Mobile Users' Ringer Mode Usage and Attentiveness and Responsiveness to Communication

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ABSTRACT
Smartphones are considered to be "always on, always connected" but mobile users are not always attentive and responsive to incoming communication. We present a mixed methods study investigating how mobile users use ringer modes for managing interruption by and awareness of incoming communication, and how these practices and locales affect their attentiveness and responsiveness. We show that mobile users have diverse ringer mode usage, but they switch ringer modes mainly for three purposes: avoiding interruption, preventing the phone from disrupting the environment, and noticing important notifications. In addition, without signals of notifications, users are less likely to immediately attend to notifications, but they are not less responsive to those they have attended. Finally, ringer mode switches, attentiveness, and responsiveness are all correlated with certain locales. We discuss implications from these findings, and suggest how future CMC tools and notification services take different purposes for using ringer modes and locales into consideration.

Author Keywords
Mobile; availability; responsiveness; notification; ringer mode, awareness; computer-mediated communication; SMS.

ACM Classification Keywords
H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces – Computer-supported cooperative work

General Terms
Human Factors; Design; Measurement.

INTRODUCTION
The growing adoption of mobile smartphones has dramatically changed the way we interact with computing technology and how we communicate with other people. The "always on, always connected" promise of mobile phones means that we can interact with information and with other people in an almost unlimited number of situations and contexts. This accessibility that the mobile smartphone enables also brings with it challenges in managing the potential for interruption and disruption. Just because we have a mobile device that is always on and always connected does not mean that we are always available for and aware of incoming communication. While mobile devices accompany their users most of the time, users only intermittently pay attention to their devices [5], depending on where they are and what they are doing [6]. Even when users are aware of or have attended to incoming communication, there are additional decisions of whether and when to respond [1].

Many computer-mediated communication (CMC) tools currently include availability signals (e.g., online, away, green, yellow, or red indicators) to help senders decide whether this is a good time to make contact. Research has shown that such a signal can help both senders and recipients coordinate communication [10,21]. But these efforts are based on research largely focused on work-based office settings (e.g.[5,7,9]). Mobile devices have brought availability and interruption issues into more diverse and unpredictable environments, making it harder to predict mobile users' availability for communication and harder to provide reliable and accurate signals of their availability.

To address this challenge, we seek to gain a better understanding of how mobile users manage interruption by and awareness of incoming communication in their daily lives, and how their attentiveness and responsiveness to incoming communication is influenced by such management practices. Specifically, we seek to understand mobile users' ringer mode usage, quantitatively and qualitatively, as it is the major function of mobile phones for managing the saliency of phone notifications. Then, we examine their attentiveness and responsiveness to incoming messages in different ringer modes and at different locales.

We conducted a two-week empirical study with 28 Android smartphone users. To collect their real usage of the phone for communication, ringer mode changes, and qualitative experiences, we employed a mixed methods approach

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including phone logging, diary study, interviews, and post-study survey. After reviewing related work, we describe the details of our study and design implications learned from it.

RELATED WORK

While much of the prior availability research has focused on work office settings, some recent studies have focused on mobile platforms. Rosenthal et al. [18] used an Experience Sampling Method (ESM) to acquire training data to develop a model for predicting phone interruptibility that automatically silences the phone when the user is uninterruptible. Pielot et al. [16] built a model to predict user's attentiveness to instant messages using features including user's interaction on the notification center, screen activity, ringer mode, and sensors. Mihalic & Tscheligi [13] explored how message type, mood, and communication channel and content affected how users would like to be notified of contact requests on their mobile phone. Fischer et al. [8] used ESM to examine how content type and time of delivery affect receptivity to SMS interruptions, and concluded that the content of a message affects receptivity more than time of delivery. Poppinga et al. [17] and Sarker et al. [20] both used location, time, and sensor information to build a model for predicting opportune moments to deliver notifications/intervention tasks. Pejovic et al. [14] used a similar approach with additional features, including emotions and engagement, to implement an intelligent prompting mechanism. While these previous studies suggested clues to predict when users would be interruptible, attentive, responsive, and receptive, respectively, our study builds on prior work to provide insights into mobile users' current practices of using ringer modes to manage interruption by and awareness of incoming messages and identify how ringer modes and locales affect their attentiveness and responsiveness.

Prior research has also explored sharing awareness and context on mobile devices. Ljungstrand [12] identified the need for sharing contextual awareness among mobile phone users to help judge their availability for receiving a call. Schmidt et al. [21] explored sharing context information to prevent inappropriate interruption, and De Guzman et al. [10] studied contextual information that helps a caller decide when to initiate a call. While these works explore sharing context among mobile users to coordinate communication, we focus on *understanding* mobile users' attentiveness and responsiveness to notifications.

Recent research has started investigating how mobile users attend to their phones, with a primary focus on notifications. Sahami et al. [19] showed that mobile users generally attended to notifications within a minute, but important notifications such as of incoming messages were attended to more quickly. Pielot et al. [15] obtained similar results, but further found that mobile users could attend to notifications within several minutes regardless of ringer mode. Ferreira et al. [6] identified users' micro usage (shorter than 15 seconds) on mobile phones and discovered that 60% of them were reportedly triggered by notifications. While their work documented why, how, and how fast mobile users attend to and deal with notifications, respectively, we explore how and why users are able to maintain this general attentiveness despite ringer mode, and further show how ringer mode and locale affect attentiveness and responsiveness more in depth. In addition, we focus on communication activities of any duration instead of only micro usages.

RESEARCH METHODS

We used a mixed methods approach, including phone logging, user diaries, surveys, and interviews to understand mobile users' ringer mode usage and attentiveness and responsiveness to incoming communication, and to uncover reasons that prevent mobile users from reading notifications. We focused on applications for interactive communication, including phone; SMS texting; Mobile Messaging Apps (MMA), such as WhatsApp, Viber, Line, Facebook Messenger; Voice over IP (VOIP) calling; and video chat, such as Skype and Google+ Hangouts. Our data analysis on communication events narrowed in on SMS messages (details explained in the result section). The study was conducted from July through August 2013.

Study Procedure

We recruited Android users living in North America who had a full-time occupation. We posted recruiting messages on several online Android forums and Android user groups in social media. Participants were instructed to complete the entire study by running our Android Logger app on their phone over 14 days and were provided with a $75 gift card gratuity. We anonymized recorded contact names collected in the data by hashing the contact label and phone numbers.

However, since contact information was important for us to identify responding messages, after the 14-day collection period, we asked participants to provide user-defined labels (e.g., wife, friend, colleague) of their frequent contacts during the study period. After labeling their frequent contacts, participants were given links to visualizations that showed their daily phone use rhythm and frequent contacts with the communication media they used with each of those contacts. In addition, they were provided a heat-map that showed where communication activities were detected. On the map, they were instructed to add labels for "locales" of highly concentrated areas of activity. This allowed us to convert GPS coordinates and nearby areas into semantically meaningful locales for data analysis. A web-based, post-study survey collected their qualitative feedback and experience in managing ringer modes, communication activities, and phone notifications. Based on the data collected, we invited a subset of participants (14) for interviews, who received an additional $25 gift card.

The Android Logger App

We developed an Android logger app that: 1) monitored communication-related events on participants' phones, 2) captured a context snapshot when detecting a targeted

event, and 3) delivered a daily diary for participants to provide more context about specific events. Logged events included sending and receiving outgoing SMS and MMA messages; and initiating, receiving, and ending phone, VOIP, and video calls. To obtain the list of communication apps to monitor, we surveyed the top communication apps in the Android Market and asked participants to name all communication apps they used on their phone. In addition, we monitored ringer mode change events and actions demonstrating users paying attention to their phones, including waking up/unlocking the phone and acting on notifications, since mobile users can already preview the content of certain incoming messages through these two actions.

To detect events and actions on the phone, we used the Accessibility Service API in Android to monitor users' actions on their phones. The Accessibility Service broadcasts user events such as clicking, typing, swiping, notification viewing, and many others. This stream of data within the context of specific apps enabled us to detect exactly when participants received, attended to, and acted on notifications; composed and sent messages; and accepted and declined a VOIP call using a particular app.

When detecting an event of interest, the logger app recorded a context snapshot of the phone. The contextual information included location, activity recognition (provided by Google activity recognition service API [22]), sensors, network, calendar, phone status (ringer mode, screen on/off), and the currently running application. Activity recognition includes five states: still, tilting (significant change of angle relative to gravity), in a vehicle, biking, and on foot. One major challenge of logging context snapshots on mobile phones is balancing power consumption and recording accurate information [11]. Because participants needed to run the logger app at all times for 14 days, we recorded contextual snapshots only when detecting a targeted event instead of continuous tracking.

Our diary aimed to obtain qualitative feedback around detected events, which included missed or declined phone calls, periods with unread notifications for over an hour, and ringer mode changes. To obtain these inputs, we devised an event-based diary that included a list of questions based on the logged events in the past 24 hours for participants to respond at the end of each day. We did not deliver event-based diaries to participants at the moments when events were detected (known as an event-based ESM [4]) because our targeted events focused on missed notifications and communications. Although ESM studies are well known for capturing real-time and in-situ responses, when users are not available to respond to communication, they also cannot respond to an ESM questionnaire [3,4]. In the event-based diary, we limited each question to no more than three randomly picked events logged within the past day to lower participants' burden.

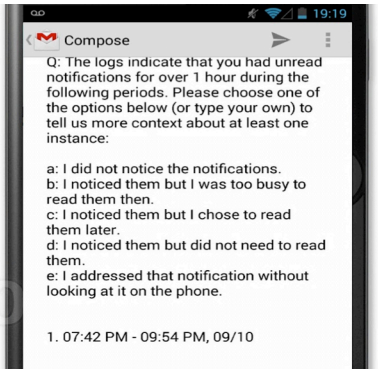

Figure 1. This daily diary question asks participants to provide more context about the periods when they did not read notifications for over an hour.

These events were listed in reverse chronological order (the most recent first) with a timestamp next to it, as shown in Figure 1. The events we asked included ringer mode changes, missed calls, and intervals where notifications were not read for more than an hour. Participants were asked to select the reason for the lapse in reading notifications and add more context. The diary also asked whether participants were interrupted by their phone and whether they missed a communication on their phone that day. By default participants received a diary notification at 9:30 PM. They could configure the delivery time to their preference, or directly open the diary whenever they wanted to submit it. Clicking on the notification brought them directly to an e-mail compose window to record and send in their responses.

Participants

We screened for participants that were over 18 years old, had a full-time occupation (including a couple of graduate students), used an Android smartphone for at least two months, did not have a substantial travel disturbance during the study period, and used the phone at least daily for texting and at least weekly for calling. We also attempted to balance the participants for gender and get a range of geographic areas and ages. All participants used an Android phone with version 4.0 or above (but below 5.0) during the study. While we started the study with 38 participants, 28 successfully completed the study (16 male, 12 female). There were several reasons why participants dropped out of the study: something happened to their phone, our logger system did not work accurately with their phone, or they did not comply with responding to the diary prompts. Most of the participants who successfully completed the study were in the 18-35 age range (25 out of 28). We refer to these participants as P1-P28 throughout this paper.

DATA ANALYSIS

Our analysis primarily focused on participants' availability and interruption management practices and their attentiveness and responsiveness under different ringer modes and locales. For the former, we mainly analyzed data from diary entries, survey responses, and interviews. We

used descriptive stats on survey results; for qualitative feedback we reviewed diary entries and responses to open-ended survey questions and interviews, and open-coded them to identify recurring themes. In the survey and interviews, we learned about participants' overall strategies of and reasons for using each ringer mode. In the diary, we gathered 368 valid responses to ringer mode change events, where participants reported reasons why changes were made, and 832 valid responses to reasons for not reading notifications for more than an hour. We logged 1,107 ringer mode changes and analyzed them to look for patterns.

For attentiveness and responsiveness we only analyzed SMS messages because we found a disparity between incoming and outgoing MMA in our logs (shown later in the descriptive result). We expect that the main reason for this disparity is that our phone logger counted notifications of all incoming MMA messages, but participants might respond on another device (tablet, computer), which would not be counted in our log. Because this disparity would bias the result, we chose to only include SMS messages into the analysis of attentiveness and responsiveness.

To analyze attentiveness and responsiveness to incoming SMS, we grouped any SMS message between "the same contacts" within 6 minutes of each other together as part of a conversation. This allowed us to look at the message threads per contact, and know when a message is a response to the same person. The 6-minute threshold was chosen because prior work [2] found that the average time between text messages was 6 minutes. We also distinguished two scenarios: receiving *new messages* (i.e., no other message within 6 minutes before the current message), and receiving *chat messages* (i.e., at least one message exchanged within 6 minutes before the current message). We separated them out because we assumed users' attentiveness and responsiveness to chat messages are higher than to new messages because they may expect to receive more incoming messages when they have been engaged in a chat.

As mentioned earlier, we logged *waking up/unlocking the phone*, *actions on notifications* (pulling down the notification bar and selecting notifications), and *composing outgoing messages in the same communication app that generated a notification*. These are three user-initiated actions that demonstrate paying attention to the phone in version 4 Android smartphones or above. We used intervals between these "attending actions" to the phone to measure *general attentiveness*, i.e., how often participants attended to the phone, and thus, how aware they were of the events on the phone. We computed intervals and compared among intervals using the 6-minute threshold, which were: <1 minute, 1-6 minutes, and > 6 minutes. We also measured specific attentiveness to notifications generated by incoming SMS to examine how promptly participants attended to the phone after receiving incoming SMS (referred to as *attentiveness to SMS*). We computed the intervals between receiving a notification of incoming SMS and initiating the first attending action after receiving that notification. For responsiveness, we coded whether an incoming SMS message was responded to with an SMS to the same contact.

For statistical analysis, we analyzed attentiveness as an ordinal dependent variable using mixed-effect ordinal logistic regression, with the categories: <1 minute (3), 1-6 minute (2), and > 6 minute (1). We analyzed responsiveness as a binary dependent variable using mixed-effect logistic regression. For both analyses we used *ringer mode* and *locale* as independent variables. We used mixed-effect regression because it allows us to add a random effect to separate out between-subject variance so that we could test the variables of interest. Similarly, we analyzed ringer mode change using mixed-effect logistic regression, including *periods of day* as another independent variable.

In the sections below, we firstly present qualitative findings on participants' interruption and availability management practices, including self-reported ringer mode usage and strategies and reasons for not reading notifications. Then we present the quantitative results, mainly focusing on the effect of ringer mode and locale on attentiveness and responsiveness to incoming SMS messages, and on the effect of locale and time of day on ringer mode change.

QUALITATIVE FINDINGS

Ringer Mode Usage

Ringer mode is a common feature of mobile phones for controlling signals of notifications the phone. In Android (before the latest Android 5.0), a phone both plays sounds and vibrates when the phone is in *Normal* mode. In *Vibrate* mode, sound is suppressed, but the phone still vibrates. In *Silent* mode there is no sound or vibration (but the screen or flashing light still activates). Because ringer modes directly affect how users notice notification signals, we sought to understand how participants used ringer modes to manage interruption by and awareness of incoming communication.

Self-Reported Ringer Mode Usage from Survey

Overall, our participants self-reported quite consistent strategies of using ringer modes for certain purposes. Most participants (23) reported in the survey that they put their phone in a quiet state (i.e. Silent or Vibrate) when they were sleeping, at work, or at occasions where they did not want the phone to interrupt them (e.g., spending time with family/friends, watching movie), and would return to the mode where they could feel or hear notifications (Vibrate or Normal) afterwards to maintain awareness of notifications. The other main usage of Silent mode was to prevent their phone from disrupting the environment. 27 out of 28 participants reported that they had switched to Silent or Vibrate mode for this purpose. For example, P15 reported, *"When at work, my phone is in Silent mode so as not to disturb my coworkers."* P11 also explained, *"My ringer is usually on, unless I am receiving a lot of notifications, then I will switch to silent."*

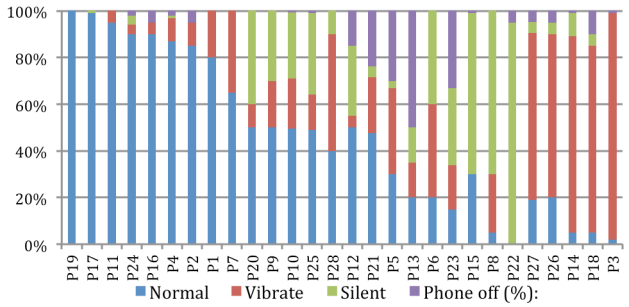

Figure 2. Comparing among participants' self-reported time their phones being in Normal, Vibrate, Silent, or off.

The main reason for using Normal mode is to maintain awareness of notifications. Six participants reported that they switched to Normal mode when they expected incoming communication, especially when they did not have their phone with them or were preoccupied with other things. As P5 stated, *"I would also turn my ringer on, so as to try to hear when someone was try to communicate with me. Since I don't always have my phone on my person at this location."*

Interestingly, we found quite diverse self-reported usage of ringer modes under these strategies. Figure 3 shows the amount of time users estimated that their phone was in each of the three ringer modes or turned off from the post-study survey. While some participants reported that they diligently switched between all ringer modes (e.g., P5, 13, 21), others switched mainly between two modes, or simply kept their phone mostly in one default mode. For example, P13 switched among all modes to manage awareness and to avoid phone interruption and disruption, whereas P17 reported that "99%" of the time he used Normal to keep high awareness of incoming communication. Overall, 16 out of 28 participants reported that they used one ringer mode more than 70% of the time. Only 3 participants had balanced usage of three ringer modes (all ringer mode usage > 25). The others mostly switched between any two of the modes.

Although this variation might have been because some participants more often encountered situations where they needed to silence their phones than the others, participants also had different preferences and attitudes toward being aware of and interrupted by notifications. There were also different concerns about their phone disrupting the environment. For example, P22 reported that he almost always used Silent mode regardless of where he was: *"I feel I am in total control of when I want to see and handle notifications."* He explained why he used Silent most of the time*:"[I] don't like the sound of my phone going off. [J]ust a personal thing."* In contrast, P4 stated that he used Silent only 3% of the time: *"I really wouldn't use [S]ilent, … usually vibrate is my choice so at least I know something came that [I] can check later OR if [I] misplace it there will be some kind of sound from the phone."* P16 also claimed that she never put her phone in Silent mode because she did not need to*: "Any time I don't need it to be quiet."*

In summary, participants' self-reported strategies and purposes for using certain ringer mode seemed quite consistent. However, they chose different combinations of ringer modes for achieving their purposes due to their different preferences.

Reasons for Changing Ringer Mode from Diary

While the surveys gathered responses regarding overall usage and strategies of using ringer modes, the diaries uncovered actual reasons why participants changed to a certain ringer mode in their daily lives. We coded reasons from 368 responded ringer mode change events (Normal: 138, Vibrate: 133, Silent: 97) in the daily diary and reported on reasons frequently cited by participants.

Overall, the reasons cited in the diaries for using certain ringer modes were consistent with participants' overall impression in the survey results. The most frequently cited reason for changing to Silent mode were that they were going to bed (41 out of 97). Other frequent reasons included going to a meeting, being at work, and being in situations where the phone sound was interrupting and disrupting, such as watching a movie, being in a library or interview, or engaged in a chat. One typical response to these events is: *"I was in a meeting and didn't want my phone to ring."(P13)*

Reasons for using Vibrate mode were similar to using Silent mode. However, while many participants thought that Vibrate mode was sufficiently quiet, it also allowed them to notice notifications. As P8 reported in his diary: *"I was going in to give blood and did not want to disturb anyone there but still wanted to be able to catch a call, text, or notification."* P14 also gave a similar comment: *"I was getting ready for work and wanted to be able to hear my phone go off then turned on vibrate because of work."* This is perhaps why compared to Silent mode, Vibrate mode was a more popular option among our participants in their daily lives. In addition, very few participants changed to Vibrate mode during sleeping. This is perhaps when sleeping they cared less about incoming notifications.

The major reasons for changing to Normal mode were: enhancing awareness of notifications after leaving work, getting up from bed, and leaving environments where phone sounds were considered disruptive. Other reasons included expecting incoming communication (mostly calls) and using mobile apps that require sound (videos, games, and navigation).

Reasons of Not Reading Notifications

We present reasons cited in the diary why participants did not attend to notifications for more than an hour. Figure 3 shows the breakdown of 832 valid coded responses. Over half of the notifications were not attended to because participants did not notice them (51%). Common explanations included that they were asleep (even though

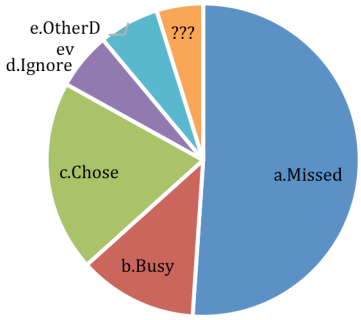

Figure 3. Responses for why users did not read notifications for over an hour: a) missed it, b) were too busy at the time, c) choose to read it later, d) ignored it, or other.

we tried to avoid asking them about intervals that occurred overnight), that the phone was inaccessible to them (in another room, charging), or that they were busy doing something else. For example, *"I will usually plug my phone in my room and leave it in there so will miss notifications for a while." (P9)*; *"was outside for swimming and didn't check my phone until afterward." (P23).*

Other frequently cited reasons included noticing but choosing to address notifications later (19.7%), or being too busy to address them (12.3%) as illustrated by P12, *"Today was an extremely busy day with work; I didn't have time or energy to read the notifications when they first came."* P8 also explained, *"I did not want to handle them at the time but did not want to forget about them. [S]o I did not address them."* Sometimes, participants had addressed the notifications or will address them on another device (6.3%). For example, P14 said, *"I was also utilizing my tablet today and for the most part would get the notification on there and ignored them on my phone until later."* However, there were times where participants ignored notifications because they thought the notifications were unimportant (5.9%). Sometimes they inferred this without actually checking their phone. P19 reported, *"I was not really looking at my phone this evening, but most of these notifications were either unimportant [or] I addressed them on my computer."*

QUANTITATIVE RESULTS & FINDINGS

Over the course of the study, we collected 11,986 incoming MMA (37.6%); 5,599 outgoing MMA (17.6%); 5,325 incoming SMS (16.7%); and 5,786 outgoing SMS (18.2%); Note that SMS and phone had an equivalent proportion of incoming and outgoing events, but incoming MMA was over 2 times the outgoing MMA. As mentioned earlier, we think this is because participants might respond on another device (tablet, computer), which would not be counted in our log.

Attentiveness to Incoming SMS

Figure 4a shows that participants' general attentiveness to the phone across ringer modes is quite similar. This result seems to agree with results recently reported by Pielot et al. [15], which indicated that people typically read notifications within several minutes regardless of ringer modes. We then focused on participants' attentiveness to incoming SMS. Regression results showed a significant effect of ringer mode on attentiveness for both SMS new and chat messages. For SMS *new* messages, both Normal ($p<.001$) and Vibrate ($p=.001$) are associated with higher attentiveness compared with Silent mode. Specifically, Figure 4b shows that the percentage of the attending actions within one minute in Silent (31.4%) was noticeably lower than in Vibrate (47.5%) and in Normal (44.8%), but the percentage for 1-6 minutes was not (Silent: 25.6%, Vibrate: 21.2%, Normal: 25%). This result suggests that without a notification signal (i.e., in Silent mode), participants were less likely to attend to their phone *immediately* after receiving incoming new SMS.

As to SMS chat messages, as expected, the attentiveness was much higher than the attentiveness to SMS new messages, as shown in Figure 4c **(< 1 minute**: Silent: 57.3%, Vibrate: 71.5%, Normal: 64%; **1-6 minutes**: Silent: 31.8%, Vibrate: 18.2%, Normal: 24.2%). We think this is because participants expected to receive more incoming SMS when they had been in a conversation. However, even with such an expectation, regression results showed that participants were still statistically significantly less attentive to SMS chat messages in Silent than in Normal ($p=.001$) and Vibrate ($p< .001$). According to Figure 4c, we believe this significant difference was mainly because participants were not able to attend to the phone immediately in Silent mode. After all, they were nearly equally attentive to incoming SMS chat within 6 minutes across all ringer modes (Silent: 89.2%, Vibrate: 89.7%, Normal: 88.1%).

These results together imply two things. First, the fact that

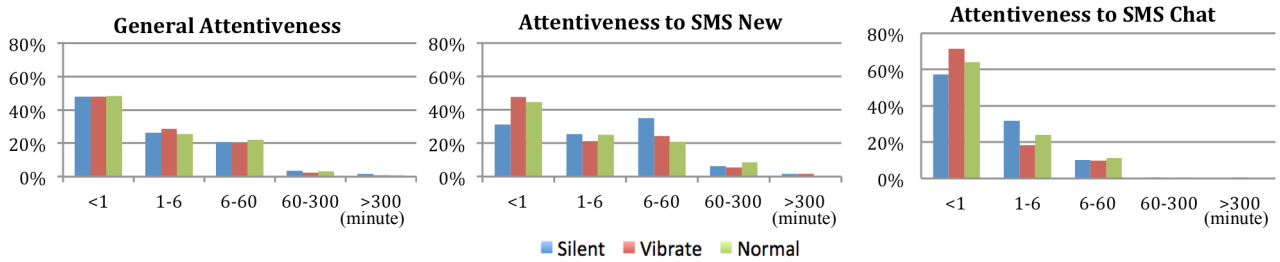

Figure 4. From left to right are: (a) intervals between attending actions, (b) intervals between receiving SMS new messages and the first attending action after it, and (c) intervals between receiving SMS chat messages and the first attending action after it.

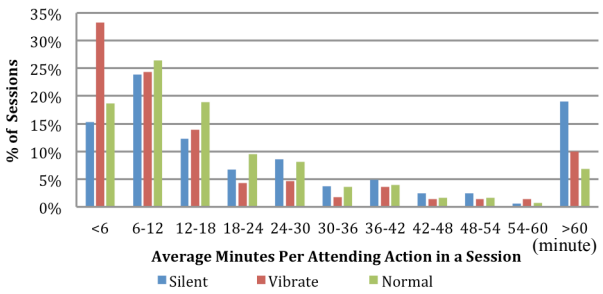

Figure 5. Average interval between attending actions in each ringer mode session.

participants have similar *general attentiveness* but achieve lower *attentiveness to incoming SMS* in Silent mode implies that in Silent mode participants' attending actions are not in reaction to incoming SMS (since they would not have any notification of incoming communication). Rather, the actions were distributed over time according to the participants' *spontaneous and proactive monitoring mechanism*. In contrast, in Normal and Vibrate modes, a notification signal (sound or vibration) evoked attending actions, suggesting a *reactive and notification-triggered monitoring mechanism*. Secondly, in terms of being able to immediately attend to messages, the reactive monitoring mechanism seemed to be more effective than the proactive monitoring mechanism without a notification signal, even when participants might have developed expectation of receiving more messages.

Furthermore, we also examined attentiveness during *sessions* of ringer mode use. We define a *session* as *a span of time using a ringer mode until switching to a different mode*. For each ringer mode session, we calculated the average interval between attending actions within that session. Thus, a small value indicates that within that session a user frequently attends to the phone, and a large value indicates otherwise. Calculating the average attentiveness within a session allows us to see if participants uniformly checked their phones frequently (low average) within ringer mode sessions or not.

Figure 5 shows the distribution of average attentiveness in 749 sessions (Silent 163, Normal: 306, Vibrate: 280). It is interesting that there is a different pattern in the distribution for Silent sessions compared to Normal and Vibrate. Silent sessions show a less steep decline as average attention interval increases, and actually shows a larger relative increase in sessions with an average longer than 60 minutes. There appears to be more variation in attention intervals for Silent sessions compared to Normal and Vibrate. This difference in pattern could be explained by two different reasons for silencing their phones. As demonstrated earlier, participants continue to proactively monitor their phone in certain situations when in Silent mode. Figure 5 shows a substantial number of Silent sessions with a short average attention interval. This likely represents times when the user is silencing their phone to avoid disrupting the environment, but still wants to maintain awareness of incoming communication. However, compared to Normal and Vibrate, there is a relatively higher proportion of Silent sessions with longer average attending intervals. This likely represents sessions where the users silence their phone to suppress notifications and avoid being interrupted. Thus, our data suggest the possibility of distinguishing when users silence their phones to avoid disrupting their environment versus interrupting themselves by tracking how often they continue to attend to their phone when in a Silent session.

In terms of the effect of locale (see Table 1), we used the Home locale as the reference group in a regression analysis. The results show that the Catch-up locale is statistically significantly associated with lower attentiveness both to SMS new ($p=.04$) and SMS chat messages ($p<.001$). Catch-up locale referred to places where participants did not spend large amounts of time, but frequently used their phones to catch-up on past incoming communications, such as train stations, parking garages, and regular lunch walks. Finding low attentiveness at Catch-up locale, especially within one minute, is unexpected because, according to our data, 74.6 % of the intervals between attending actions at catch-ups were within 6 minutes (< 1 minute: 59%, 1-6 minute: 15.6%). The high general attentiveness at Catch-up locale may be a side effect of being generally active on the phone. Perhaps the highly mobile, transitory nature of Catch-up locale means that users are not able to address notifications immediately after receiving them.

The regression results also showed that attentiveness to SMS chat messages at "Other" locale is statistically significantly lower ($p=.01$). The Other locale referred to places where participants visited frequently during the study period, such as gyms, grocery stores, bookstore, etc. It seems that at these places participants were less able to chat. This might be because at these places they usually had a goal to accomplish and were engaged in certain activities.

Responsiveness to Incoming SMS Messages

Participants' overall response rate to SMS new messages was 39.1%, and to SMS chat messages was 70.3%. Since participants might be unresponsive because of they were inattentive to incoming SMS, we are primarily interested in their responsiveness to messages to which they had attended. The results showed that participants' response rate to already attended SMS new messages was 57.5%, and to already-attended SMS chat messages was 78.2%, which, expectedly, were both higher than the overall response rate. However, this shows that still about 40% of messages to which they attended but not responded within 6 minutes.

Interestingly, while Table 2 shows that participants seemed to be most responsive to attended SMS new messages in Vibrate mode and most responsive to attended SMS chat messages in Normal mode, regression results did not show any statistically significant difference among ringer modes in responsiveness to either type of SMS messages at the 0.05 level of significance. This suggests that participants'

	Home	Work	Catch-up	Social	Other
Attentiveness					
New SMS					
< 1 minute	45.8%	45.0%	25.9%	41.7%	52.6%
1-6 minutes	25.4%	19.4%	18.5%	22.3%	15.8%
> 6 minutes	10.1%	3.6%	25.9%	8.7%	7.9%
Chat SMS					
< 1 minute	69.5%	66.0%	33.3%	66.5%	62.8%
1-6 minutes	21.5%	22.4%	25.9%	21.1%	20.9%
> 6 minutes	9.0%	11.6%	40.8%	12.4%	16.3%
Responsiveness					
Attended New SMS	56.7%	65.4%	75%	65.2%	50%
Attended Chat SMS	80.7%	73.9%	68.8%	84.7%	63.9%

Table 1. Attentivenss to SMS new and chat messages and responsiveness to already attended messages by locales

responsiveness to incoming SMS differed likely because they were differently attentive to incoming SMS: once they were able to attend to a message, they did not significantly differ in their responsiveness in different ringer modes.

When investigating the effect of locales on responsiveness using the Home locale as a reference group, regression results showed that participants were statistically significantly less responsive to attended SMS chat messages when they were at the Other locale (p=.003) and at the Work locale (p=.02). However, the results did not show any statistically significant difference among locales for attended SMS new messages. These together suggest that participants seemed equally likely to respond to an SMS new message once they had attended to it at different locales. However, they were less likely to get engaged in a continuous conversation when they were at work or were at places where they were often preoccupied by other things.

Ringer Mode Switches by Locales and Time of Day

We also investigated whether participants' ringer mode changes were associated with any locale and time of day. We logged in total 1,107 ringer mode changes (avg: 39.5, med: 27; max: 159; min: 3; std: 38): 475 were to Normal mode, 379 were to Vibrate mode, and 253 were to Silent mode. In particular, the majority (53%) of switches were between Normal and Vibrate modes (Vibrate to Normal: 290; Normal to Vibrate: 283); 29% were between Normal and Silent modes, and only 18% were between Vibrate and Silent modes. These results were consistent with participants' self-reports that overall participants more often used Vibrate as a *quiet mode* than Silent mode. Perhaps participants thought Vibrate mode was quiet enough and meanwhile allowed them to notice notifications. We plotted the distribution of ringer mode changes by locale and hour of day to look for distinct patterns of ringer mode switches. This allowed us to group hours into periods for a logistic regression analysis. We found several distinct patterns when ringer mode changes occurred. Regression results showed that changes to Silent mode were statistically significantly more associated with the Home locale from 9pm-2am (p<.001), which is likely linked to going to bed. Secondly, changes to Vibrate mode were statistically significantly more associated with the Catch-up locale

	Silent	Normal	Vibrate	Overall
Attended New SMS	56.7%	53.6%	69.8%	57.5%
Attended Chat SMS	75.0%	80.6%	75.0%	78.2%

Table 2. Responsiveness to already attended SMS new and chat messages by ringer mode

(p<.001). Thirdly, changes to Normal mode were statistically significantly more associated with 4pm-6pm (p=.008), perhaps corresponding to getting off work or the commute from work. In addition, switches to Normal mode were also statistically significantly more associated with the Other locale (p=.008), perhaps at these places when participants were engaged in other activities, they wanted a more salient signal to notice notifications.

DISCUSSION

Learning the Purposes behind Ringer Mode Uses

Our participants self reported quite diverse ringer mode usage. Based on their responses from the survey and the diary, the diversity was not merely because they were exposed to different contexts, but also they had different preferences of ringer modes and attitudes toward being aware of notifications and being disrupting the environment. Because of such diversity, in similar contexts participants used different ringer modes, and that some participants kept their phone in one ringer mode across different contexts, creating a challenge of inferring people's attentiveness/responsiveness primarily based on the ringer mode in use. Although we identified several patterns of ringer mode changes, those patterns only represented a small portion of a day. Furthermore, participants put their phone in the same ringer mode for different reasons, in which they might display different attentiveness and responsiveness. For example, while sometimes participants used Silent mode for avoiding interruption, at other times they wanted to prevent their phone from disrupting the environment. These together indicate that ringer modes themselves may not be a reliable signal of mobile users' attentiveness and responsiveness.

However, we found that a more reliable signal is the *purposes behind ringer mode uses*. Based on our findings, there are at least three purposes that can be distinguished: 1) for avoiding interruption, 2) for avoiding disrupting the environment, and 3) for noticing important notifications. For the first, users prefer not noticing a notification; they would set ringer mode in a way that the phone does not distract them. For the second, users mainly want to minimize the saliency of notifications *for the environment*—users themselves may still want to aware of the notification. For the third, users want to make notifications more noticeable for themselves, usually because they are expecting certain notifications. Users may use different combinations of ringer mode for achieving these purposes, depending on their preferences (in our study, a popular combination was between Normal and Vibrate modes); however, we believe that these three

purposes are useful signals of their current or upcoming attentiveness or responsiveness compared to ringer mode per se, especially when users just have switched a ringer mode. We also found a few patterns of ringer mode switches associated with certain locales and periods. We think it is worth associating the purposes behind ringer mode uses with locales and periods, perhaps creating *personas* representing common patterns of ringer mode use for designing future notification services.

One advantage of learning purposes and using them as an indicator is that they are presumably persistent and are independent from the features of mobile systems, whereas ringer modes vary on different systems and may evolve overtime. Moreover, once wearable devices become more pervasive and affordable, more mobile users are likely to attend to notifications across multiple devices. Focusing on why and when users want to avoid and to be aware of notification allows designing a notification service without being limited to any mobile system. We provided an example of computing the intervals between attending actions in Silent sessions to distinguish purposes of using Silent mode. Future research can devise more sophisticated heuristics to learn and distinguish the three purposes.

How are Ringer Modes and Locales Related to Mobile Users' Attentiveness and Responsiveness

We analyzed logs to investigate attentiveness and responsiveness in different ringer modes and locales. Our results provide a number of implications. First, while two recent studies showed that mobile users generally attend to notifications within several minutes, especially for those from communication apps [15,19], our results showed that, in terms of being able to *immediately* attend to a message, participants were less attentive in Silent mode than in Normal and Vibrate modes. We believe this difference was not because they were less interested in notifications in Silent mode (given that they had a similar distribution of attending actions across all ringer modes, as shown in Figure 4a), but because without signals of notifications it was difficult for them to notice notifications immediately, even if they might have developed expectations of receiving more messages in a chat. This reason may explain why participants more often chose Vibrate mode as *the quiet mode*, as it allowed participants to more likely to notice notifications. One suggestion we have is providing additional undisruptive but noticeable signal for users (e.g., visual feedback). If a notification service can *infer* users' purposes for using ringer modes, providing multimodal signals of notifications whenever appropriate is generally useful (note that the top reason for not reading notifications is "not noticing them.") Secondly, our results did not show statistical significant difference in responsiveness to already attended incoming SMS across ringer modes. This implies that ringer modes mainly affect attentiveness but not responsiveness to already attended messages: once users are able to attend to a message, being responsive or not is less correlated with which ringer mode they use. We think this perhaps that diverse ringer mode usage weakens the relation between context and the use of a particular ringer mode.

Thirdly, we found an influence of locale on attentiveness and responsiveness. Participants were less attentive to incoming SMS at Catch-up locale, showing the highly mobile and transitory nature of these locations. They were also less responsive to incoming SMS chat messages when they were at the Work locale and at the Other locale. We believe at these places, because participants were often preoccupied, they were less available for continuously chatting. In addition, participants also self-reported their own individual behavioral pattern of ringer mode use at different locales (e.g. not reading notifications at church or at social places). Taken these together, we believe that locale is useful information for inferring attentiveness and responsiveness.

Recently, Pielot et al. [16] showed that it is feasible to predict attentiveness using various features including ringer modes and screen activities. We think it is also worth exploring how the locale information, converted from GPS coordinates through users' input, improves the prediction. In addition, it may be also worth including "purposes behind ringer mode uses" as a feature for predicting attentiveness and responsiveness. One remaining challenge is predicting responsiveness as it involves an additional users' decision i.e. whether to respond. Although we identified the effect of locale, we believe another factor is *who* sends the message [18], which, unfortunately, was not examined in this paper. Once estimated attentiveness and responsiveness become reliable and acceptably accurate, we propose providing this information for message senders, as it can signal senders when a good time would be to make contact. It would be interesting to explore this concept in a working prototype.

STUDY LIMITATIONS

The current study is subject to several limitations. First, our study focused on attentiveness and responsiveness on mobile phones. Thus our findings may not apply to other devices such as computers and tablets. Second, we were not able to analyze MMA messages because several of our participants have multiple devices for MMA communication. Thus our analysis of attentiveness and responsiveness to SMS may not apply to MMA. Third, to reduce participants' burden, we only asked them to provide labels of frequent contacts, and did not ask them to name the closeness with each of them. Although we could have inferred it through contact labels (e.g., spouse, best friend), that might not be reliable. As a result, we were not able to examine the impact of contacts on attentiveness and responsiveness. Fourth, we could only measure user attentiveness through users' related actions on the phone, as other previous work has done (e.g. [15,16]), but we did not have the ground truth of whether they *actually* read each of the messages. Finally, we could not reliably estimate the duration of using each ringer mode for each participant

because we did not know the duration of the phone being off.

CONCLUSIONS

In this paper, we investigated how mobile users use ringer modes to manage interruption by and awareness of incoming communication, and how that practice and locale affect their attentiveness and responsiveness. We highlight that mobile users have diverse ringer mode usage, but they switch ringer mode for three main purposes: 1) avoiding interruption, 2) preventing their phone from disrupting the environment, and 3) noticing important notifications. We suggest future notification services be designed for these three purposes. We also highlight that ringer mode mainly influences attentiveness but not responsiveness to attended messages. Without signals of notifications users are less likely to immediately attend to SMS messages than with signals. In addition, mobile users are less attentive and responsive to SMS at certain locales. We suggest CMC tools learn to infer the purposes for using ringer modes associated with locales, and use them as features for building predictive models for attentiveness and responsiveness. This benefits not only CMC tools, but also researchers attempting to identify opportune moments for sending notifications and tasks to mobile users.

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