From Default to Distinct: Exploring the Effectiveness of Customized Notification Alerts in Improving User Awareness of and Attendance to Mobile Notifications

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Research indicates that smartphone users often speculate about notifications upon sensing their arrival, aiding their decision to attend to them. This speculation, however, relies on the presence of sufficient clues to associate with the notification, which are not always available. To overcome this challenge, we explored the concept of users assigning specific meanings to notification alerts to aid in their speculation and response strategies. We conducted an ESM study with 37 participants, comparing the effectiveness of constant user-assigned alerts with context-aware delivery. Results indicate that user-assigned alerts significantly enhance notification awareness, improving both speculation accuracy and the effectiveness of notification attendance. This heightened awareness also led participants to ignore notifications more often due to unavailability rather than assuming irrelevance. However, context-aware alert delivery, which delivered alerts only in certain conditions, introduced confusion. Finally, in determining alerts for specific notification types, participants considered factors including familiarity, uniqueness, disruptiveness, and emotional resonance.

CCS Concepts: • **Human-centered computing → Empirical studies in ubiquitous and mobile computing**.

Additional Key Words and Phrases: Mobile notifications; mobile receptivity; speculation; attentiveness; ESM

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1 INTRODUCTION

Prior research has indicated that smartphone users often engage in speculation about the origin and content of notifications upon receiving an alert, aiding them in selectively attending to these notifications [9]. Building on this insight, it has been proposed that providing users with a *preview* of the notification through the alert could serve as a beneficial strategy for enabling users to decide whether to direct their attention to their device. This approach leverages users' distinct notification preferences [29, 48, 54], suggesting that by allowing users to assign specific alerts to particular types of notifications—especially those they prioritize—users could, upon hearing the alert, gain a preliminary understanding of the incoming notification. This process could presumably empower them to make more informed decisions about whether to engage with the notification, thereby enhancing the selectivity and effectiveness of their attention allocation. Furthermore, by assigning unique alerts to certain notifications, users could distinguish these from others, achieving a more selective notification management strategy from the moment of notification arrival. However, this hypothesis remains untested, and the potential benefits of assigning specific alerts to notifications—namely, improved notification awareness and selective engagement—have yet to be empirically validated. Given the potential advantages of this approach for enhancing human-notification interaction and effectiveness of users' attention switch, it

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is crucial to examine these assumptions to determine whether the strategy merits further exploration and development. Consequently, this leads us to our primary research question:

RQ1: Does enabling users to assign specific alerts to notifications based on their meanings enhance the accuracy of their speculation and the effectiveness of their notification attendance?

In addition, prior research [9] has shown that users are adept at speculating the nature of notifications when contextual clues are present, such as recent interactions with apps or contacts, providing a foundation for accurate speculation. However, the accuracy of speculation significantly diminishes in the absence of such context. In light of this observation, our study extends to investigate the efficacy of a context-aware delivery system. This system is designed to trigger users' custom alerts only in scenarios devoid of context—e.g., when there has been no recent interaction. A context-aware approach could reduce the frequency of custom alerts, potentially decreasing user disturbance and confusion associated with a plethora of custom alerts, thus ensuring alerts are most beneficial when users face challenges in speculation. Yet, the impact of transitioning from constant custom alerts to a context-aware model on users' speculation accuracy, notification attendance, and perceived disturbance is unclear. This leads us to our second research question:

RQ2: How does a context-aware mechanism, which restricts the deployment of user-defined alerts based on the absence of contextual clues, affect users' speculation accuracy, notification attendance, and their perceived disturbance?

Moreover, we are interested in delving into the strategies users employ for linking specific meanings and alerts to their notifications. This exploration encompasses understanding the types of meanings users associate with particular notifications and the corresponding alerts they choose for these associations. Gaining insight into these personalization strategies is essential for understanding how users tailor their notification experience to better manage their attention and interaction with incoming notifications. Thus, we introduce our third research question:

RQ3: How do users navigate the assignment of meanings and alerts to their notifications?

To answer these questions, we held preliminary co-design workshops with 29 participants to get an initial understanding of how they think about user-defined alerts to assign meaning to specific notifications. Informed by these insights, we developed an Android application, NotiSpeculate, that provides customized alerts for specified notifications. Following this, we initiated a three-week within-subject field study where participants experienced three distinct conditions: 1) a default setting where NotiSpeculate only issued original alerts; 2) an alert-assistance setting where user-defined alerts replaced original ones for specific notification types; and 3) a context-aware alert-assistance setting where NotiSpeculate avoided substituting alerts when deemed unnecessary (i.e., the user was presumed to anticipate the arriving notifications with the original alert accurately). We employed the experience-sampling method (ESM) [57] to measure participants' notification awareness, attendance, and perceived disturbance. Lastly, we carried out post-study interviews to gain qualitative insights into participants' perceptions and day-to-day experiences with NotiSpeculate.

This paper's main contributions are as follows.

- It establishes that delivering customized notification alerts for specific types of notifications could lead to more accurate user speculation about notifications and enhance the efficiency of their attendance to notifications.
- It indicates that a context-aware mechanism, providing customized alerts only on a sporadic basis, did not decrease the perceived disturbance, nor did it improve the accuracy of users' speculations about notifications.
- It pointed out that in situations where awareness is increased but notifications cannot be attended to because of unavailability, the assistance provided by user-defined alerts would decrease.

- It classified the strategies of how users assign meaning to alerts.

2 RELATED WORK

Numerous studies in notification research have investigated users' notification management and attentiveness. One common topic is how different contextual factors influence users' receptivity to and their interaction with their notifications. These context factors include: activity context [1, 5, 8, 10, 14, 15, 22], location [36, 40, 50, 56], time of day [3, 40, 46, 47, 50, 56], recent phone interaction [39, 48], ringer mode [16, 22], sensor information [16, 22, 24, 26, 32, 37], conversational context [51, 52], personal characteristics [59], and arousal and arousal emotional states [21, 38].

Alongside the impact of context, several studies have investigated how users' perceived characteristics of a notification influence their alertness and responsiveness. These studies indicate that smartphone users typically pay high attention to notifications [14, 18, 42, 48], even when their device is set to silent mode [11, 41]. However, only a small proportion of the myriad of notifications are considered critical or urgent by the users [58]. This observation implies that while users frequently engage with their phones, many interactions involve unwanted or irrelevant notifications. Such ineffective engagement is largely due to the insufficient cues notifying users about the content and sender of the notification [9]. Research has also revealed specific user preferences towards notifications: they tend to prioritize notifications related to interpersonal communication [31, 45, 48] and may not appreciate notifications about certain topics or from specific sources [31]. Even within the same app, users show different attentiveness levels towards different notifications. For instance, they are generally more alert to messages from individuals with certain relationships [29, 36, 37, 59] than the others. However, the existing notification systems fall short of offering a way to differentiate among specific notifications. This deficiency often results in users not having enough cues upon the arrival of notifications, making it challenging for them to selectively attend to the ones they prefer.

Researchers have adopted several strategies to protect users' attention from unnecessary notification disruptions. One line of approach involves determining suitable moments for notification delivery [1, 12, 17, 35, 39], presuming that if notifications are sent at the non-suitable timing, any notification (even preferred ones) would be regarded as disturbance or distraction [8]. Another area of research aims to restrict users' notification awareness by either suppressing notification alerts or disabling them entirely. Evidence has shown that muting phones can aid users in managing disruptions and disturbances [11] and could potentially mitigate inattention [27]. Disabling notifications has also been found to reduce external interruptions [43, 44]. However, the downsides of these approaches are also reported. Some studies indicate that the absence of notification alerts can trigger users to check their phones by themselves, driven by the fear of missing out on important or time-sensitive notifications [2, 43, 44]. This self-initiated phone checking does not result in less phone checking than when the phone's notification alert stayed activated [11]. As a result, prior research shows that people quite often check notifications, even when they have been engaged in a task-at-hand [8]. Consequently, earlier research points out that individuals often check notifications, even while actively engaged in a task [8]. This behavior, sometimes referred to as self-interruption [13], may not be less impactful than external interruptions [11], suggesting that the strategies aimed at suppressing notifications may not always achieve the desired outcome, especially sometimes users still desire to be notified [9]. Therefore, some research explores how users perceive and utilize different ringer modes as effective means to manage their attention [25]. When users finish situations where they cannot be disturbed, they switch to vibrate mode or normal mode to maintain awareness of notifications [11], and most people commonly use the mute button to change the alert mode [41]. Regarding different ringer modes, Mashhdi et al. found that notifications with accompanying alerts are 12 times more likely to be immediately attended to compared to those without alerts [34]. Furthermore, research shows that the vibrate mode is considered by many as a mode that allows them to be aware of notifications while being less disturbed [11, 41].

Additionally, recent research have indicated that notification alerts act as crucial cues enabling users to speculate about the source and content of notifications [9, 19, 20], which can positively improve their decision to attend or not. However, the present notification system, with alerts associated more with apps than with the content or sender [9], often fails to provide informative cues. As a result, it has been proposed that enabling users to have a 'preview' of notifications through alerts could theoretically aid in more informed decision-making. Yet, this assumption has remained largely unexplored in the literature. Therefore, the connection between user-assigned alerts and accurate speculation about notifications, as well as their effect on notification attendance decisions, remains unclear. This study stands as the first to validate this approach, offering empirical evidence and setting the groundwork for future research in advancing this method.

We introduce our study in the following sections.

3 DESIGN PROCESS

To gain insights into the design of NotiSpeculate, we conducted co-design workshops to identify 1) the key attributes of notifications users wish to differentiate from others, and 2) their preferred alerts to pair with these particular notifications.

3.1 Workshop Procedure

Our workshop participants comprised 15 males and 14 females aged 19-41, recruited through several Facebook groups that exist to connect researchers with research participants. The 29 participants were evenly divided into ten workshop groups. Each group underwent four stages: 1) discussion of the notifications they preferred to receive and differentiate from others, with their reasons; 2) categorization of the notifications discussed during the first stage; 3) exchange of ideas about their desired alert formats for each category of notifications; and 4) designation of key terms for each notification category that could indicate their arrival. Each participant was compensated US$10.75 for their time. Due to the restrictions of the pandemic, our design workshops were carried out online through the Google Meet platform. The design activities were facilitated using an online collaborative design tool named Miro. Subsequently, we thoroughly examined the transcripts and the results of the discussions using affinity diagramming [33], a method involving iterative labeling and grouping of notes transcribed from audio recordings of interviews. The research team collaborated in each labeling and grouping session, sorting each note and examining the entire affinity diagram.

3.2 Workshop Results

Notification Categories and Keywords. The workshop participants identified six categories of notifications they wanted to distinguish from others. These were from or about 1) specific individuals; 2) items of likely personal interest; 3) friends; 4) informational updates such as news and weather reports; 5) their work or other members of their profession; and 6) issues that would impact others, such as food-delivery times and friends' questions.

When we collected all the keywords associated with each category, we noted that the same keyword could appear in multiple categories, and also that keywords were distributed broadly within the same category. We attribute this to the diversity of the participants, as different individuals received different types of content within the same category, and undoubtedly had distinct perspectives on how to classify their notifications. Given this high degree of individual variation, in the field study, we decided to let users create and customize their categories and keywords without any preset assumptions.

Thoughts on Notification Alerts. The workshop participants expressed a desire for alerts that would evoke specific emotions or concepts according to the nature of each category. Broadly, they wanted to gain a sense of urgency from work-related notifications, a feeling of happiness or relaxation from those friends, and a sense of warmth from family-related notifications. Nevertheless, individual preferences varied considerably. Consequently, we offered a diverse range of alerts for users to choose from to convey the emotions they associated with specific types of notifications.

4 FIELD STUDY

To address our research questions, we carried out a three-week experience sampling study. The specific details of this study are delineated in the sections that follow.

4.1 Participant Recruitment

The target scenario for our field study is users' attendance decisions made after sensing a notification alert when their phones are not in use. Extensive prior research (e.g., [11, 18, 34, 36]) suggests that non-silent modes are more prevalent than silent ones on Android systems, meaning that this study's design was relevant to a high proportion of smartphone users. Therefore, the study's target demographic is smartphone users who received notifications via sound or vibration alert, specifically those who 1) kept their phones in normal or vibration mode for 16 hours a day or more.

Recruitment messages were posted on various forums and Facebook pages. Some of these were specifically for research-subject recruitment, while others were general pages for residents of particular cities in our country. The recruitment posts directed interested parties to a sign-up form. Throughout the recruitment process, we aimed for a balanced mix of participants in terms of gender, age, and occupational background.

The study was completed by 37 participants aged 20 to 47, of whom 14 were females and 23 were males. Just under half (n=18) were students, while the rest came from a variety of job sectors, including manufacturing, information technology, and entertainment, among others. All participants were invited to optional interviews conducted at the end of the study, and 27 of them took part in them.

4.2 The Research App: NotiSpeculate

NotiSpeculate is an Android application we developed for this study to capture notifications by leveraging the Android Notification Listener Service API[1] and examine whether incoming notifications align with a category that users have assigned for a specific alert. If there is a match, NotiSpeculate delivers the user-assigned sound or vibration alert, depending on the phone's ringer-mode setting. That is, if the phone is set to normal mode, both the sound and vibration alerts are delivered, whereas if it is set to vibration mode, only the vibration alert is delivered. However, setting the phone to silent mode (which participants were cautioned against unless necessary) results in none of the alerts being delivered. If no match is identified, NotiSpeculate delivers the default alert similar to the scenario without NotiSpeculate. In cases where a notification belongs to more than one category, only the category with the higher priority will trigger an alert. In addition to its primary functionality, NotiSpeculate serves other research purposes: sampling notifications, sending out questionnaires, and recording notifications, participant behavior, and phone-context data such as status (e.g., battery life, network connectivity), location, and activity.

[1]Notification Listener Service API: https://developer.android.com/reference/android/service/notification/NotificationListenerService

Table 1. Example of 7 types of keyword setting's rule on category "Research"

	Category: Research
sender	Prof. Chang
content	meeting
app	Slack
sender-content	sender: Jack; content: how
sender-app	sender: Andy; app: Messenger
content-app	content: research; app: Gmail
sender-content-app	sender: Jay; content: discuss; app: Line

4.2.1 Notification Alert Design. Our creation of sound alerts was informed by a previously published guideline [6], which differed across three dimensions: sound mode, melodic arrangement, and timbre. We used major and minor modes to vary our sound alerts because people's emotional responses can be affected by sound mode [23]. We established four modes that fall between the minor and major modes. To simplify these choices for non-musical individuals, we used the descriptors "bright" and "dark" to represent the major and minor modes, respectively. Our second dimension of variation, melodic patterns, was influenced by both melodic direction and tempo, which have been shown to shape people's emotional reactions to sounds [4, 23, 55]. We created five distinct melodic patterns to widen the emotional range our sound alerts could evoke. Lastly, we altered the timbre of the sounds, as prior research shows that differing timbres can provoke various emotional responses [4]. Seven types of timbre were created, comprising sounds produced by instruments, synthesized sounds, and recorded non-musical sounds from the real world.

For vibration alerts, rather than pre-designing options, we permitted app users to create their own patterns. This was because designing a vibration pattern is relatively simple - requiring adjusting just two aspects: the length of each vibration fragment, and the gaps between the fragments. We provided example patterns using short and long vibrations, as mentioned in the literature [49], and various combinations of these two patterns. This helped demonstrate to the participants how different vibration patterns could influence the perceived urgency of notifications.

4.3 Pre-study Setup

4.3.1 Defining Rules for Notification Categories. To facilitate the customization of notification alerts, we designed a configuration webpage on which the participants could set their notification categories. Participants need to set the category name and priority. At the webpage, we provided six primary categories derived from the co-design workshops as a reference. For each created category, the subjects needed to define the keywords that, when they appeared in specific fields, would categorize notifications into that category The three fields for keyword specification were as follows.

1. Sender: If the notification's sender information (where known) contained the keywords.
2. Content: If the content of the notification contained the keywords.
3. App: If the app sending the notification exactly matched the keywords (the researcher manually confirmed this to mitigate potential naming errors).

If an incoming notification satisfied the rule, it was categorized accordingly. Each category could be linked to multiple keyword-setting rules, and rules that required the simultaneous presence of two or more pieces of information could also be established. Table 1 presents example rules that users set for a category called "Research".

Figure 1. Interface of Sound-alert Selecting

4.3.2 Associating Notification Alerts with Categories. To enable users to assign specific notification alerts to each category, we presented all available sound alerts on the configuration webpage. This webpage was divided into seven sub-pages, each presenting one type of timbre and containing 20 different sound alerts, for a total of 140 unique sound-alert options (as shown in Figure 1). Each of the 20 sound alerts on a given sub-page is a unique combination of one of the four modes displayed in the pink box and one of the five melodic arrangements in the blue box.

We developed a separate app for participants to install on their phones to set vibration patterns because they could not experience these patterns via a webpage, only through their phones. The interface of this vibration app is shown in Figure 2. After designing a vibration pattern, the participants were allowed to test it directly on their devices to ensure that it met their expectations. Once satisfied with their design, they could assign the pattern to a specific notification category and submit their selection. This completed the process of setting the vibration pattern for a given category, as depicted in Figure 2b.

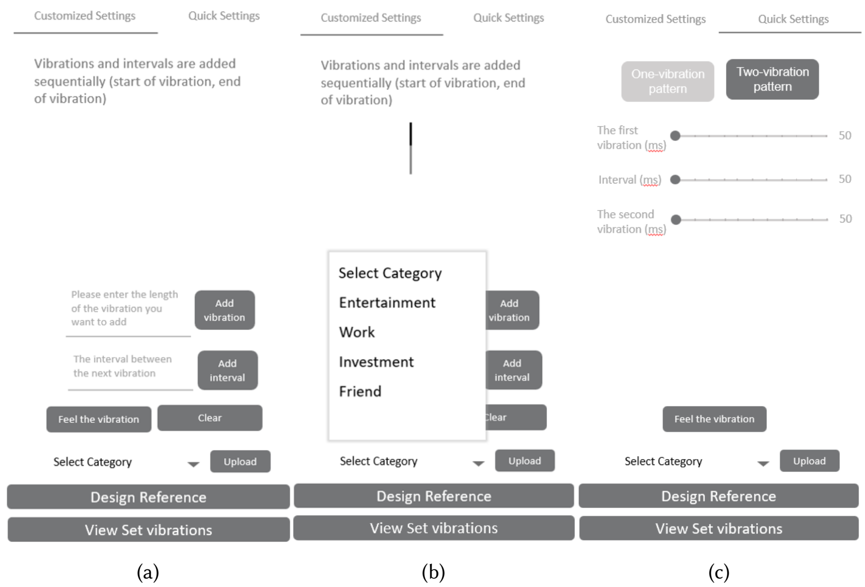

Figure 2. (a) Subject setting a short fragment of vibration lasting 400ms, followed by a gap of 400ms. (b) Subject selecting a category for which they want to set a vibration pattern. (c) Example of a subject using the "fast-setting" option for a two-vibration pattern

4.4 Experience-sampling Study

4.4.1 ESM Sampling Procedure. NotiSpeculate allows its users to specify a 12-hour window each day during which they are comfortable with having their notifications sampled and receiving ESM questionnaires. This window can be set differently for weekdays and weekends, catering to potential variations in users' schedules. NotiSpeculate sampled notifications according to whether they fell into user-defined categories (i.e., 50% were within those categories and 50% were not). The app also took account of the time elapsed since the beginning of the daily 12-hour window during which the participant had agreed to receive ESM questionnaires, as well as the time since the last ESM questionnaire was filled out. This balanced our need for NotiSpeculate to wait for infrequent notifications against the chance of a whole day passing without a person receiving any such rare notifications, which are notifications from categories with fewer notifications. We iteratively tested our weighting parameters and elapsed-time thresholds with pilot participants until NotiSpeculate was able to capture sufficient quantities of a relatively balanced array of notifications from a range of sources.

When a notification was sampled, NotiSpeculate waited for one minute before proceeding, allowing for the subject to complete their immediate response to the notification, if any. Then, an ESM questionnaire was issued through a silent phone notification, to minimize potential disruption. Based on feedback from our pilot test, we established that a 30-minute maximum response threshold was sufficient to capture diverse sensing and speculation scenarios without overly taxing the subjects' recall. The effectiveness of this ESM expiry-time threshold is also supported by previous research [9]. After a participant completed an ESM questionnaire, there was a cool-down period of at least one hour, and no participant was issued more than eight questionnaires per day.

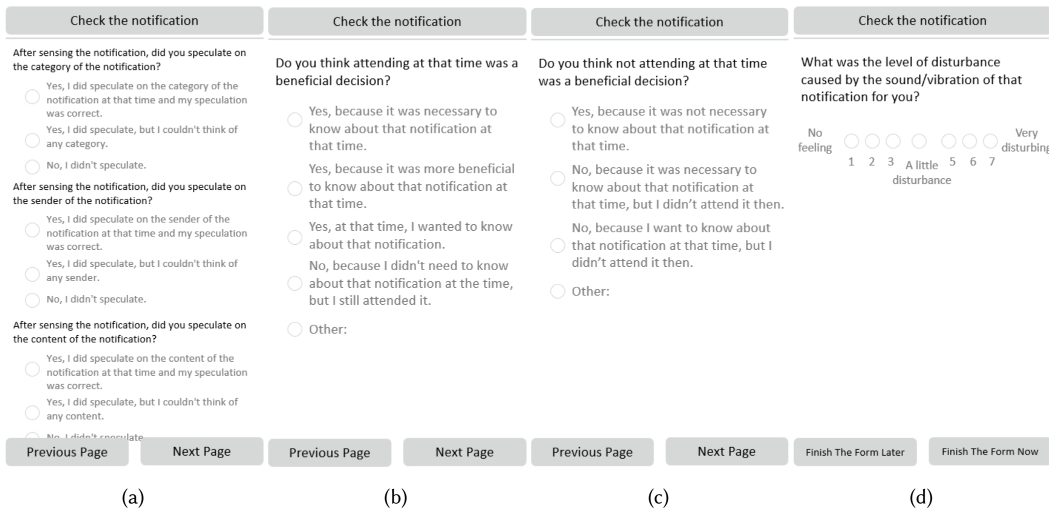

Figure 3. The research application's questions about the participants' (a) speculation about the four types of sources; (b) self-evaluation of their decision to attend to the notification; (c) self-evaluation of their decision not to attend to the notification; (d) perceived disturbance by alerts

4.4.2 ESM Questionnaire. Each ESM questionnaire provided detailed information about its focal notification, including the sender, originating app, time of arrival, and content. It then inquired about participants' awareness of the sampled notification, with "Unsure" included among the answer options. Its remaining questions covered the following three dimensions.

Notification Speculation. As shown in Figure 3a, the questionnaire asked whether participants' speculations about the category they set, app, sender, and content of the notification were correct. Even in cases where a customized alert had not been used, it also asked whether they perceived that type of alert as helpful in facilitating their speculation. Responses were provided on a seven-point Likert scale ranging from 1="Not helpful" to 7="Very helpful".

Notification Attendance. Subjects were asked about the reasons for their decision to attend to or ignore the notification. They were also asked to evaluate whether their decision to attend or disregard was beneficial at that time, as illustrated in Figures 3b and 3c. Their response to this question served as an indicator of the effectiveness of their notification attendance.

Perceived Disturbance. Lastly, the participants were asked about their perceived level of disturbance caused by the focal notification's sound or vibration alert and answered using the seven-point Likert scale depicted in Figure 3d.

4.5 Field-study Design

Our field study was structured such that each subject sequentially underwent three different conditions, each lasting for seven days. These conditions were as follows.

1. Baseline Condition: In this condition, the participant's phone did not produce any customized sound or vibration alert, regardless of notifications' categories.
2. Alert Assistance Condition: In this scenario, the participant's phone would play the customized sound and/or vibration alerts assigned during the preset stage, according to the category of the incoming notification.

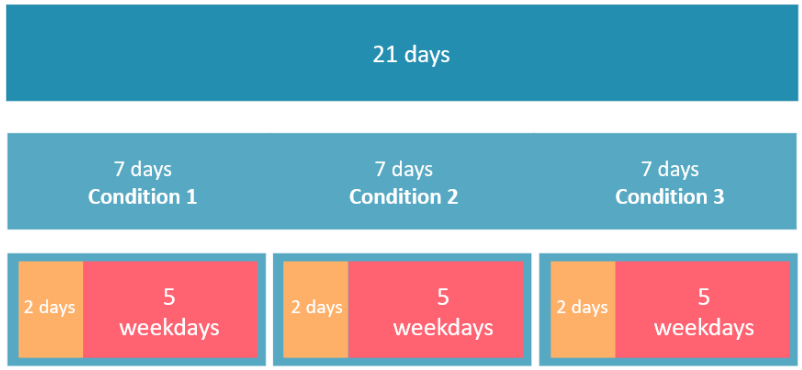

Figure 4. Flow of the ESM study

3. Context-aware Condition: This was similar to the alert assistance condition, with the only difference being that the customized sound or vibration alert would be played at specific moments only. Based on previous research findings that users often speculate accurately about notifications in the wake of recent messaging interactions with the same sender [9], we posited that there would be minimal utility in the phone playing a custom alert to assist with such speculation. Therefore, if a participant had used any of six instant-messaging apps (namely Facebook, Messenger, Line, Instagram, Slack, and/or Gmail, selected due to their popularity among our participants) in the preceding 30 minutes, and the newly classified notification from one of the same apps was from the same sender as a previous notification within that timeframe, NotiSpeculate did not play a customized sound or vibration alert.

To counteract any potential effects of the order of these three conditions, such order was counterbalanced, resulting in six combinations. Each participant was randomly assigned to one of these six orders, and every order is counterbalanced. Figure 4 presents exemplifies the sequence of the condition orders. Given that participants might need some time to adjust when switching to a new condition, we decided not to analyze the data from the first two days of each new condition (highlighted in orange in Figure 4). To maintain data consistency across the three conditions, the remaining five days that we considered for each condition were all weekdays (indicated in Figure 4 by a red box).

4.6 Experiment Procedure

Having confirmed the identities of the people who had signed up for the study, we organized a meeting in which the research team explained the study's objectives and procedures to them. Once they had agreed to participate, a researcher guided them on how to configure notification categories and assign notification alerts to these categories.

We scheduled follow-up appointments at least three days after the pre-study meeting to install NotiSpeculate on the participants' phones. This gap was intended to allow them ample time to complete the configuration before the experiment began and to ensure that they were familiar with the notification alerts set before entering an experimental condition in which customized alerts would be delivered. This approach enabled us to assess participants' awareness when they were familiar with the alerts. To facilitate this, we included a test page in NotiSpeculate that allowed its users to assess their familiarity with the sound or vibration alerts they had set for the categories they defined. To pass the test, participants had to correctly identify the category of every sound and vibration alert.

Upon completion of the ESM study, we compensated the subjects with US$50 and sent them an email invitation to an interview. To obtain richer contextual information and help them recall specific situations in which they had answered ESM questionnaires, we used the cued-retrospective method, which involved showing the subjects their ESM responses during their interviews. All interviews were audio-recorded and transcribed. Participants who elected to be interviewed received a bonus of US$7.

4.7 Data Analysis

For our statistical analysis, we ran mixed-effects regression models using the "lmerTest" [28] package in R software[2]. The dependent variables included four binary ones covering the correctness of speculation about four notification characteristics – i.e., sending app, category, sender, and content – and one numeric one: the degree to which attending to the notification was perceived as beneficialFor binary events, we used mixed-effects logistic regression, including participants as a random effect to address individual differences due to multiple data points from each participant's ESM responses.

For qualitative data, our analysis involved open coding of interview transcripts using Atlas.ti[3] to gain insights into NotiSpeculate users' experiences. Regular team meetings aided in refining emerging codes and categories, ensuring a thorough understanding and accuracy as we integrated new insights into our analysis.

5 RESULTS

Over the 15-day study period (excluding the initial two days in each condition), the participants collectively received 164,794 phone notifications: 59,167 (35.9%) in the alert assistance condition, 53,215 (32.3%) in context-aware, and 52,412 (31.8%) in baseline. Slightly more than one-fourth (n=41,628) fell into the participants' pre-set categories. Specifically, out of these 41,628 notifications, there were 15,995 (38.4%) in the alert assistance condition, 12,133 (29.2%) in context-aware, and 13,500 (32.4%) in baseline. In the context-aware condition, where the use vs. non-use of customized notifications was governed by contextual factors rather than user preferences alone, 64.5% of categorized notifications were accompanied by a customized alert and 35.5% were not.

During the same 15-day period, the participants completed or partially completed 2,897 ESM questionnaires. Of these responses, 997, 1,833, and 67 were collected when their phones' ringers were set to normal, vibrate, and silent modes, respectively. Among the notifications that yielded ESM responses, 2,106 were accompanied by a default alert and the remaining 791, by a customized alert. In the following sections, we start answering our research questions.

5.1 Awareness of Notifications with Default vs. Customized Alerts

In RQ1, we ask whether a notification system that delivers customized alerts enhances users' awareness of incoming notifications. First, we assess how users recognize the "arrival" of notifications. Table 2 sets forth the pathways by which participants became aware of each notification (i.e., noticed it while using the phone vs. via a notification alert), and their frequency of speculating about the notifications. As the table indicates, notifications were 59.0% (467 out of 791) of the time noticed by the participants when they were associated with a customized alert. Although this likelihood is higher than when a default one was used (972 out of 2,106, or 46.2%), the difference was not statistically significant ($z = -1.343$, $p = 0.179$). However, among the notifications that were noticed due to the alert, a higher proportion of those

[2] R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
[3] https://atlasti.com.

Table 2. Distribution of participants' awareness and speculation about their notifications

Notification	Features	Percentage
Default-alert	Not sensed	53.8% (1134)
	Sensed directly (using the phone)	13.4% (282)
	Sensed by ringtone or vibration (no speculation about any of them)	7.0% (148)
	Sensed by ringtone or vibration (have speculation about any of them)	25.7% (542)
Customized-alert	Not sensed	41.0% (324)
	Sensed directly (using the phone)	19.7% (156)
	Sensed by ringtone or vibration (no speculation about any of them)	3.5% (28)
	Sensed by ringtone or vibration (have speculation about any of them)	35.8% (283)

with customized alerts were speculated about (283 out of 467, or 60.6%) than those with default alerts (542 out of 972, or 55.8%). Logistic-regression results demonstrated that the difference was statistically significant ($z = 5.139$, $p < .001$).

5.2 Participants' Speculation about Notifications Was More Accurate with Customized Alerts

Next, we examine whether assigning meanings to alerts enhanced our participants' ability to accurately discern the sources and participants of notifications.

First, we looked at speculation instances that encompassed both notifications paired with the default alerts and those with customized alerts within a single condition. Our results show that participants were not significantly more accurate in their speculation about the app, sender, and content of notifications in the alert assistance (app: $z=1.255$, $p=0.209$; sender: $z=1.429$, $p=0.153$; content: $z=-0.026$, $p=0.980$) or the context-aware conditions (app: $z=0.148$, $p=0.883$; sender: $z=-1.104$, $p=0.270$; content: $z=-0.804$, $p=0.422$) as compared to the baseline condition. It is important to note that only a portion of notifications was accompanied by a customized alert in the alert assistance and context-aware condition.

Next, we specifically compared notifications accompanied by customized alerts against those with default alerts in the alert assistance and the context-aware condition, respectively. Figure 5 illustrates the accuracy of the participants' speculation about notifications with customized alerts vs. default alerts across each of the conditions. The regression results showed that while customized alerts in the alert assistance condition helped participants make more accurate speculations about apps ($z=4.366$, $p<0.001$), senders ($z=3.102$, $p=0.002$), and content ($z=3.743$, $p<0.001$), as compared to default alerts, this was not the case in the context-aware condition (app: $z=1.307$, $p=0.19133$; sender: $z=0.161$, $p=0.872$; content: $z=0.092$, $p=0.927$). This suggests the significance of *consistent* delivery of customized alerts in bolstering users' ability to speculate notifications accurately. Intermittently delivering customized alerts does not seem to maximize their potential benefits.

5.3 Participants' Decisions to Attend to Notifications

5.3.1 Frequency of Attending to and Ignoring Notifications. In this section, we aim to address RQ1. As shown in Figure 6, participants were more likely to attend to notifications with customized alerts (71%) than those with default ones (56%). They were one and a half times more likely to ignore default alerts than custom ones (44% vs. 29%). This difference was statistically significant ($z=4.093$, $p< .001$).

When we compared the conditions, we did not observe any important differences in participants' decisions to attend to the notifications. None of the pairwise comparisons was statistically significant. This may have been because the high volume and high proportion of notifications with default alerts across all conditions minimized the contrast between the conditions.

5.3.2 Effectiveness of Attendance Decision. As attendance decisions take into account both decisions to attend to notifications and to ignore them, we analyzed these two decisions separately, as combining both could average out some differences between these two phenomena. Figure 7 illustrates the participants' perceptions of their decisions to either attend to or ignore notifications, with the notifications further separated into those with customized alerts and those with default alerts, across all three conditions. Firstly, the figure shows that, overall, participants perceived their decisions to attend to be very helpful. In the baseline condition, they perceived such decisions as helpful 91.9% of the time. However, they saw them as even more helpful in the alert assistance (96.6%, z=2.141, p=0.032) and the context-aware conditions (96.6%, z=2.704, p=0.007). When asked to compare their notification-attendance decisions

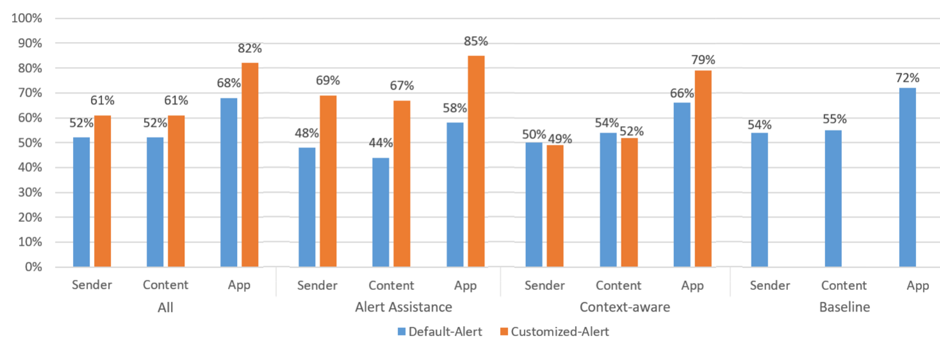

Figure 5. Comparison of the correctness of speculation about notifications' apps, senders, and content across the alert assistance, context-aware, and baseline conditions. Each bar represents the percentage of correct speculations for a particular source in each condition

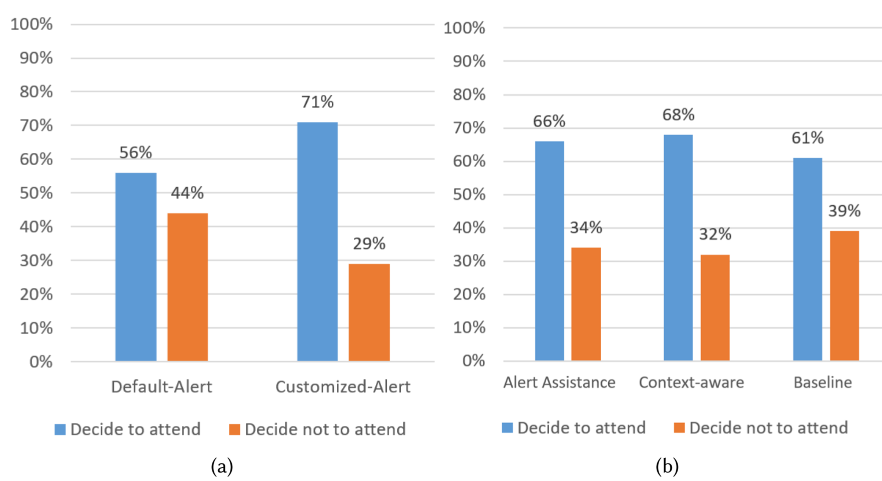

Figure 6. Comparison of the decide to attend and decide not to attend across (a) default-alert and customized-alert; (b) alert assistance, context-aware, and baseline conditions

Table 3. Participants' self-reported reasons for ignoring notifications, by customization status

	Default-Alert	Customized-Alert
No time to read at that time	28.6%	61.2%
Thought it might take time to respond	17.14%	28.6%
Thought content not worth seeing	11.4%	6.1%
Thought sender was not important	8.6%	6.1%
Thought content was not important	8.6%	6.1%
Thought notification from this sender is not urgent	25.7%	12.2%
Thought content was not urgent	34.3%	30.6%

across customized and default alerts, the participants perceived attending to customized ones as more helpful (98.7% vs. 93.7%, z=2.716, p=0.007).

When asked about their decisions to ignore notifications, their helpfulness ratings were not as pronounced. We found no significant pairwise differences in the perceived helpfulness of ignoring alerts across the alert assistance (75.8% helpful), context-aware (78.6%), and baseline (74.4%) conditions: i.e., Alert Assistance vs. Baseline: z=1.051, p=0.293; Context-aware vs. Baseline: z=1.034, p=0.301; Alert Assistance vs. Context-aware: z=0.056, p=0.956.

However, a difference in the perceived helpfulness of decisions to ignore alerts was observed between customized and default ones (68% vs. 79% helpful, respectively; z=-2.448, p=0.0144). In the alert assistance condition, our participants were substantially less likely to perceive their decision to ignore customized alerts as helpful, as compared to ignoring default alerts (63% vs. 85% helpful; z=-3.011, p=0.003). On the other hand, no such notable difference was observed in the context-aware condition (customized, 74% helpful vs. default, 81% helpful; z=-0.124, p=0.901). This further again suggests a fundamental difference between the experience of receiving customized alerts consistently vs. only intermittently. To further understand this phenomenon, we delved into the reasons participants chose to ignore certain notifications, particularly in cases where they viewed that decision as unhelpful.

These reasons are outlined in Table 3. The primary reason participants gave for ignoring notifications with customized alerts was their unavailability, which accounted for more than three-fifths of the responses. This suggests that they perceived their decisions to ignore customized alerts as less effective primarily because they felt unable to address them at the time, rather than due to a lack of awareness or understanding of the underlying notification's content or

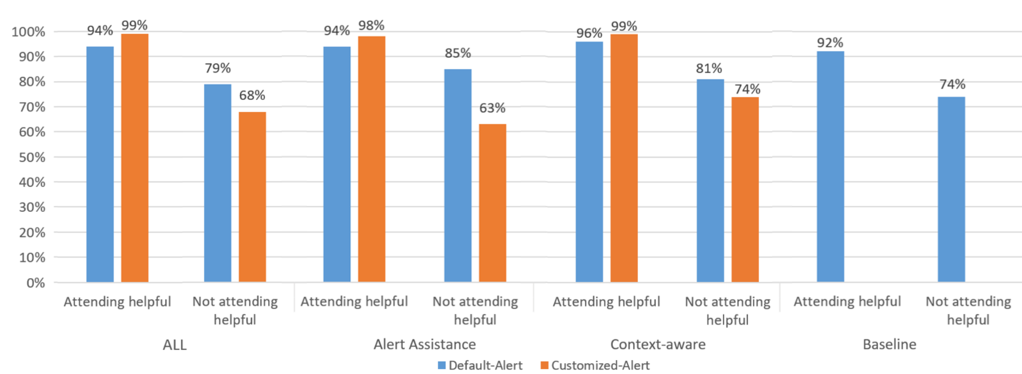

Figure 7. Participants' perceptions of the helpfulness of their own decisions to attend or not attend to notifications, by alert-customization status and experimental condition

source. For notifications with a default alert, in contrast, unavailability was cited less than one-third of the time. The primary reason participants ignored this latter type of notification was speculation that its content was unimportant or non-urgent. This contrast indicates that, while participants seemingly found their decisions to ignore customized alerts less helpful, the reasons they chose to ignore customized and default alerts were different; and the logic behind their perceptions of unhelpful decisions likely varied across alert types as well.

5.4 Customized Alerts Did Not Cause Additional Disturbance

To enable us to answer RQ2, we evaluated whether customized alerts from NotiSpeculate led to participants perceiving more disturbances. Contrary to our hypothesis, our regression results indicated that the disturbance scores for notifications accompanied by customized alerts (M=2.15, SD=1.61) were lower than those for notifications accompanied by default alerts (M=2.48, SD=1.84), and that this difference was statistically significant (z=-2.591, p=0.010). When we compared perceived disturbance across the three conditions, we found the lowest disturbance scores in context-aware condition. However, differences in perceived disturbance across the conditions were all non-significant (Alert Assistance: M=2.48, SD=1.89; Context-aware: M=2.21, SD=1.59, Baseline: M=2.43, SD=1.83). That is, our findings do not support the notion that reducing the quantity of customized alerts by delivering them only under certain circumstances can reduce perceived disturbance.

5.5 Selecting Sound and Vibration Alerts

5.5.1 Configuration of Sound and Vibration Alerts. Lastly, we aim to address RQ4 in this section. The participants' choices of sound alert were highly diverse across timbre, melody, and mode. However, they exhibited a general preference for brighter-sounding modes over darker ones. Table 4 outlines the distribution of ringtone modes against melodies. When we look deeper into the configuration of a certain type of notification, we find the result is still based on participants' preferences. For example, Table 5 shows the distribution of ringtones against melodies about the categories of work.

Table 4. Modes and melodic configurations of the user-defined categories

Mode / Melodic	Dark-Bright				Total
Monotone	11	5	12	9	37
Rushing	8	5	1	4	18
Lightweight	7	8	4	18	37
Slow, sinking sensations	2	9	5	12	28
Long, slow delay	5	10	9	14	38
Total	33	37	31	57	158

Table 5. Modes and melodic configurations of the user-defined work categories

Mode / Melodic	Dark-Bright				Total
Monotone	4	3	4	2	13
Rushing	3	1	0	1	5
Lightweight	2	2	1	1	6
Slow, sinking sensations	1	3	1	2	7
Long, slow delay	1	1	3	4	9
Total	11	10	9	10	40

Looking at vibration settings, the intervals and durations were highly diverse. More than half of the categories had one interval between vibrations (88 categories, or 55.3%). Categories with no interval were the second most common, accounting for 35.2% of settings. Nine categories had two intervals, and two categories had three. There was also one category, related to food delivery, that was assigned seven intervals. When we delve deeper into the configuration of certain types of categories, we find that the results still reflect participants' preferences. For example, some participants set a single short vibration, while others opt for several long vibrations in the same type of notifications.

5.5.2 Strategies of Setting Sound and Vibration Alerts. Regarding their approaches to assigning meanings to notification alerts, we classified four main strategies:

- Familiarity with Alerts: This approach used familiar cues or associations with the notifications, such as those resembling the original app. P10 explained, *"[s]ince most of the notifications in that category come from LINE, I set the vibration to be the same as Line's vibration, which helps me get familiar with this alert."* P09 opted for a sound similar to the original Twitter notification sound (the current X) and explained that it does not require additional time to become familiar with the sound.
- Distinctiveness: This approach is aimed at creating unique and distinguishable alerts for each category. For instance, some participants would configure short or soft sound alerts for categories with a higher volume of notifications, while others chose a different alert compared to the original app. P24 mentioned, *"Regarding vibration, I don't have any special design logic. I aim to distinguish each category with different vibration patterns."* Some participants manage the noticeability of notifications in specific notifications. They believe that longer, faster, and more pronounced differences in high and low-frequency sounds as well as vibrations with more frequency and longer duration are more noticeable. They configure these characteristics for notifications they deem important. P36 said, *If the vibration is very brief, I'm concerned that I might not notice it and miss something urgent.*
- Control alert disturbance: This approach is aimed at controlling the alert disturbance. Participants set shorter alerts for categories that might contain a large amount of notifications. P34 explained, *For notifications from family and friends, I prefer shorter alerts because there are many, and I don't want the alert to be too lengthy.*
- Musicality Expression: This strategy involves using alert disturbance, for example, the duration of the alert, and musical characteristics to express different notification essences.
  Time urgency: Participants used alerts to express the time urgency of the notification. For example, they opted for a fast-paced sound for notifications deemed more urgent, while using smooth sound for not urgent notifications. P16 explained, *Interest-related ones are those that sound slower and less urgent. I know I received the message, but I can deal with it when I have time.* In the case of vibration, P34 used a long-duration vibration to express the urgency of the notification.
  The proximity of the relationship with oneself: Participants configured different alerts based on the proximity of the relationship. For instance, P10 used higher-pitched tones for closer senders.
  Responding to received emotions: This strategy involved choosing alerts that were reflective of the emotion evoked by this type of notification. For sound, they selected a lower tone for notifications associated with work because these notifications make them feel burdened, while a lighter tone for social-related ones because of the happiness. P44 said, *"For the category related to the lab, I chose a somewhat low tone. Notifications from this category are often serious and perhaps less cheerful, hence the lower tone."* This approach extends to vibration settings as well, considering that increased vibration frequency can be more irritating. Therefore, they aligned the vibration intensity with notifications that tend to evoke a more unpleasant feeling. P06 explained, *Multiple vibrations are more annoying, so I set it to vibrate more times for important matters. For notifications related to family and shopping, I set it to vibrate only once, as these are more casual and relaxed for me.*
  Regulating received emotions: In contrast to the previous strategy, this approach is designed to balance the emotions brought about by the notifications. For the type of notifications that may induce stress, participants

set more pleasant ringtones. P45 mentioned, *I used a guitar sound for work because I found work can be stressful, and I want to have a more soothing sound in that context.*

6 DISCUSSION

6.1 Context-Aware Alert Does Not Decrease Disturbance, and May Even Decrease Speculation Accuracy

Prior study [9, 53] suggested assisting only when it is challenging to speculate the notification. However, our findings indicate that refraining from providing a user-defined alert in situations where users can easily speculate the notification does not reduce disturbance; in fact, it may even decrease speculation accuracy. This can be attributed not only to the non-disruptive nature of user-defined alerts but also to the confusion introduced by the inconsistency in the alert delivery in context-aware conditions. First, the overall frequency of receiving customized alerts was lower in the context-aware condition, and this decreased exposure could have led to lower familiarity. Second, the fact that a given type of notification was sometimes accompanied by a customized alert, and sometimes not, could have been seen as inconsistent and caused confusion. In the original notification system condition, users may speculate about notifications based on the context of previous notifications. However, in the case of utilizing a customized alert, users will directly speculate about the notification based on the alert. For example, even when, at the moment, the notification is easily speculated because it is from the same app and sender as the previous minutes, if the participants sense a default alert, they might consider it to come from an uncategorized notification. Context-aware alerts can be effectively employed when users are attentively engaged in receiving notifications. In this scenario, future work should explore alternative contexts to mitigate potential disturbances caused by customized alerts, rather than resorting to default alerts solely for the sake of accurate predictions.

Therefore, if a future system is intended to allow its users to 'preview' their notifications via customized alerts, it can allow users to decide when to use each mode (i.e., customized alert, context-aware alert, default alert). Otherwise, we recommend providing these customized alerts consistently in all cases, rather than intermittently.

6.2 Customized Alerts Provide Cues Helpful for Correct Speculation, but Is Heightened Awareness of Notifications Always Good?

Our findings indicate that, as we expected, customized alerts were more effective than default ones at aiding users' speculation. This positive impact suggests that customized alerts serve as cues, enabling users to 'preview' certain notifications before shifting their attention toward them.

Increased awareness of notifications has self-evident advantages to people making decisions to switch attention to their phones, and this probably underlay our finding that our subjects saw their decisions to attend to customized alerts as more beneficial than their decisions to attend to default ones. However, our results also highlight a greater likelihood that people will perceive their decisions to ignore notifications as unhelpful when customized alerts are consistently delivered. In other words, heightened awareness resulting from customized alerts appears to be a double-edged sword.

During our experiment, on most occasions when our participants decided to ignore notifications, they were aware that these were notifications they had categorized themselves. The main reason they cited for not attending to them was their current unavailability. Sometimes, they deemed it acceptable to have not engaged with customized notifications. More often, however, they perceived the act of ignoring such notifications as less beneficial than ignoring ones that did not carry customized alerts. It should of course be borne in mind that the experimental subjects did not necessarily have a precise understanding of the content of the notifications they received before they actually read them; and in that context, it is worth noting previous research findings [9, 43, 44] that the anticipation or expectation of certain notifications might increase participants' anxiety if they cannot attend to them. As such, increased awareness may not always be advantageous. When smartphone users are unable to engage with notifications due to their current circumstances, we risk distracting them from their tasks at hand and even causing them anxiety by alerting them to the arrival of notifications that – sight unseen – they can accurately identify as very important.

The primary aim of this research has been to enhance phone users' awareness of notifications, as a means of making their engagement with them more productive. Raising the question of whether heightened awareness is always beneficial might seem paradoxical in this context. However, this line of inquiry allows us to explore ways to improve notification awareness while mitigating undue worry. For instance, NotiSpeculate did not factor in users' levels of busyness [59], their current states of attention [30], or their respective optimal timings for notification delivery [7, 44, 46]. Reworking NotiSpeculate to take account of such matters might involve reducing its users' awareness of certain notifications under specific circumstances, thereby averting the potential distress associated with an inability to respond to categorized notifications. But of course, any such 'planned avoidance' of notifications should be carefully calibrated and allow users to set varying levels of alert. For instance, during periods of intense busyness, only the most urgent and critical notifications would deliver their customized alerts, while less important ones could have their customized alerts postponed. Ultimately, these findings underscore the importance of looking beyond mere awareness, of context and availability, when studying the dynamics of dealing with notifications. Having established that NotiSpeculate improves notification awareness, our next logical step will be to adapt it to account for its users' busyness and availability.

6.3 Implications for Notification Alerts

Our results reveal four strategies users employ to set sound and vibration alerts. Since user preferences vary significantly, allowing them to manually define their notification alerts is essential. However, the notification system should also assist in automatic configuration after learning user preferences or intervene when users cannot decide on their own. For automation, one approach is to leverage generative AI. Generative AI designed for music can be utilized to create unique ringtones or auditory patterns conveying the emotional 'essence' of each notification, considering its specific content and characteristics. For example, rapid vibrations or rhythms could indicate urgency. However, implementing such an approach might result in more extensive variations in individuals' alerts than observed in our experiment. While it would enhance the alert system, it carries certain risks. One risk is the potential to exceed thresholds of annoyance, disturbance, or confusion. Another concern is that AI-generated ringtones or vibrations may not accurately represent the subjective meanings users assign to their notifications. Therefore, careful consideration of user interpretation and understanding is necessary before endorsing such an approach. Future research should investigate the effectiveness of generative AI in designing notification alerts and how to better design automated methods for setting notification alerts.

6.4 Research Limitations

This paper is subject to several limitations. First, the study's setup made it impossible to track how people used desktop or web apps or wearable devices, which could affect how they interacted with notifications. For example, participants might decide not to answer an IM notification on their smartphone if they already replied to the relevant message on their laptop. However, our ESM questionnaires did not ask participants to tell us about what they did on other devices. So, we couldn't tell how much these devices might have influenced their speculation and attendance. Second, the ESM items covering the participants' self-reported correctness of attendance used the statement, "No, I don't need to know that notification at that time, but I chose to see it." If people choose this statement, they might feel like they are being critical, which might make them choose another option. Third, the ESM items covering the participants' self-reported speculation on the source of the notification used the statement, "Yes, I speculated the notification at that time, but I have no idea what the category/sender/content/app is." Participants may feel confused if they speculate wrongly about the source, but the meaning of the statement above is not the same as "speculate wrong," and this may lead them to choose other options. Fourth, to reduce recall bias in the ESM, we only sampled notifications sent within 30 minutes of the last time a participant used their phone. Due to the length of the ESM questionnaire, self-reported attentiveness could have been skewed toward times when participants were more attentive to their phones. Fifth, due to the specifications of our target scenario, we did not consider users who mainly kept their phones in Silent Mode. These users might display different kinds of speculation when they switch their phones to Normal or Vibrate Mode. Nor did this research consider alerts other than those based on ringtone and vibration, e.g., the flashing lights offered by certain phones. Finally, we conducted our field study in the authors' home country; most of our participants were in their twenties, and half of them were students. As a result, it is unclear whether our findings can be generalized to other groups of people from other age groups and/or cultures.

7 CONCLUSION

Alert systems are intended to inform users of the arrival of notifications on their phones, but users would not receive additional information about notifications through alerts. This paper had a first attempt at assigning meaning to alerts on the phone to customized alerts that bring user-defined information and found that the system using this approach was favored by participants. Our preliminary co-design workshop with 29 participants and ESM study with 37 participants had four high-level takeaways. First, our results offer a more complete picture of how speculation and attendance on notifications and the factors that may affect users' perceived disturbance. Secondly, our results show that the inconsistency of alerts in conditions where users can easily speculate the notification might confuse. Third, while user-defined alerts increased speculation accuracy, they simultaneously decreased perceived helpfulness when users were unable to attend to the notification immediately. Finally, we categorized strategies for assigning meanings to alerts. To summarize, an alert that brings user-defined information is worth supporting in future notification systems due to its effect on speculation and selective attendance, and it is hoped that this paper's design recommendations will assist smartphone users in speculating about notifications more accurately, and make better decisions about whether to attend to them or not.

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