"I Want Lower Tone for Work-Related Notifications": Exploring the Effectiveness of User-Assigned Notification Alerts in Improving User Speculation 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 address this challenge, through an experience sampling study, we investigated the effectiveness of delivering user-assigned alerts in influencing users' speculation accuracy, attendance effectiveness, and perceived disturbance. Our findings suggest that while user-assigned alerts enhanced the accuracy of speculation and improved participants' decisions to attend to notifications, the increased notification awareness sometimes led participants to view their decision to ignore notifications as less favorable. Moreover, we found that sporadic alert delivery disrupted the association between the alert and the notification, leading to no reduction in perceived disturbance nor improvement in speculation accuracy. In assigning alerts to notifications, participants considered five strategies: familiarity, distinctiveness, disturbance, emotional resonance, and dimension representation.

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 [8]. 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 [30, 54, 58], suggesting that by allowing users to assign specific alerts to particular types of notifications—especially those they prioritize—users could, upon sensing the alert, gain a preliminary understanding of the incoming notification [8]. This mechanism is theorized to enable more strategic decisions about notification engagement, thereby optimizing attention allocation and differentiating important notifications from less critical ones upon arrival. However, this assumption remains untested, and the potential benefits of assigning specific alerts to notifications—namely, improved notification awareness and effectiveness of notification attendance—remains empirically under-explored. Recognizing the potential of this approach for enhancing human-notification interaction and the effectiveness of users' attention switch, it 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 lead to more accurate speculation and more effective notification attendance?

In addition, prior research [8] has shown that users are adept at speculating the nature of notifications when contextual clues, such as recent interactions with apps or contacts, are present. These clues provide a foundation for accurate speculation; however, the accuracy of speculation significantly diminishes without them. Considering that immediate contextual cues often allow users to make accurate speculations, and introducing new alerts might cause additional disturbance, we aim to explore the potential of delivering user-assigned alerts primarily in situations where users lack these strong clues—specifically, when there has been no recent interaction. This approach is intended to reduce the frequency of new alerts, thereby mitigating users' perception of disturbance from user-assigned alerts, while potentially still enhancing users' overall accuracy in speculating about notifications due to the assistance provided in challenging scenarios. To investigate the potential and effectiveness of this approach in reducing perceived disturbance and improving speculation accuracy, respectively, we ask the second research question:

RQ2: How does a notification-delivery mechanism, which restricts the deployment of user-assigned alerts based on the presence of recent interaction, affect users' speculation accuracy, notification attendance, and perceived disturbance?

Finally, understanding how users decide on specific alerts for their notifications is crucial for designing an effective alert configuration interface. This involves exploring the meanings users attach to different notifications and the rationale behind their chosen alerts for these meanings. Therefore, our third research question focuses on the strategies users employ in this selection process:

RQ3: What strategies do users employ in the assignment of alerts to notifications?

To answer these questions, our research commenced with preliminary workshops aimed at understanding user perceptions towards the idea of assigning specific alerts to notifications. The positive feedback and initial insights garnered led to the development of the NotiSpeculate Android application, a system enabling users to create notification groups and assign distinctive alerts to these groups. A within-subject field experiment followed, comparing three conditions: a *Baseline* condition setting with default alerts, an *Assigned-Alert* condition where users' assigned alerts were used, and a *Recent-Interaction* condition implementing a context-aware alert mechanism. We adopted the experience sampling method (ESM) to capture study participants' self-reported notification speculation accuracy, notification attendance, and perceived disturbance, and conducted post-study debriefing interviews to understand participants' strategies in notification alert assignment. This paper makes several significant contributions:

- It presents empirical evidence that user-assigned alerts can enhance the accuracy of notification speculation and increase the effectiveness of the decision to attend to notifications.
- It shows that an alert delivery mechanism, which refrains from delivering user-assigned alerts when the situation presumably allows users to easily speculate about notifications, specifically when there has been recent interaction—does not decrease perceived disturbances or enhance speculation accuracy. This outcome is attributed to the intermittent delivery of user-assigned alerts, which undermines the system's effectiveness.
- It uncovers five main strategies in assigning alerts to notifications, providing valuable insights for the design of future notification systems.
- It reveals the paradoxical effect of heightened notification awareness, where increased awareness can lead to negative self-assessment of ignoring notifications, especially when immediate action is perceived as not feasible.

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, 7, 9, 14, 15, 21, 32], location context [38, 45, 55, 61], time of day [3, 45, 51, 52, 55, 61], recent phone interaction [44, 54], ringer mode [16, 21], device context [16, 21, 24, 26, 33, 39, 60], conversational context [56, 57], personal context [31, 64], and arousal emotional states [19, 40].

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, 47, 54], even when their device is set to silent mode [10, 46]. However, only a small proportion of the myriad of notifications are considered critical or urgent by the users [63]. 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 [8]. Research has also revealed specific user preferences towards notifications: they tend to prioritize notifications related to interpersonal communication [32, 50, 54] and may not appreciate notifications about certain topics or from specific sources [32, 62]. Even within the same app, users show different attentiveness levels towards different notifications. For instance, they are generally more attentive to messages from individuals with certain relationships [30, 32, 38, 39, 64] 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.

On the other hand, 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, 11, 17, 37, 42, 44], presuming that if notifications are sent at the non-suitable timing, any notification (even preferred ones) would be regarded as disturbance or distraction. 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 [10] and could potentially mitigate inattention [28]. Disabling notifications has also been found to reduce external interruptions [48, 49]. However, 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, 48, 49]. This self-initiated phone checking does not result in less phone checking than when the phone's notification alert stayed activated [10]. As a result, prior research shows that people quite often check notifications, even when they have been engaged in a task-at-hand [7]. This behavior, sometimes referred to as self-interruption [13], may not be less impactful than external interruptions [10], suggesting that the strategies aimed at suppressing notifications may not always achieve the desired outcome, especially sometimes users still desire to be notified [8]. Therefore, some research explores how users perceive and utilize different ringer modes as effective means to manage their attention [10, 25]. When users finish situations where they cannot be disturbed, they switch to vibrate mode or normal mode to maintain awareness of notifications [10], and most people commonly use the mute button to change the alert mode [46]. Regarding different ringer modes, Mashhdi et al. [36] found that notifications with accompanying alerts are 12 times more likely to be immediately attended to compared to those without alerts. 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 [10, 46].

Additionally, recent research has indicated that notification alerts act as crucial cues enabling users to speculate about the source and content of notifications, which can positively improve their decision to attend or not [8]. However, the present notification system, with alerts associated more with apps than with the content or sender [8], 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 theory has remained unexplored in empirical studies. 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.

3 Methodology

Our methodology was designed to explore users' reception to the concept of assigning specific alerts to notifications and the overall effectiveness of such a practice in a real-world context. Based on initial positive feedback from users from preliminary workshops, we developed the NotiSpeculate Android application, which allows users to create notification groups and assign unique alerts to these groups. Then we conducted a three-week field experiment. This phase was dedicated to evaluating the effectiveness of NotiSpeculate, focusing on its impact on users' 1) accuracy of notification speculation, 2) notification-attendance effectiveness, and 3) any shifts in users' perception of disturbance due to notification alerts.This section outlines our methodological approach.

3.1 Preliminary Workshop

The aim of the workshop was to explore users' reception to the concept of assigning distinct alerts to specific types of notifications and to gather initial insights to guide the design and development of our research application. We organized ten small-scale workshops with a total of 29 participants (15 males and 14 females), ranging in age from 19 to 41. The 29 participants were organized into 10 workshop groups, nine containing three people and one containing two. These individuals were recruited via Facebook groups designed to connect researchers with potential study participants in our country. Each workshop encompassed four phases: 1) participants sharing the types of notifications they wished to distinguish from others and their reasons; 2) participants categorizing and assigning abstract meanings to these notification categories; 3) participants brainstorming on preferred alert formats for each notification categories; and 4) participants identifying key terms associated with the notification categories to signal 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[1]. The design activities were facilitated using an online collaborative design tool named Miro[2]. Subsequently, we thoroughly examined the transcripts and the results of the discussions using affinity diagramming [34], 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.

Six types of notifications were frequently mentioned by participants to differentiate from others: 1) communication from specific individuals; 2) items of personal interest; 3) notifications for social purposes; 4) informational updates from specific apps, such as news and weather; 5) work- and professional-related notifications; and 6) notifications impacting others, like food delivery or requests. These results underscored the necessity for users to create notification groups based on application information, sender, and content to effectively meet their needs. Additionally, we observed a great diversity among participants regarding their preferences for keywords for defining these groups, due to the variety of notifications they received, even within the same type of notifications. As a result, we recognized the importance of allowing users to create and customize their notification groups and keywords flexibly in notification-group configuration. Regarding preference for notification alerts, most participants expressed a desire for alerts that would elicit specific emotions or concepts related to the nature of each notification group, such as a sense of urgency for work-related alerts or happiness or relaxation from notifications about friends. However, individual preferences still varied significantly, leading us to offer a high degree of flexibility in selecting alerts for specific notification types again.

Overall, the positive reception to the idea of customizing alerts for certain notifications, evidenced by participants' detailed discussions on specific notification preferences, reinforced our motivation to develop and evaluate a system facilitating such customization. Importantly, the workshop highlighted the deeply personal nature of notification management, emphasizing the need for a highly flexible configuration user interface for satisfying their individual needs.

3.2 The Research App: NotiSpeculate

To support our field study, we developed NotiSpeculate, an Android application designed to record notifications, dispatch ESM questionnaires, and log participant interactions along with contextual phone data. This data includes battery status, network connectivity, location, and physical activity, providing a comprehensive dataset for our analysis. NotiSpeculate integrates with the Android Notification Listener Service API[3], enabling it to monitor incoming notifications and assess whether they align with any user-defined notification groups. To ensure participants only heard notification alerts generated from our research app and not from their phone's operating system, we changed the phone's default notification alert to a silent sound. Simultaneously, our research app was configured to generate the same default notification alert when a notification arrived. For apps that deliver their own custom sound alerts, we instructed participants to turn off these alerts from the system's settings, and our research app delivered identical sounds downloaded from the web. Given

[1]Google Meet platform: https://meet.google.com/
[2]Miro: https://miro.com/
[3]Notification Listener Service API: https://developer.android.com/reference/android/service/notification/NotificationListenerService

the variety of apps with custom sounds, we targeted only those commonly used by our participants, including Facebook, Messenger, Line, Instagram, Slack, and Gmail. Depending on the device's ringer mode, NotiSpeculate triggers the appropriate alert—sound and/or vibration—associated with the matched group. If a notification does not fit into any predefined group, it defaults to delivering the originating app's default alert. To leverage the app's user-assigned alert functionalities, users must initially set up notification groups and select their alerts, detailed further below.

3.2.1 Defining Notification Groups. To define notification groups, users access a configuration webpage where they can name each group and assign it a priority level. The priority level plays a key role in determining which alert is activated for notifications that could fit into multiple groups, with the highest priority group's alert being chosen. The six common types of notification groups that emerged in the workshops were provided as example to inspire users. To categorize notifications into groups, users define keywords in three critical areas:

1. **Sender**: Matches the sender information of the notification with the specified keywords.
2. **Content**: Searches for specified keywords within the notification's content.
3. **App**: Associates the notification with the originating app based on specified keywords, verified manually by the researcher to avoid naming discrepancies.

NotiSpeculate supports flexible configuration through "OR" and "AND" logic conditions. The "OR" logic means any matching condition will trigger the alert, whereas "AND" requires all conditions to be met. For instance, as illustrated in Table 1, a user creates a group called "Research" and defines it to include notifications that mention "meeting," are sent by "Prof. Chen," or originate from the "Slack" app. Additionally, the user sets up more complex rules, such as a notification being flagged as "Research" only if it contains "research" in its content and is from the Gmail app.

Table 1. Example of keyword configuration for a notification group "Research."

	Notification Group: Research
sender	Prof. Chen
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

3.3 Assigning Alerts to Notification Groups

The process for linking alerts to specific notification groups was tailored to the type of alert. For vibration alerts, participants were given the freedom to create their own vibration patterns because the process is relatively straightforward, involving only the adjustment of vibration burst durations and the intervals between them. To facilitate this, we developed a dedicated Android application (see Figure 1) for this purpose, enabling participants to directly design and test their vibration alerts on their phones, providing an immediate sense of how the patterns would feel in real use, an experience that cannot be replicated through a web interface. Upon finalization, they associated their designed vibration patterns with notification groups directly in the same application.

Conversely, acknowledging the complexity involved in creating sound alerts for notification groups, we opted to offer participants a selection from our list of predefined sound alerts. We assembled a collection of 140 sound alerts, made available through a dedicated web configuration page.

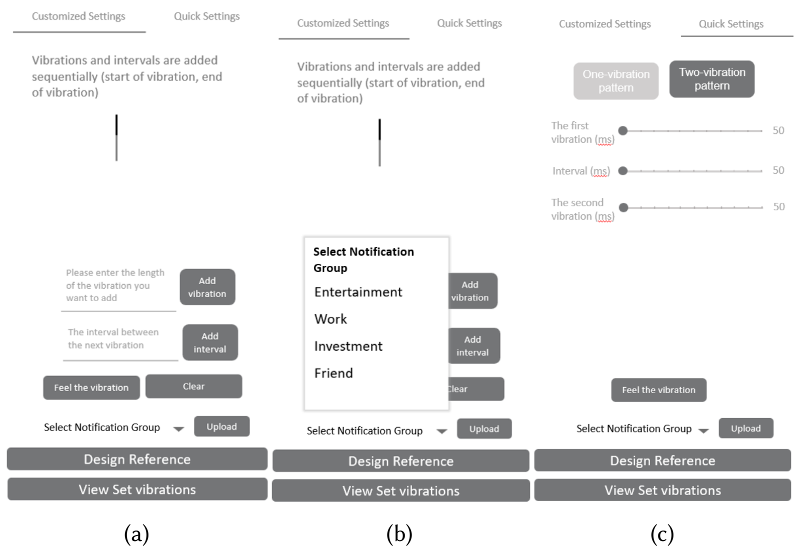


Figure 1. (a) Participant setting a short fragment of vibration lasting 400ms, followed by a gap of 400ms. (b) Participant selecting a notification group for which they want to set a vibration pattern. (c) Example of a participant using the "fast-setting" option for a two-vibration pattern

The development of these sound alerts was informed by established auditory design guidelines [6], with a particular focus on sound mode, melodic arrangement, and timbre. To cater to a broad emotional spectrum, we utilized both major and minor modes, introducing four intermediate modes to enrich the selection. Descriptors such as "bright" for major modes and "dark" for minor modes were employed to simplify choices for participants without a musical background. The composition of melodic patterns considered direction and tempo—factors are known to influence emotional responses to sounds [4, 23, 59], resulting in five distinctive melodic patterns. The timbral variety, featuring a mix of instrumental sounds, synthesized notes, and natural non-musical sounds, aimed to evoke a comprehensive range of emotions [4]. Consequently, the resulting 140 sound alerts (7 by 5 by 4), were organized across seven sub-pages on the configuration webpage, as depicted in Figure 2. Each sub-page, focused on a specific timbral theme, presented 20 sound alerts. These alerts were distinct combinations of the four sound modes (indicated in a pink box) and one of the five melodic patterns (marked in a blue box), streamlining the selection process for our participants.

3.4 The Experience Sampling Study

3.4.1 Study Design. We adopted a within-subject design. This design enabled participants to sequentially experience three different conditions over three consecutive weeks, with each condition lasting seven days. The conditions were as follows:

1. **Baseline Condition (Baseline)**: This is a baseline scenario, where the participant's phone operated using the default, original sound and vibration alerts without any user-assigned alerts.
2. **Assigned-Alert Condition (Assigned-Alert)**: Here, the participant's phone delivered user-assigned sound and/or vibration alerts for their created notification groups.
3. **Recent-Interaction Condition (Recent-Interaction)**: This condition modified the Assigned-Alert scenario by introducing recent interaction; a user-assigned alert was only activated

Figure 2. Interface for Sound-alert Selection

under specific circumstances. Drawing on findings that users can make highly accurate notification speculations following recent interactions with the sender [8], we assumed that playing a user-assigned alert would be unnecessary in such cases. Therefore, in scenarios where a participant had engaged with any of six instant-messaging apps popular in the study region (Facebook, Messenger, Line, Instagram, Slack, and Gmail) within the last 30 minutes, and a new notification from one of these apps originated from a sender with whom there had been recent communication, NotiSpeculate would refrain from delivering the user-assigned alert.

To mitigate potential biases arising from the sequence in which participants experienced these conditions, we counterbalanced the order, resulting in six possible sequences. Participants were randomly assigned to one of these sequences to ensure a balanced representation across the study. Recognizing the adjustment period required when transitioning to a new condition, we designated the initial two days of each condition as an adaptation phase. During this phase, participant data were not included in the analysis (this adaptation phase is marked in orange in Figure 3). To ensure uniformity in data collection across all three conditions, we focused our analysis on the data collected from the subsequent five days of each condition period, which were exclusively weekdays (these analysis days are delineated in Figure 3 with a red box). This approach helped to minimize

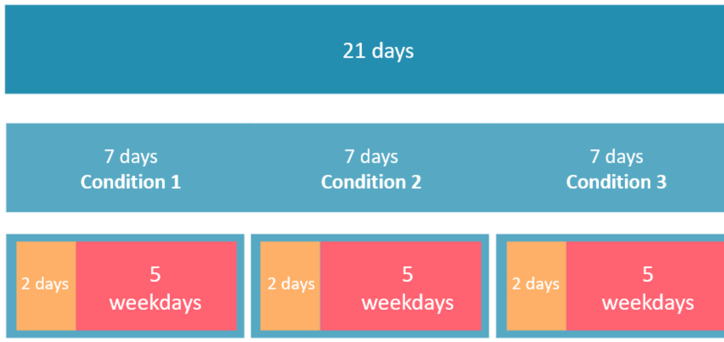


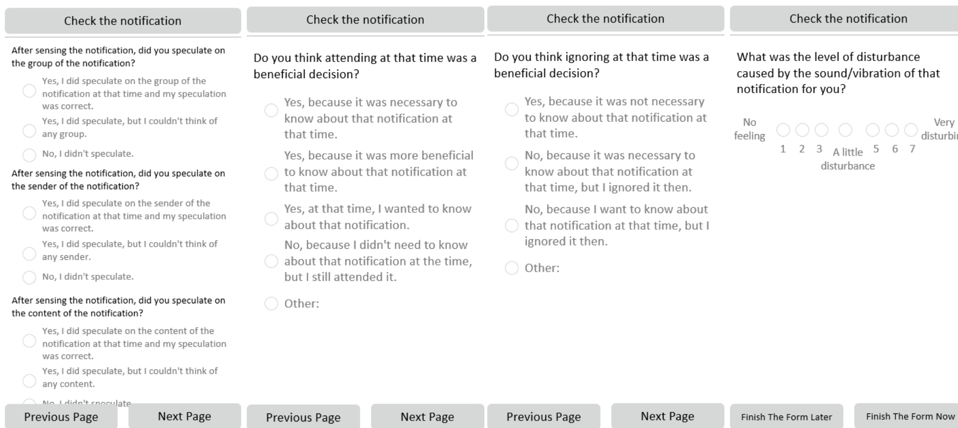
Figure 3. The Structure of the ESM Study

variability and ensure that our findings reflected a consistent and accurate measure of participant responses to each condition.

3.4.2 The Sampling Mechanism. To ensure the study was tailored to participants' daily routines, they were asked to designate a 12-hour window for each day during which they were comfortable with having their notifications sampled and receiving ESM questionnaires. Recognizing the variability in personal schedules, this window was allowed to differ between weekdays and weekends. NotiSpeculate aimed to maintain a balance between notifications accompanied by user-assigned alerts and those with default alerts. This strategy was employed to prevent a disproportionate sampling of one type over the other, which could affect the validity of our quantitative analysis. To achieve this balance, the app assigned a higher priority to the notification type that had received fewer samples up to that point in the day. As the day advanced, this weighting was adjusted to gradually increase the representation of the more frequently occurring notification type, ensuring a balanced collection of data.

Upon the selection of a notification for sampling, NotiSpeculate implemented a one-minute delay before deploying the ESM questionnaire. This delay was strategically designed to allow participants ample time to interact with the notification, if any, ensuring that their immediate response was not interrupted. Following this period, a silent notification was employed to deliver the ESM questionnaire, minimizing any potential disruption to the participant. Although an ESM questionnaire was delivered through a notification, NotiSpeculate did not sample any ESM questionnaire notification. The expiration time for the questionnaire was set to 30 minutes. This decision aligns with insights from prior research [8], which also advocates for this timeframe, and feedback from our pilot study indicated that this period strikes a balance between avoiding recall bias—where participants might forget their speculation and experience with the notification—and allowing enough time to capture a wide range of notification interaction scenarios without disproportionately favoring moments when users are immediately available to respond to the ESM questionnaire. Following the completion of an ESM questionnaire, a cooldown period of at least one hour was enforced, during which no additional questionnaires were sent. Each participant was limited to a maximum of eight questionnaires per day.

3.4.3 The ESM Questionnaire. Each ESM questionnaire provided information about its sampled 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.



(a) (b) (c) (d)

Figure 4. 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 to ignore the notification; (d) perceived disturbance by alerts

Notification Speculation. As shown in Figure 4a, the questionnaire asked whether participants' speculations about the notification group they set, app, sender, and content of the notification were correct. Even in cases where a user-assigned alert had not been used, it also asked whether they perceived that type of alert as beneficial in facilitating their speculation. Responses were provided on a seven-point Likert scale ranging from 1="Not beneficial" to 7="Very beneficial".

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 to ignore was beneficial at that time, as illustrated in Figures 4b and 4c. 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 sampled notification's sound or vibration alert and answered using the seven-point Likert scale depicted in Figure 4d.

3.5 Hypotheses

Based on our research questions, we developed hypotheses that guide our data analysis regarding three aspects: notification speculation, notification attendance, and perceived disturbance.

H1: Notification Speculation. Our first set of hypotheses (H1a-H1c) focused on notification speculation. We hypothesized that user-assigned alerts would lead to more accurate speculation than default alerts in both the Assigned-Alert condition and the Recent-Interaction condition.

- H1a: Receiving user-assigned notification alerts results in more accurate speculation than receiving default alerts.
- H1b: Receiving notification alerts in the Assigned-Alert condition results in more accurate speculation than receiving alerts in the Baseline condition.
- H1c: Receiving notification alerts in the Recent-Interaction condition results in more accurate speculation than receiving alerts in the Baseline condition.

H2: Notification Attendance. Our second set of hypotheses (H2a-H2c) centered on notification attendance. We hypothesized that user-assigned alerts would result in more effective attendance than default alerts in both the Assigned-Alert and Recent-Interaction conditions.

- H2a: Receiving user-assigned notification alerts results in more effective notification attendance than receiving default alerts.
- H2b: Receiving notification alerts in the Assigned-Alert condition results in more effective notification attendance than receiving alerts in the Baseline condition.
- H2c: Receiving notification alerts in the Recent-Interaction condition results in more effective notification attendance than receiving alerts in the Baseline condition.

H3: Perceived Disturbance. Our third set of hypotheses (H3a-H3d) focused on perceived disturbance. We hypothesized that user-assigned alerts would cause more perceived disturbance than default alerts. Additionally, we anticipated that a recent-interaction mechanism could mitigate users' perceived disturbance.

- H3a: Receiving user-assigned notification alerts results in more perceived disturbance than receiving default alerts.
- H3b: Receiving notification alerts in the Assigned-Alert condition results in more perceived disturbance than receiving alerts in the Baseline condition.
- H3c: Receiving notification alerts in the Recent-Interaction condition results in more perceived disturbance than receiving alerts in the Baseline condition.
- H3d: Receiving notification alerts in the Assigned-Alert condition results in more perceived disturbance than receiving alerts in the Recent-Interaction condition.

3.6 Participant Recruitment

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. We set this target audience because the target scenario for our field study is users' attendance decisions made after sensing a notification alert when their phones are not in use. 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.

3.7 Study Procedure

Following the confirmation of participation by interested individuals, we conducted an introductory meeting where the research team thoroughly outlined the study's aims and methodologies. During this session, participants were guided through the process of creating notification groups and assigning specific alerts to these groups, with the team encouraging questions to clarify any aspects of the procedure and ensure full comprehension.

To allow participants ample time to thoughtfully configure their notification groups and familiarize themselves with the alerts they had chosen, a follow-up meeting was scheduled no less than three days after the initial orientation. This preparatory period served a crucial dual purpose: it ensured participants were well-acquainted with their custom alerts, thereby minimizing potential biases in their speculation abilities across different study conditions. Our goal was to facilitate a fair comparison between the Assigned-Alert and the Recent-Interaction conditions, by eliminating performance discrepancies that might arise from unfamiliarity with the alerts, rather than from the effectiveness of the alert delivery mechanisms themselves. To achieve this, NotiSpeculate was equipped with a Test feature that allowed participants to evaluate their recognition of the sound and vibration alerts associated with their defined notification groups. Successful identification of the alerts was a prerequisite for moving on to the Assigned-Alert or Recent-Interaction phases, ensuring participants had reached a necessary level of alert familiarity.

Upon concluding the ESM portion of the study, participants were compensated US$50 and invited via email to participate in an optional post-study debriefing interview. 27 of the participants took part in the interview and received a bonus of US$7. All interviews were audio-recorded and transcribed.

3.8 Data Analysis

As mentioned earlier, assuming that participants might need some time to adjust when switching to a new condition, we did not analyze the data from the first two days of each new condition. To explore the effects of different conditions and the receipt of user-assigned alerts on our target dependent variables, we performed statistical analysis utilizing mixed-effects regression models with the "lmerTest" [29] package in R software[4]. Our dependent variables include participants' notification speculation, attendance effectiveness, and perceived disturbance. For binary variables, including speculation accuracy across various notification characteristics and attendance effectiveness, we employed mixed-effects logistic regression. For perceived disturbance, a numeric variable, we used mixed-effects linear regression models. Throughout our analysis, participants were treated as random effects to address individual differences due to multiple data points from each participant's ESM responses. Using mixed-effects regression models allowed us to account for both fixed effects and random effects.

Our qualitative data analysis involved open coding of interview transcripts using Atlas.ti[5] to gain insights into NotiSpeculate users' experiences with NotiSpeculate and strategies of alert assignment. Regular team meetings aided in refining emerging codes and categories, ensuring a thorough understanding and accuracy as we integrated new insights into our analysis.

4 Results

4.1 Data Overview

Over the 15-day study period (excluding the initial two days in each condition), the participants collectively received 164,794 phone notifications. The distribution of these notifications across the different conditions was as follows: 59,167 (35.9%) in the Assigned-Alert condition, 53,215 (32.3%) in the Recent-Interaction condition, and 52,412 (31.8%) in the Baseline condition. A significant share, 25.3% or 41,628 of these notifications, were allocated to notification groups predefined by the participants. The breakdown of notifications within these predefined groups as a percentage of the total notifications received in each condition was: 27.0% (15,995 out of 59,167) for Assigned-Alert; 22.8% (12,133 out of 53,215) for Recent-Interaction; and 26.5% (13,500 out of 52,412) for Baseline. This indicates that a substantial portion of the notifications, ranging from roughly one-fourth to one-third, were recognized as part of user-created notification groups. Particularly in the Recent-Interaction condition, designed to trigger user-assigned alerts based on the recency of interaction with the contact associated with the notification, 64.5% of the notifications within user-assigned

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

groups actually triggered the user-assigned alerts, with the remainder, nearly one-third of the cases, reverted to using their default alerts.

Participants responded to 2,897 ESM questionnaires, among the notifications that yielded ESM responses, the median time between the notification-triggered cue and the time the participants started to fill the questionnaire is 1,009 seconds. Despite NotiSpeculate's attempts to balance the sampling between notifications with default alerts and those with user-assigned alerts, the distribution mirrored the overall notification distribution mentioned above. Specifically, 27.3% (791) of the notifications prompting ESM responses were accompanied by a user-assigned alert, while the remaining 72.7% (2,106) had the default alert. Among these 791 instances with the user-assigned alert, 59.0% (467 out of 791) of the time participants noticed the notification alert. And among these instances, 60.6% of the time participants speculated about the notifications based on the alerts (283 out of 467), which is higher than the instances where participants speculated about default alerts (55.8%, 542 out of 972, $z = 5.139$, $p < .001$). In addition, participants also attended to notifications with user-assigned alerts at a higher rate (71%) compared to those with default alerts (56%). In the following sections, we start answering our research questions.

4.2 H1: Participants' Speculation Accuracy for Notifications with User-Assigned Alerts vs. Default Alerts

Figure 5 showcases the comparison in speculation accuracy about notifications when accompanied by user-assigned versus default alerts across different conditions. In the overarching comparison across conditions, speculation accuracy did not significantly differ. Specifically, in both the Assigned-Alert (app: z=1.255, p=0.209; sender: z=1.429, p=0.153; content: z=-0.026, p=0.980) and Recent-Interaction conditions (app: z=0.148, p=0.883; sender: z=-1.104, p=0.270; content: z=-0.804, p=0.422), participants' ability to accurately speculate on the app, sender, and content of the notifications showed no notable improvement over the Baseline condition. This result may be partially explained by the fact we presented earlier that only a quarter to a third of notifications were part of the notification groups set by participants, leaving the bulk accompanied by default alerts.

However, a significant difference was observed when delving into the accuracy of speculation between default and user-assigned alerts within each condition. In the Assigned-Alert condition, the presence of user-assigned alerts markedly improved participants' speculation accuracy regarding

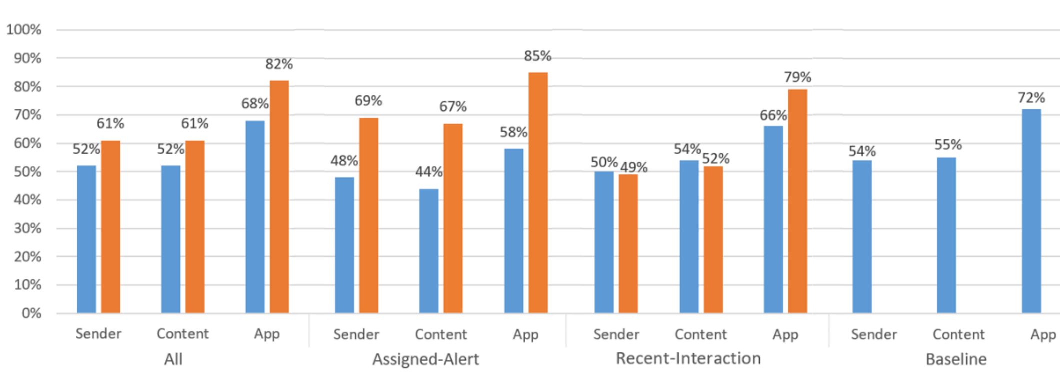


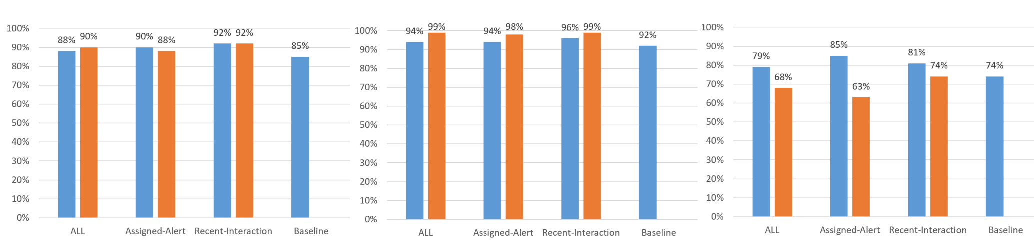
Figure 5. Comparison of the correctness of speculation about notifications' apps, senders, and content across the Assigned-Alert, Recent-Interaction, and Baseline conditions. Each bar represents the percentage of correct speculations for a particular source in each condition

the app (85% vs. 58%, z=4.366, p<0.001), sender (67% vs. 44%, z=3.102, p=0.002), and content (69% vs. 48%, z=3.743, p<0.001) compared to notifications with default alerts. However, this improvement was not replicated in the Recent-Interaction condition, where the differences were minimal (app: 79% vs. 66%, z=1.307, p=0.191; sender: 52% vs. 54%, z=0.161, p=0.872; content: 49% vs. 50%, z=0.092, p=0.927). Furthermore, the accuracy in speculation regarding the sender and content of the notifications with user-assigned alerts experienced a significant drop in the Recent-Interaction condition, declining from nearly 70% to about 50% compared to the Assigned-Alert condition. This indicates that the positive impact of user-assigned alerts on enhancing speculation accuracy was only evident when the alerts were delivered consistently, and diminished with intermittent delivery. Thus, our H1a is partially supported, and both H1b and H1c are not.

This outcome was reinforced by feedback obtained during debriefing interviews with participants. Many expressed their dissatisfaction with the sporadic delivery of user-assigned alerts. They highlighted that the purpose of assigning specific alerts was to ensure they could immediately recognize the arrival of particular notifications. It was perceived that, once an alert was determined for recognizing a certain notification group, it became a critical cue for identifying the notifications within that group, irrespective of the context. For instance, P16 shared his perspective on why continuous delivery of user-assigned alerts was essential, even during active engagements in conversations through messaging apps. He stated, *"The reason we use messaging apps intensively over a short period is that both parties consider the matter important. We want to clarify and resolve the issue quickly. Therefore, in such situations where we both deem the matter crucial, receiving the [user-assigned] alert is beneficial for me."* His experience of receiving a default alert for a notification group led him to mistakenly believe that the notification was from a different source or related to a different content than the one he was actively engaged with. Similarly, P9 voiced his concerns about the occasional delivery of alerts, despite understanding its intended purpose, *"I find the occasional delivery quite odd. It should either be all in or not at all. It'd be rare that someone prefers intermittent alerts. For example, if Gmail sometimes triggers the [user-assigned] alert and sometimes doesn't, and if the messages that don't send this alert are important, I wouldn't know about them immediately."*

4.3 H2: Effectiveness of Decision to Attend to and Ignore Notifications

Illustrated in Figure 6b, participants across all conditions generally viewed their decision to interact with specific notifications positively. However, regression analysis showed that even the minor differences between the Baseline condition and the respective user-assigned alert conditions were



(a) Overall effectiveness of attending and ignoring notification (b) Effectiveness of attending notification (c) Effectiveness of ignoring notification

Figure 6. Participants' perceptions regarding the effectiveness of their decisions to attend or ignore notifications across the Assigned-Alert, Recent-Interaction, and Baseline conditions. Each bar represents the percentage of choosing the decision as beneficial

statistically significant (vs. Assigned-Alert: 91.9% vs. 96.6%, z=2.141, p=0.032; vs. Recent-Interaction: 91.9% vs. 97.4%, z=2.704, p=0.007). Moreover, participants also more often considered attending to notifications with user-assigned alerts beneficial than attending to those with default alerts (98.7% vs. 93.7%, z=2.716, p=0.007).

Unexpectedly, a distinct pattern was observed regarding participants' perceptions of ignoring notifications. As shown in Figure 6c, there was a tendency among participants to view ignoring notifications as more beneficial when these notifications were accompanied by default alerts than user-assigned alerts (79% vs. 68%, z=-2.448, p=0.014). This effect was especially marked in the Assigned-Alert condition (default: 85% vs. user-assigned: 63%, z=-3.011, p=0.003), while the difference in the Recent-Interaction condition was not statistically significant (default: 81%, user-assigned: 74%; z=-0.124, p=0.901). This suggests that the overall perception of the benefit of ignoring notifications between user-assigned and default alerts was predominantly influenced by the Assigned-Alert condition, where ignoring user-assigned alerts was viewed as not beneficial nearly two-fifths (37%) of the time. In the subsequent section, we present participants' reasons for ignoring certain notifications, particularly those instances deemed not beneficial. According to these results, all H2a, H2b, and H2c are only partially supported, particularly in the case where participants decided to attend to the notifications.

4.4 The Reasons for Ignoring Notifications of Which the Decisions Perceived as Not Beneficial

In this section, we delve into participants' self-reported reasons for ignoring notifications when they perceived such decisions as not beneficial. Participants were allowed to select all applicable reasons for each sampled notification. The frequency of the reasons selected is detailed in Table 2. Nearly 90% of the time, for notifications accompanied by user-assigned alerts, participants selected reason related to the lack of time availability to read or act upon the notifications at that moment. In contrast, for notifications with default alerts, time considerations were cited much less frequently. Instead, participants often mentioned content-related reasons as the reason for these notifications. This suggests that the perceived unfavorable decision of ignoring notifications with user-assigned alerts, towards which they had heightened awareness of, was primarily due to time constraints rather than the content's appeal or relevance. In contrast, with notifications that came with default alerts, the absence of heightened awareness (due to the default alert) led participants to more frequently judge their decision to ignore as not beneficial because they assumed the content was not relevant (although they might have discovered its relevance later). This observation suggests intriguing implications regarding the potential impact of heightened awareness of notification, particularly its distracting effect, which will be further discussed.

Table 2. Participants' self-reported reasons for ignoring notifications

	Default Alerts	User-Assigned Alerts
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%

4.5 H3: Perceived Disturbance of User-Assigned Alerts vs. Default Alerts

Our results indicated that participants' perceived disturbance of the notifications accompanied by user-assigned alerts (M=2.15, SD=1.61) was lower than those for notifications accompanied by default alerts (M=2.48, SD=1.84), and this difference was statistically significant (std=-0.241, p=0.010). This result is somewhat unexpected, as it suggests that user-assigned alerts overall led to lower perceived disturbance. Moreover, when we compared perceived disturbance across the three conditions, the pairwise differences in perceived disturbance across the conditions were all not statistically significant (Assigned-Alert: M=2.48, SD=1.89; Recent-Interaction: M=2.21, SD=1.59, Default: M=2.43, SD=1.83; Assigned-Alert vs. Recent-Interaction: std=-0.089, p=0.337; Assigned-Alert vs. Baseline: std=-0.005, p=0.960; Recent-Interaction vs. Baseline: std=0.084, p=0.369). This result indicates that the rationale of the mechanism onsidering recent interaction in our study–reducing the frequency of user-assigned alerts by triggering them only under specific conditions–did not decrease the overall perceived disturbance of alerts among participants. Given these results, all H3a, H3b, H3c, and H3d are not supported.

4.6 Challenges in Setting a "Boundary" for Notification Groups

In this section, we used interview data to delve into the challenges when the participants set the notification groups. We identified two main challenges in setting rules for creating notification groups, primarily around defining appropriate boundaries for these groups. The first challenge is translating abstract preferences into concrete keywords. Participants often knew which notifications they wanted to prioritize and had a clear mental image of these notifications. However, translating this abstract concept into concrete, specific, and representative keywords that could effectively include all relevant notifications proved difficult. P11, for example, noted, *"I have an app for Yahoo News, and there are certain types of news I am particularly interested in, but I did not set it up to receive those specific notifications. Because there are so many different kinds of news, my interests fluctuate, and at the time, I didn't configure it to receive notifications for that particular group of news."* Secondly, which was deemed more challenging for certain notification groups, is excluding less-interested notifications within the group. P16 highlighted this issue: *"I am interested in certain news or want to see it immediately, but it's hard to use keywords to include just the news you want to see. If you set it broadly, you will catch a lot of irrelevant notifications."* The challenge was particularly pronounced when the notification content was diverse and unpredictable, making it difficult to anticipate beforehand which keywords would be effective. P34 shared a personal example: *"I set the keyword to be my husband because I want to know about almost all the messages he sends. But sometimes, he still sends trivial messages. You can't just use the sender information to judge, but you also can't rely solely on keywords because his messages can be too complex."* Therefore, although notification groups help participants be aware of the arrival of certain types of notifications, the diversity within these groups often leads to the receipt of some notifications deemed unanticipated or unimportant to the participants.

4.7 Participants' Strategies Behind Notification Alert Assignment

Finally, in addressing RQ3, we delve into the variety and rationale behind participants' selections of sound and vibration alerts for their specified notification groups. Despite the diversity in choices, five primary strategies emerged, reflecting common themes in how participants approached alert assignment, including: familiarity with the alert, distinctiveness, potential for disturbance, emotional resonance, and representation of dimension.

- **Familiarity with Alerts**: Several participants highlighted a preference for alerts mirroring those they were already familiar with on their devices, indicating a desire to reduce the learning curve associated with adapting to new alerts, thereby increasing ease of recognition. For instance, P10 noted, *"Since most of the notifications in that group come from the Line app, I set the vibration to be the same as Line's vibration, which helps me get familiar with this alert quickly."* This preference for familiarity was echoed by participant P09, who opted for a sound similar to the original Twitter (now X) notification sound, explaining, *"Because I used to hear Twitter's notification sound often, switching to this ringtone made it easier for me to get accustomed to it."*

- **Distinctiveness**: The concept of distinctiveness emerged as a pivotal strategy among many participants, who emphasized the importance of having a notification alert that is easily distinguishable from others. This approach was particularly crucial for notifications deemed highly important or of special interest, where the uniqueness of the sound or vibration pattern could guarantee that these alerts are immediately recognized and are not overlooked. For instance, P36 explained her strategy, *"I set a longer alert for things I believe I need to check immediately, like family-related notifications, to differentiate them from work. This is because I'm worried that a short vibration might not catch my attention, and then I might miss the notification if there's no distinct sound, especially in situations that might require urgent attention."* Similarly, P27 shared a similar approach for work-related notifications, *"Work is more critical, so I set it to be longer and to vibrate more frequently. I think if the phone is in my pocket, since I won't feel it as sensitively, I'm really worried about missing out."*
- **Minimizing Alert Disruptiveness**: In our study, a significant concern for participants was minimizing the disturbance caused by alerts, particularly for notification groups anticipated to be frequent. Several participants expressed a preference for selecting shorter and less intrusive alerts for such notification groups to reduce the likelihood of constant interruptions. For instance, P08 described their strategy for managing alerts by saying, *"For close friends, I prefer it short and sweet, family messages are frequent, and so I don't want them to be too long."* Similarly, P28 emphasized the importance of the alert's tone, especially for messages or notifications from communication apps that might occur frequently throughout the day, stating, *"For something like messages, where you might get many in a day from messaging apps, some might not be that important to you. In that case, I prefer them to be soft and melodious. If the notifications keep popping up, and you are already in a bad mood or have received many messages that day, hearing a loud and noisy tune can make you not want to check them at all. So, I prefer something less noisy."*
- **Emotional Resonance**: The emotional impact of an alert also played a crucial role in many participants' choices, with many selecting alerts that evoke a specific feeling associated with the notification's content. This strategy aimed to mirror the anticipated emotional response upon receiving notifications from specific categories. For instance, P16 described, *"For hobby-related ones, I chose something less noticeable or sounding slower, less urgent. This way, I know I've received the message, but I can deal with it when I'm free."* Similarly, some participants preferred a lower tone for work-related notifications, associating these alerts with a sense of duty and a less joyful reaction. P09, for example, explained *"I chose a tone that's a bit lower because it feels more serious, perhaps related to the lab, and it's somewhat unwelcome, less cheerful, so the sound is deeper, descending."* P6 also noted, *"More vibrations mean it's more annoying to me, so I set formal notifications to vibrate more. For family and shopping, just one vibration. For things that are more relaxed, I let them vibrate once. And the more bothersome ones, I set to vibrate more."* An interesting tactic was used by P14, who chose a guitar sound for work notifications to counteract feelings of irritation with a soothing tone: *"For work, I remember using a sound written by a guitar, thinking that work can sometimes be frustrating, so I wanted to put a more calming sound."*.

- **Representation of Dimension**: A notable strategy among participants involved using a single auditory characteristic to delineate the importance or relevance of notification groups according to a specific dimension they valued. This technique involved adjusting a specific alert feature to symbolize where each notification group stood on that dimension, enhancing the ease with which participants could discern and prioritize notifications based on this dimension. P10, for example, utilized pitch to signify the closeness of relationships, stating, *"I use pitch to gauge the proximity of relationships; the closest to me are family, then friends, followed by work and interests. The higher the pitch, the closer the relationship; the lower the pitch, the more distant the relationship [...] This way, I can quickly discern the difference in sounds, and promptly identify the source of the message and the app it's from. The closer the relationship, the more likely I am to engage."*

5 DISCUSSION

5.1 Occasional Delivery of User-Assigned Alert Neither Reduced Disturbance Nor Improved Speculation

Previous research [8] has advocated for providing users with contextual cues to aid in notification speculation only when needed to avoid adding unnecessary alerts. This suggestion guided our exploration of a mechanism that does not deliver a user-assigned alert when participants were presumed to be able to speculate about the notification sender. However, our result suggests that this approach did not reduce participants' perception of the disturbance from notification alerts as we expected. In contrast, notifications accompanied by user-assigned alerts were perceived by the participants as less disturbing than those with default alerts, possibly because participants might have grown accustomed to and appreciative of the alerts they have created, finding them meaningful rather than merely additive or complex. Moreover, we found that this alert delivery mechanism potentially compromised the benefits of user-assigned alerts in improving users' accuracy in speculating notifications. Although further research is necessary to fully comprehend the factors contributing to the observed reduction in speculation accuracy within the Recent-Interaction condition, we identified three main potential causes. Firstly, the diminished frequency of user-assigned alerts in the Recent-Interaction condition may have led to decreased familiarity with these alerts, adversely affecting speculation accuracy. Secondly, participants anticipating a user-assigned alert following recent interactions with a contact may incorrectly associate a default alert with a different notification, leading to mistaken speculations. Lastly, the inconsistency in alert delivery—where the same notification group could trigger either a user-assigned or a default alert—may have weakened the association between the alert and the notification group, resulting in speculation inaccuracies. Several participants also explicitly expressed their dislike for the sporadic nature of alert delivery, indicating a preference for consistent alert patterns for specific notification groups to ensure accurate anticipation and response. These results suggest that while dynamically adapting interactions with users based on context has been widely adopted in graphical user interfaces (GUI) (e.g., [20, 27, 41, 53]), this approach appears less effective in adapting alert patterns. The ineffectiveness may stem from the fact that the dynamically changing element—often the primary or sometimes the only source of information for users to associate with the target outcome (i.e., what the notification is likely about)—differs significantly from adjustments made to the visual structure or organization of items on GUIs, which does not aim to provide a stable reference for forming consistent anticipations. Expanding upon these insights, we suggest that future notification systems should not apply context-awareness to dynamically change alert patterns. That being said, context-awareness still holds potential for assisting users' attention shifts. For instance, it may be used to enhance the clarity or strength of alerts in scenarios where they may not be clearly noticed, such as when a phone is placed in a pocket or bag [8]. Additionally, it can be used to select the most suitable device to deliver notifications, thus drawing users' attention more effectively, based on the context of the users' owned devices [60]. Both applications do not involve altering the inherent alert pattern, thereby not subject to the potential disruption of established links between alerts and notifications.

5.2 The Impact of Enhanced Notification Awareness: Benefit or Burden?

This study illuminated a key aspect of user behavior: participants showed a marked preference for engaging with notifications that fell into the notification groups they had personally established. This increased engagement was evident both in their increased speculation about the notification's content and in a greater likelihood of attending to these notifications. Importantly, this pattern underscores the dual role of user-assigned alerts: not only did they elevate awareness of incoming notifications, but they also promoted engagement with notifications that participants had identified as important enough to warrant a distinct grouping. The enhanced engagement with these notifications was not only attributable to participants' personal preference toward specific notifications [30, 32, 38, 39, 64], but also largely attributable to their ability to recognize the arriving notifications. Consequently, this recognition led to more informed decisions about attending to notifications, contributing to the remarkably high rate (99%) at which participants found their decisions of attending to these notifications beneficial. This finding suggests that the ability to recognize notifications through user-assigned alerts enables decisions based on an understanding of the notification's relevance, thereby enhancing the perceived value of engagement. It is noteworthy that, however, participants' perception of their attendance decisions was generally positive, even with default alerts. This implies that while user-assigned alerts do improve decision-making around notification engagement, the baseline effectiveness of these decisions is already notable. Thus, the benefit provided by user-assigned alert assignments might be incremental, highlighting the need for a judicious approach in implementing an alert-assignment mechanism, aimed at optimizing notification awareness.

On the other hand, our investigation also ventured into unexpected areas, uncovering nuanced insights into the impact of increased notification awareness. In addition to the result that heightened awareness would boost selective attention to notifications, the study also revealed that participants more often perceived their decision to ignore notifications with user-assigned alerts as non-beneficial compared to those with default alerts. A deeper examination revealed that this shift was attributed to a change in the reasons for ignoring notifications: from assuming irrelevance to considerations of current time constraints. This suggests that the informed decision-making enabled by accurate speculation of notification often led users to skip engagement not because of disinterest, but due to immediate lack of time. Unexpectedly, this nuanced approach to ignoring notifications often led to a perception of these decisions as less beneficial, reflecting an unintended consequence of increased awareness of the receipt and existence of notifications of interest that could not be addressed immediately. Previous studies [8, 48, 49] have highlighted the anxiety associated with not being able to promptly attend to notifications. Our results may imply a similar sentiment among our participants, albeit primarily due to their consciousness of the notifications' existence.

This observation prompts a reevaluation of the notion that more awareness is invariably beneficial, suggesting situations where a more selective awareness could actually enhance focus on current tasks and lessen the cognitive burden linked to non-essential notifications. This idea aligns with a recent study by Chang et al. [7], which shows that users may choose to review and dismiss notifications before starting new tasks because they are concerned about potentially overlooked tasks or information that could divert their attention from the task at hand. Our results indicate that heightened notification awareness could, paradoxically, induce this form of "pending-task distraction," which occurs particularly when users recognize the presence of certain notifications of importance but have to postpone engagement until they can allocate sufficient time.

Building on these insights, it becomes evident that while assigning specific alerts to notifications offers clear benefits, as demonstrated in this study, the overall value of such strategies needs to be balanced with their potential to disrupt users' focus on current tasks. This approach should not only assess notifications based on their inherent importance but also consider the urgency of immediate attention against the risk of distracting users from their ongoing activities. Implementing a system capable of dynamically adjusting notification priorities could strike a balance between alerting users to essential notifications and reducing unnecessary distractions stemming from an increased awareness of notifications. This careful prioritization aims to ensure that improvements in notification awareness enhance rather than hinder user engagement with immediate tasks. For example, the system might evaluate the importance and urgency of both current tasks and incoming notifications, drawing on users' past responses to similar situations, to decide when to deliver user-assigned alerts. Such alerts would ideally be activated only at times unlikely to cause pending-task distractions, like during users' natural breaks or when the system deduces that the cost of not responding to a notification promptly exceeds the cost of interrupting the current task. We believe incorporating advancements in breakpoint identification [12, 22, 43] and understanding the costs of interruptions [35, 65] into the delivery of custom alerts could significantly enhance users' ability to switch attention efficiently, making their decisions to attend to or ignore notifications more informed and less distracting.

5.3 Research Limitations

This paper is subject to several limitations. Firstly, our study design did not account for participants' interactions with desktop or web applications or wearable devices, which could influence their response to smartphone notifications. For instance, a participant might ignore a smartphone notification for an instant message if they had already responded to it on a computer. Our ESM questionnaires did not inquire about activities on other devices, limiting our understanding of their potential impact on notification speculation and response behaviors. Secondly, to minimize recall bias, we chose to sample notifications only if they were received within 30 minutes prior to participants using their phone. This approach, coupled with the detailed nature of our ESM questionnaire, may have biased self-reported data towards moments when participants were already more engaged with their phones, potentially skewing our insights into their attentiveness to notifications. Thirdly, our implementation of a context-aware mechanism only considered users' recent interactions with the senders, based on findings from prior research [8] indicating that users can make highly accurate notification speculations following recent interactions with the sender. However, this mechanism does not account for broader contexts such as the user's current activity, thereby constraining the scope of our findings. Fourthly, we opted not to offer participants the option to create their own sound alerts, to avoid overburdening them. However, allowing such customization might have enabled users to select alerts that are more personally meaningful, enhancing their ability to recognize and recall notifications. Fifthly, our study did not specifically focus on users who predominantly keep their phones in Silent Mode. These individuals' behaviors and speculation strategies may differ significantly when they occasionally switch to Normal or Vibrate Modes, suggesting that our findings might not fully encapsulate their experiences. Sixth, we did not analyze the workload involved in configuring notification groups. While this task was primarily for the research setup, we recognize that understanding this aspect is crucial when considering the deployment of a real-world system. Seventh, we did not consider the potential information loss from the original notification alert, which might convey specific details, such as the app origin, that could influence the user's decision to attend to them. Although analyzing this information loss is beyond the scope of this study, future research could explore the trade-offs between customized alerts and the loss of information typically conveyed by standard app notifications. Additionally, our research did not explore the use of alternative alert modalities, such as flashing lights, which some smartphones offer. The exclusion of these alert types may limit the applicability of our findings to users who rely on these features. Lastly, the demographic composition of our study participants, primarily individuals in their twenties and half of whom were students from the authors' home country, raises questions about the generalizability of our results to other age groups and cultural backgrounds.

Together, these limitations suggest that while our study offers valuable contributions to human-notification interaction, further research is needed to explore these aspects comprehensively and to understand their implications across a broader spectrum of user behaviors and preferences.

6 Conclusion

This study aimed to investigate whether enabling users to assign specific alerts to certain notifications could enhance their ability to accurately speculate about these notifications when they arrive, thereby facilitating more informed decision-making due to increased notification awareness. On one hand, we confirmed that user-assigned alerts improve speculation accuracy and effectiveness of notification attendance. On the other hand, delivering a user-assigned alert only when there is no recent interaction neither alleviated perceived disturbances nor improved speculation accuracy. Moreover, our study uncovered the unintended consequence of heightened notification awareness potentially leading to "pending-task distraction." This occurs when users become aware of important notifications but are unable to act on them immediately, leaving them not satisfied with the decision of ignoring them and meanwhile putting them at risk of distraction from their current tasks. Additionally, our study identified five main strategies employed by users in assigning alerts to notifications. These strategies provide valuable guidance for the design and development of notification systems that support user speculation.

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