A REPORT
ON

‘Human Computer Interaction Techniques to Investigate User- Experience: A privacy and security perspective’

BY

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CERTIFICATE

This is to certify that the thesis report titled, 'Human Computer Interaction Techniques to Investigate User- Experience: A privacy and security perspective' is an outcome of my original work and submitted in partial fulfilment of the course 'BITS F421T Thesis'. The work is done under the supervision of Dr Mukesh Kumar Rohil (Department of Computer Science and Information Systems, BITS Pilani) and Dr. Sameer Patil (Luddy School of Informatics, Computing, and Engineering, Indiana University Bloomington, USA).

I have duly acknowledged all the sources from which the ideas and extracts have been taken. I certify that the work in this thesis has not previously been submitted for a degree nor has it been published previously as part of requirements for a degree except as fully acknowledged within the text.

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ABSTRACT

Notifications form a primary feature of the present smartphone devices. Around 95% of the people reported that they received at least one notification in their smartphone within the last hour of participating in this study. Receiving multitudes of notifications in a day poses the risk of accidental information disclosure and privacy breaches. For example, onlookers may see notifications on the smartphone device lock screen, notifications popped up during screen casting may be expose sensitive content to audience, etc. We quantify the prevalence of such unintended information leaks and investigate user preferences and privacy concerns. Our results are derived from a survey of 235 participants through a questionnaire deployed on Amazon Mechanical Turk. 61.35% (N = 72) of the respondents reported facing at least one negative experience in their life due to their smartphone notifications. Through our study, we find that the real or perceived risk from smartphone notifications depend of various factors like type of apps sending the notification, context of surroundings at time of notification delivery, mobile users information privacy concerns, digital difficulties. Additionally, we have explored the use cases of various smartphone features like Do Not Disturb, Silent Mode, App Locks, Device Locking mechanisms.

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1 Introduction

Notifications form an important feature of smartphone devices and people receive dozens or hundreds of notifications per day. Third party applications or system services often send nudges to inform users about updates, warnings, reminders and various events like new messages, appointments, etc. Due to increasing availability of services and recent advances in mobile information technology, there has been an increase in the number of potentially disruptive notifications on mobile devices. This makes investigation about smartphone notifications relevant.

Prior work has investigated what types of notifications users receive on a daily basis and which notifications are valued by users [1]. Regardless of their value, it has been shown through various studies that notifications can induce negative effects such as distractions, interruptions, and increased stress [2, 3]. However, little is studied and known about the privacy cost of notifications.

Privacy cost is concomitant to notifications because people are frequently present around us, who may see notifications on our screen. Unintended information disclosures could also happen if the device screen with notification preview remains on for a long time. Uncomfortable situations could arise if a a sensitive notification pops up when user has given his device to someone else. For example, notifications can often reveal details about the sender, subject fields of e-mails, personal information about user health, finances and relationships, etc. Also, notifications may be visible to a large crowd when a personal device is connected to a projection screen during a presentation.

On the dominant mobile operating systems Android and iOS notifications can be displayed on lock screen when phone is locked or from notification list commonly referred to as the notification drawer (Android), notification center (iOS), notification tray, or notification panel. Notifications could also pop up on screen either as floating notifications and disappear (Android) or display as banners (iOS) and remain permanently or temporarily. For lock screen notifications settings android based smart phones offer three broad options- 'Show all', 'Hide sensitive content' and 'Hide All', besides, the option to customise for individual app settings. Similarly, notifications on iOS based smart phones have three options- 'Always Show', 'Only on unlock', 'Never', for previewing the content of a notification when phone is locked. Various choices are available to users namely- system settings, phone and app passwords, third party applications, features like 'Do Not Disturb' mode, 'Silent' mode, 'Airplane' mode for notifications management in smartphones.

We believe that such instances of embarrassments, inconveniences and privacy breaches caused from notifications are common. It is also shown by prior research [4] that individuals are willing to trade privacy for convenience or bargain the release of personal information in exchange for relatively small rewards.

These notifications settings do not take into account the context of environment. We believe that the current smart phone notifications settings and users behaviour risk their privacy in a trade-off with user convenience. Although a large body of prior work on notifications exists, the privacy and security aspects

of notifications on smartphones have not been explored in detail so far. However, this is a crucial aspect for a complete under- standing of mobile notifications.

In this research, we investigate the possibility of the complex context- dependent attitudes and behaviors of smartphone users. We designed our study to collect a multitude of signals that characterize how device settings, device sharing, type of content, and contexts of surroundings interact with one another to create situations in which people are uncomfortable (or comfortable) receiving notifications. We complement prior research work by asking the following research questions:

RQ1 Do notifications become a concern for users in the context of privacy? If so, how much and how often can notifications be a cause of negative experience for users?

RQ2 How do user preferences and smartphone notification settings like mode of delivery affect instances of information disclosures?

2 Related Work

In the following section, an overview of related work on mobile notifications, their disruptive effects, user privacy concerns for personal information and notification management preferences are provided. Subsequently, research gaps in the existing literature are discussed.

2.1 Differences in Information sharing between Notifications and Social Media

Notifications may differ from the intentional information sharing scenarios explored in past work such as with websites or social networking services (SNSs). Previous studies like [5] infer that people often perform an informal risk-benefit analysis before taking actions that may have privacy implications. To conceal their identity, people also enact preventive strategies, including self-censoring, managing access control groups, and taking actions [6]. However, agency and control is not available in cases where people receive push notifications. Instead, the notification scenario bears resemblance to the scenario in which people are tagged in photos shared to SNSs without consent [6] or posts being unintentionally shared on SNSs [7]. Here, users can often take corrective actions by either untagging the photos or deleting the contents before more people see the posts. On the contrary, in the case of push notifications, disclosures are instantaneous, and it is unclear what corrective actions can be taken after the event. A similar situation arises with the accidental disclosure of web browsing history [8]. Through a survey of 155 people, Hawkey et al. found that, as before, comfort level is related to one's level of control (e.g., control over the mouse and keyboard). Moreover, people's comfort is higher when disclosures are to spouses or close friends, and lower with colleagues.

2.2 User interactions with and attitudes for notifications

Through a working prototype of a notification assistant system for Android devices, it was shown [9] that users are compelled to face a trade-off between privacy and convenience in consuming notifications in Android smartphones due to a trend in application behavior. A study by Shirazi *et. al.* [10] presents a large-scale analysis of mobile notifications. The study suggests that important notifications are about events or provide information about the user's context or contacts and important notifications do not require immediate attention. They suggest that users need to be aware that notifications can also be a significant attention-grabbing distractor. Weber *et. al* [11], developed an Android app to investigate user-defined deferral of notifications by allowing users to manually snooze notifications for per user requirement. Their study concluded that people deferred addressing notifications to prevent context switches and that notifications of the categories SMS/Instant Messaging, Calendar/Reminder, Social, and Email, were snoozed most often. how the concepts of private status sharing and sender-controlled notifications can be applied in future designs and explorations. In another research [12], mobile users were allowed to annotate notifications using privacy-aware system, while preserving the notifications' content and context. The researchers classified notifications into clusters of four based on the importance and attention required.

2.3 Productivity Costs of Notifications

Previous work on notifications focused on analysing negative impacts of ill-timed notifications on productivity. Various studies show the potential negative effects of interruptions on task performance [13, 14, 15], task resumption rate [16] and emotional state [17] and justify the need for systems that mediate interruptions in order to minimise their cost. A large number of studies investigate low-cost opportune moments to interrupt user through notification. The study by [17], showed that coarse and fine breakpoints occur between tasks and sub-tasks and that coarse breakpoints make for the more opportune moments for interruptions of notifications. Studies show that low cost interruptible moments can be identified based on sensing mobile phone activity to find task transitions (e.g., finish an episode of mobile interaction), which lead to significantly quicker handling of notifications [18]. A study [19] showed that real time user data like activity, emotions and engagement, time and location is helpful in determining satisfactory moments to deliver smartphone notifications. However, it has also been identified [20], [21] that there can be costs associated with delaying notifications, suggesting that such notification management policies must consider both the cost and benefits of delays. To lower the pressure for an immediate reply and reduce unnecessary interruptions by untimely notifications, two design concepts for Mobile Instant Messaging were examined-private status sharing and sender-controlled notifications- that aimed to decrease the negative effects of ill-timed notifications in smartphones [22]. Our study differs from these previous studies as we consider privacy cost associated with notifications, rather

than productivity cost of notifications.

2.4 Privacy Cost of Notifications

To understand the potential privacy cost of ill-timed notifications, pioneering research includes the Westin Privacy Segmentation Index [23]. In his work he categorized people into three groups: privacy fundamentalist, marginally concerned, and pragmatist. As per Westin's classification, 'Privacy fundamentalists' are those who are very concerned about their privacy and very reluctant to share any of their information. 'Marginally concerned' are generally willing to share details or data about themselves. 'Privacy pragmatists' are people who are somewhat concerned about their privacy, but are willing to compromise some privacy for convenience.

Most closely related to our work is by Kim et al.(2019) [24] on examining the privacy costs of receiving notifications in an enterprise environment performed in the scenario of a person receiving an email notification on their notification-capable devices while attending a meeting. The authors quantify information disclosure risks arising from email notifications to recommend social-context aware notification strategies. The researchers conduct a retrospective survey and a contextual-labeling study. This is followed by developing machine learning models to classify, given an email-meeting pair, if the delivery of an email notification would result in an uncomfortable situation. However, the real risks of information disclosures will be different from both self-reported and predicted risks, which the study does not take into account. This is because, in reality, the type of notification capable device one carries, user preference for notification display settings enabled in the device (e.g. 'Hide All' lock screen notifications, DND mode) during meetings, device sharing behaviours in a meeting and use of third- party apps for notification management may further influence the risks. The research results can not be generalized to different countries, organisational cultures. Additionally, there are challenges to adoption of the proposed machine learning prediction model in real- life, because it has been trained only for email notifications and the details of hyper-parameters are not specified. Also, these models have not been validated for overfitting or under-fitting the data. The authors consider one of the meeting features as 'numAttendees', whereas a more relevant feature would be the number of people who can view the device screen. For example, when the device screen is projected/casted it is visible to all attendees. The study also did not take into account the information disclosure risks of the sender of emails, which our study takes into account.

Finally, we note that existing mobile devices and applications provide some minimal options for managing notifications. Typically, such options are binary (e.g. turning on and off notifications, enabling notifications for "important" emails in Gmail, and enabling notifications to show previews). Recognizing the privacy risks of notifications, some applications (e.g., WhatsApp) and mobile devices (e.g., iPhone X) have disabled notification previews by default, preferring instead to provide generic indicators (e.g., "You have a new message.") These solutions are context independent, and employ a one-size fits all strategy.

Hence, users must accept trade-offs between minimizing privacy risks (e.g., by suppressing notifications) and maintaining easy and timely access to information. In contrast, our study takes into consideration both user contexts and notification contents. In addition to this, user preferences of controlling their device settings (like Silent Mode, DND mode, etc.) and behavioral habits (e.g., Clearing all notifications before handing over smartphone device to someone else) have been taken into account.

As more and more internet-connected devices and services become capable of displaying information via notifications, there is a need to better understand people's preferences and concerns about notification-induced information disclosures. There is also a need to develop designs and strategies that can adapt both to a notification's content and the user's context.

3 Method

A survey is designed and deployed to gain an understanding of our research questions. The recruitment materials provided some background information about this study without disclosing too many details, and required that participants be 18 years of age or older to participate in the survey. At the beginning, we presented participants with a detailed study information sheet. Only those who explicitly consented to participate could proceed to the study. All study materials and procedures were reviewed and approved by the Indiana University Institutional Review Board (IRB). (See Supplementary Material for the complete study instrument and questionnaire.)

3.1 Survey Development

The questionnaire included the pre-validated perceived measures described in our Research Framework. We included several measures within the study to ensure collection of high quality responses. These are listed as follows:

- At the beginning, we included a screening question asking participants if they intended to provide high quality answers. Only those who answered in the affirmative were allowed to proceed; others were asked to exit.
- Within the study, we included two attention check questions that asked participants to select the specified answers from the given options.
- We set a browser cookie to reduce the chances of multiple submissions by the same person, and we ensured that no AMT worker completed the study more than once.
- To avoid priming, we did not use the term 'privacy' anywhere within the study description.

3.2 Study Deployment

We first conducted a pilot study with 10 participants to identify logistical problems and gain an initial understanding of participation. After the preliminary study, few questions and options were edited in the questionnaire and made available to participants.

We administered the survey by providing a link to the online study on the Amazon Mechanical Turk (AMT)- a crowdwork platform for participants from US. The link would direct participants to the Qualtrics platform, for taking the survey, as shown in Figure [1] .

To ensure the quality of responses, we paid $1.80 to all the participants who successfully completed the questionnaire i.e. passed the attention check questions. We a total of 235 responses between November 12, 2020 and November 27, 2020, out of which 185 were complete and valid responses.

Figure 1: The flow of various steps in the survey.

4 Analysis

4.1 Demographics

The mean and median of questionnaire completion time was 19.89 minutes and 10.9 minutes respectively. Participants were between 18 to 70 years of age (median 34.50, mean 36.1). 64.86% (N = 120) of the participants reported identifying as male, 34.05% (N = 63) as female, and 1% (N = 2) did not specify their genders. Most participants were white (74.46%; N = 137) with the remaining covering a variety of ethnic backgrounds: 7.06% (N = 13) Asian, 10.87% (N = 20) Black or African American, 0.54% (N = 1) American Indian or Native American, 3.80% Hispanic (N = 7), 0.66% (N = 1) Native Hawaiian or Pacific Islander, 1.63% (N = 3) as multi-ethnic. 1.08% (N = 2) chose not to report their ethnicity. The income distribution of participants is shown as in 2. The participants come from diverse professions like construction, manager, IT professional, business, media production, pharmacy technician, etc.

4.2 Significance of Smartphone Notifications

95.78% (N = 175) of the users mentioned that they received at least one notification in the last one hour of taking the survey. 57.30% (N = 106) of the

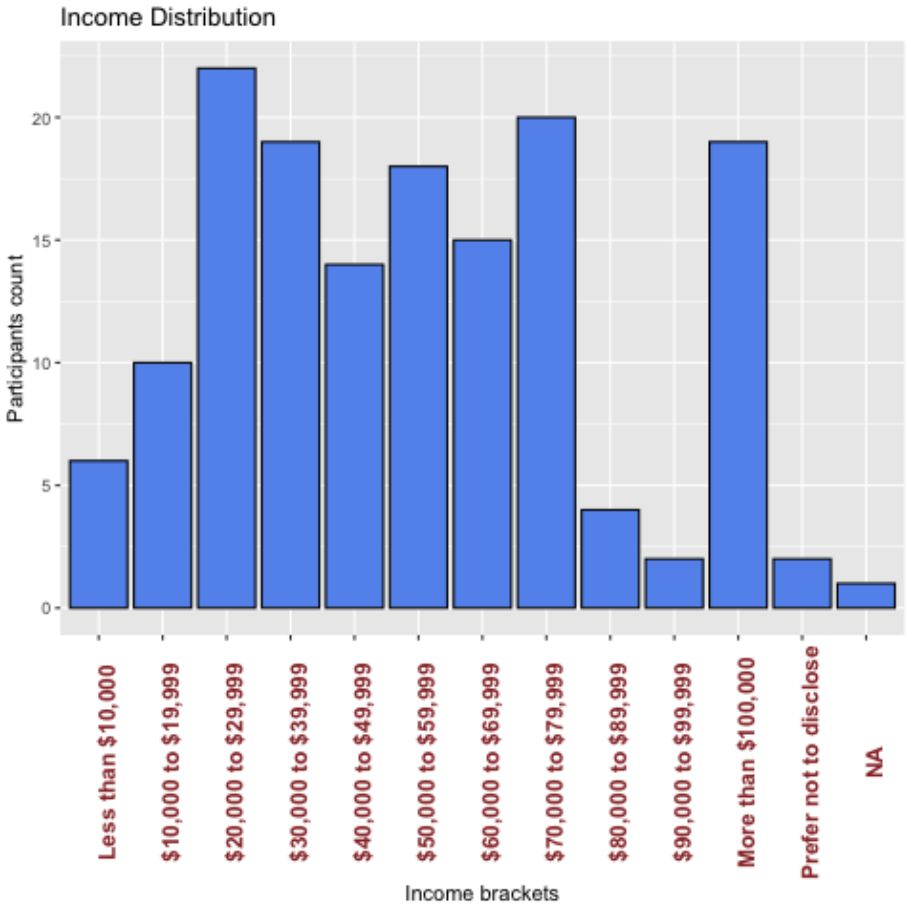

Figure 2: Income distribution of various participants.

users reported that they received 1-9 notifications on their smartphone in the last one hour. 24.32% (N = 45) of the users reported that they received 10-19 notifications on their smartphone in the last one hour.

To understand the types of notifications smartphone users receive, we asked the respondents of questionnaire to answer, "Think about the latest notification that you received on your smartphone. Which app sent this notification?". The apps listed by users can be classified into the following categories:

1. Social Media Apps: Instagram, twitter, snap chat, Facebook, etc.
2. Messaging Apps: Gmail, Messages, whats App, iMessages, Outlook, Telegram
3. Productivity Apps: Trello, Zoom, new app downloader
4. Financial Apps: Simple Bank
5. Personal Care Apps: Bed Bath and Beyond
6. News Apps: CNN, COVID-19 APP
7. Dating: okcupid, Twilio, Kik
8. Shopping Apps: Amazon, AliExpress, ebay
9. Entertainment Apps: Youtube, Pluto TV, Dominoes
10. Transport Apps: Ola
11. System notifications from smartphone operation system
12. Others: Famisafe, notification bubbles, learning genie, mixpanel, nugapp, amber alert, line, discord

This gives us an idea about the prominence of notifications in the lives of smartphone users and the variety in the source of those notifications. Since people get all kinds of different notifications from diverse apps, it makes it tough to personalise the delivery and management of notifications. Hence, it is pertinent to understand user preferences and privacy concerns for different types of content delivered through variety of notification sending apps.

4.3 How do Users Interact with Notifications

To understand how users interact with smartphone notifications, we asked users to think about the latest notification that they received on their smartphone and answer some questions with respect to that notification, e.g. "How quickly did you address the notification after you first saw it?" 60.0 % (N = 111) of the users picked up their phone at least once in 30 minutes to check, clear, or address notifications, as shown in Figure 3.

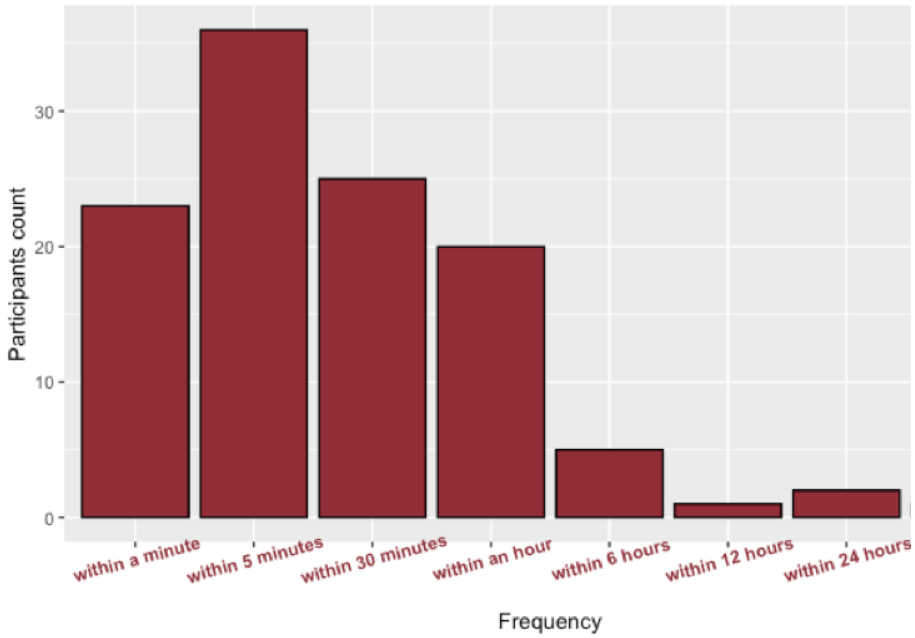

Figure 3: Response time for addressing the latest notification.

4.4 Negative Experiences from smartphone Notifications

Figure 4 shows the prevalence of negative experiences due to smartphone notifications in the lives of survey participants.

We asked users to answer, "Of the negative experiences related to notifications that you have encountered, please tell us a bit about the most negative experience." Some of the responses were as follows:

1. "It was a private message on Instagram and I did not want my partner to see it".
2. "one time i clicked the link on the notification received without studying in details resulted phone affected with virus".
3. "One of my friends read a message that was about her, and it made her upset".
4. "the ads mainly where adult content ads are shown sometime from specified apps,It will be negative appearance when a small child saw that".
5. "When I was working on something for work where i had to cast my device screen for others to see. The notification was highly personal".
6. "I had given my phone to my friend when the notification arrived. in that time, I left the phone screen unlocked and also I forgot to take the

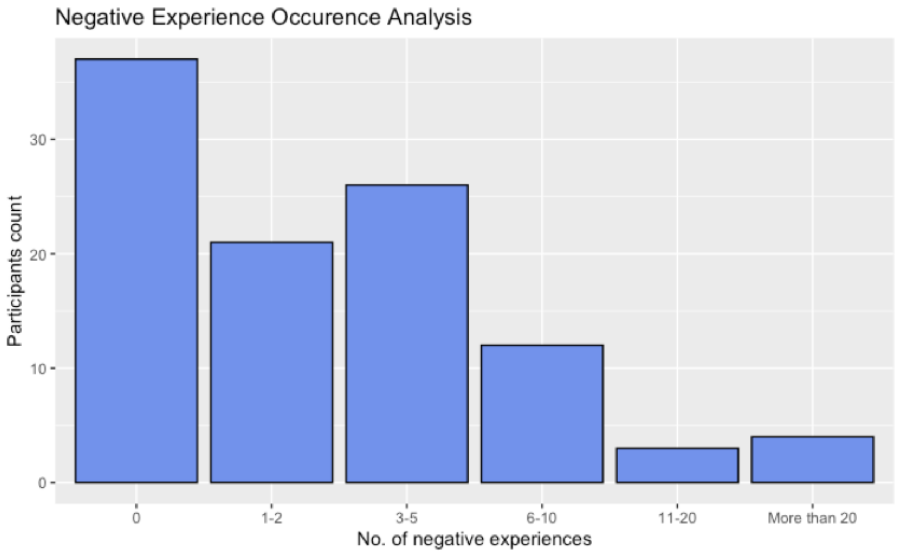

Figure 4: Occurrences of Negative Experience due to smartphone notifications.

appropriate actions to silence the notifications."

7. "I had an ex get jealous because he saw a text from an unknown number. He accused me of cheating when it was not the case".
8. "My notification for Blink, Amazon's camera security service, kept going off due to movement and it was distracting".
9. "Negative experiences mostly had to do with notifications waking me up in the middle of the night with a ping and screen".
10. "unwanted apps will download always".
11. "bad photo and videos".
12. "Group chats are always annoying and they send a lot of notifications. It is distracting and irritating especially when you're busy. Also, some of the apps frequently send notifications and it's frustrating that I can not customize them".
13. "i was texting something personal with my hubby, suddenly when i was with my colleague it popped up and the person read out, it was a negative experience".
14. "I forgot to clear the notification and my spouse saw some secret messages."

Table 1: Negative Experiences among smartphone users due to smartphone notifications

No. of Occurrences	Percentage of respondents
0	35.92
1-2	20.39
3-5	2.91
6-10	25.24
11-20	11.65
More than 20	3.88

As seen from Table 6, 64.08% (N = 67) of the respondents reported facing at least one negative experience in their life due to their smartphone notifications. This shows that notifications are indeed a potential cause of concern for smartphone users and require analysis from privacy lens (**RQ1**).

4.5 Use of Smartphone Features

94% (N = 175) participants mentioned that their smartphone device used any type of lock (e.g., PIN, password, pattern, fingerprint, faceID, etc.), out of those 34.6% (N = 61) reported that no one other than them can unlock their device. The use of various smartphone features like Do Not Disturb (DND) Mode, Silent Mode, Turning device off, Airplane mode and smartphone applications for Notification Management Apps is prevalent among smartphone users. 56.07% (N = 97) of the users reported the use of Do Not Disturb Mode, 79.77% (N = 138) of Silent Mode, 44.5% (N = 77) turn off, 42.77% (N = 74) airplane mode and 61.85% (N = 107) notification management apps in their smartphones for at least one hour in a typical day. The mean and median usage (in hours) of these smartphone features in a typical day is listed in Table 2. It can be seen that users prefer to use silent mode and notification management apps over other alternative features to manage their smartphone notifications.

Many users prefer to have their phone turned off or on silent during sleep, e.g. a user reported "I generally have my phone on silent for the 8 hours I sleep at night and then for at least about 4 hours in the evening when spending time with the family". Many users took necessary steps to prevent distractions from notification alerts during sleeping hours and said, "I usually just keep DND on and check my phone on my own accord", "I don't like alerts or noises. So I keep my phone in silent mode at all times. I find this works best for me and limits distractions". Few users mentioned the use of silent or DND mode during working hours like someone told, "I usually have my phone on silent, and DND while working". Few other users mentioned, "Usually I mostly use silent mode when working or hanging out with family or friends" and "Silent mode is the best with a 'shake' alert. In this case I'm notified 'minimally' without the dreaded sound going off interrupting any important task at work or with friends and family", "I make sure I can't be disturbed at all when I'm working. It's

just easier to turn on DND than fiddle with individual apps". A mentioned the use of a notification management app for 16 hours in a typical day and said, "i do use a notification manager from samsung to group notifications".

Table 2: Use of smartphone features (in hours)

Smartphone Mode	Mean	Median
Use **Do Not Disturb (DND)** Mode	2.85	1.0
Use **Silent** Mode	6.61	4.0
Turn the device **off**	2.19	0.0
Use **Airplane** mode	2.28	0.0
Use notification management apps	4.63	2.0

We then try to understand how the use of various features is associated with the occurrences of negative experiences due to smartphone notifications. To this end, we grouped the responses based on number of negative occurrences and calculated the group-wise mean usage (in hours) and correlation of these features in a typical day, as shown in Table 3 and Table 4. The p-values in Table 4 have been adjusted using "Bonferroni" correction because multiple hypothesis are being tested in the same sample.

Table 3: Negative Experiences and Mean use of features (in hours)

Negative Experiences Occurrences	DND Mode	Silent Mode	Turn Off	Airplane Mode	Notification Apps
0	1.60	5.63	1.49	1.37	2.11
1-2	2.38	7.38	1.00	1.43	3.62
3-5	2.42	4.62	2.92	2.92	5.46
6-10	8.50	11.00	7.08	9.25	12.00
11-20	6.50	5.75	5.25	5.75	4.25
More than 20	0.5	3.00	0.50	0.25	0.25

Table 4: Correlation of use of smartphone features and occurrences of negative experiences due to notifications.

Smartphone Mode	Correlation values	Adjusted p-values
Use **Do Not Disturb (DND)** Mode	0.29	0.014
Use **Silent** Mode	0.033	1.00
Turn the device **off**	0.27	0.028
Use **Airplane** mode	0.28	0.024
Use notification management apps	0.26	0.036

It can be seen from Table 3 that participants who reported high number of

negative experiences (i.e. More than 20) with notifications have the least usage of smartphone features- 0.5 hours Do Not Disturb, 3.00 hours Silent Mode, 0.5 hours Turn Off, 0.25 Airplane Mode and 0.25 Notification Management Apps. It can be seen from Table 4 that weak correlation values occurs in the use of Do Not Disturb Mode, Turning device off, use of airplane mode and notification management apps with significant p-values (less than 0.05).

4.6 Differences due to Mobile Operating System

The plot 5 shows the relation of negative experiences with the phone Operating system(OS) category. Kruskal Wallis test is run to understand if the differences between smartphone OS- Andriod and iOS is significant. The Kruskal-Wallis chi-squared test statistic= 0.042289 with p-value = 0.8371, which is not statistically significant at 5% level. The differences in mean usage of various smart-

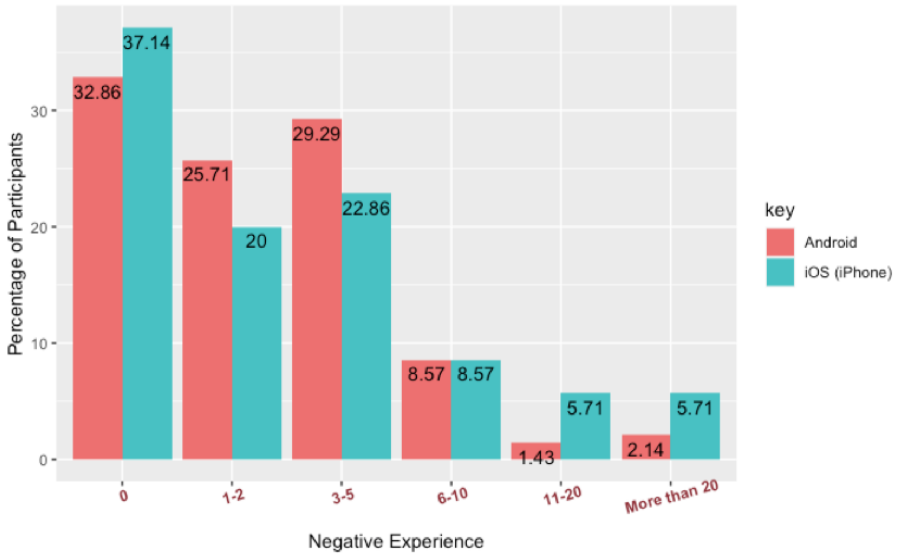

Figure 5: Negative experiences based on smartphone OS

phone features is shown in Table 5. It can be seen that people use silent mode more in iOS than in Android but this difference is not statistically significant (Kruskal- Wallis chi-squared = 2.0423 with p-value = 0.153). The differences in mean turning off device, use of airplane mode and use of notification management apps is statistically significant with p-values as 0.04051, 0.007954 and 0.07604, respectively as per Kruskal- Wallis test.

Table 5: Mean use of smartphone features based on operating system.

Smartphone Feature Mode	Android	iOS
Use **Do Not Disturb (DND)** Mode	2.92	2.66
Use **Silent** Mode	5.80	9.39
Turn the device **off**	2.43	1.34
Use **Airplane** mode	2.46	1.63
Use notification management apps	4.72	4.18

4.7 Concern for different types of app content

To understand notifications from which types of apps are sensitive for users, we asked participants to answer on a 5-point Likert scale, "How concerned would you be if a **family member reads the content of a notification** from each of the app categories listed below?" and "How concerned would you be if a **colleague reads the content of a notification** from each of the app categories listed below?". The app categories were: Instant Messaging, Social Media, Calendar, E-mail, Banking and Payments, Health and fitness, and Dating. The comparison of user concern if notification content is read by a family member or a colleague for different app categories is shown in the following plots: Figure 6, Figure 7, Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12.

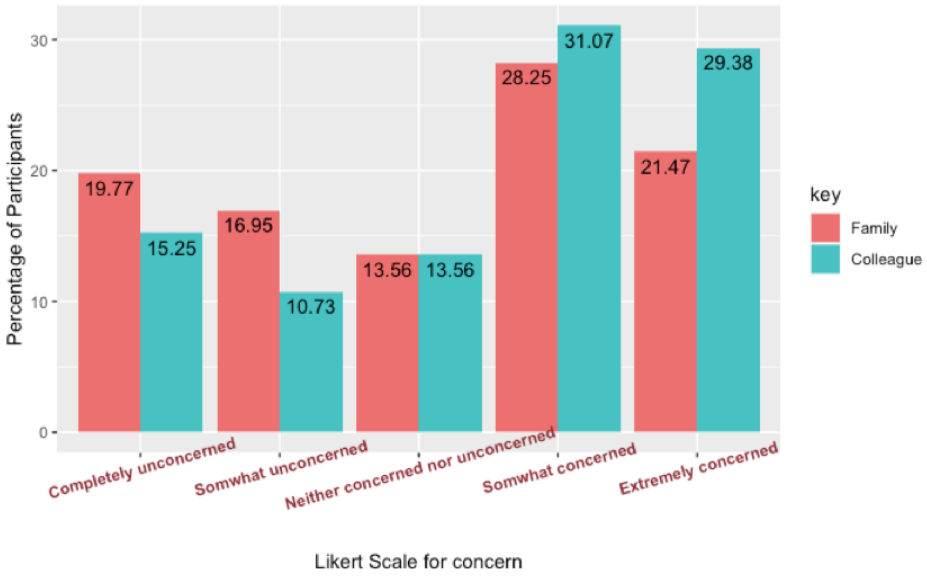

Figure 6: User Concern if someone else (key) reads notification content from Instant Messaging Apps.

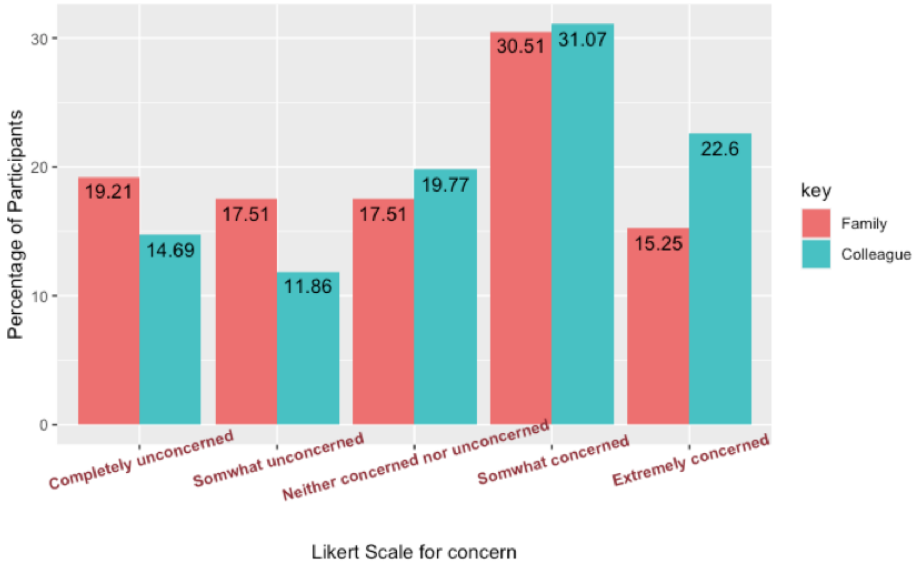

Figure 7: User concern if someone else (key) reads notification content from social media apps.

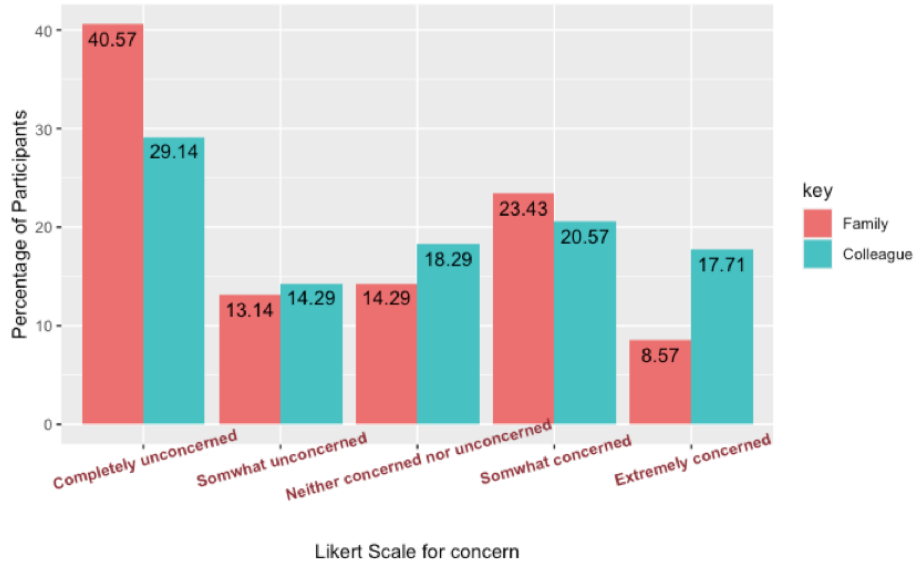

Figure 8: User concern if someone else (key) reads notification content from calendar apps.

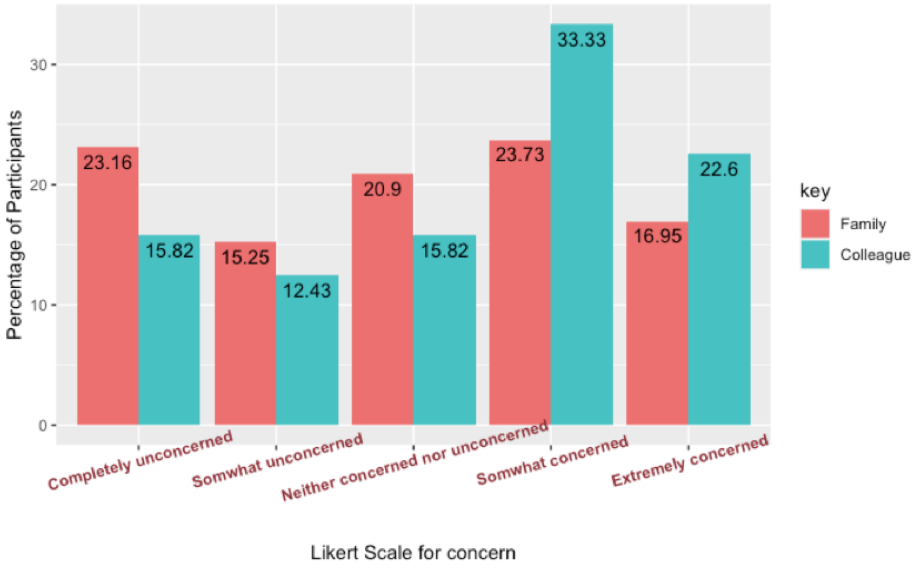

Figure 9: User concern if someone else (key) reads notification content from email apps.

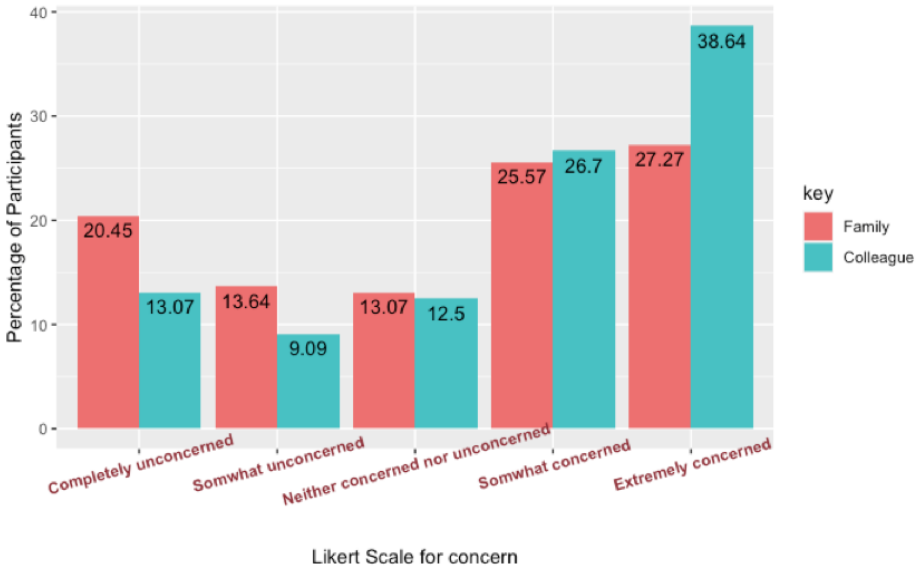

Figure 10: User concern if someone else (key) reads notification content from banking and payments apps.

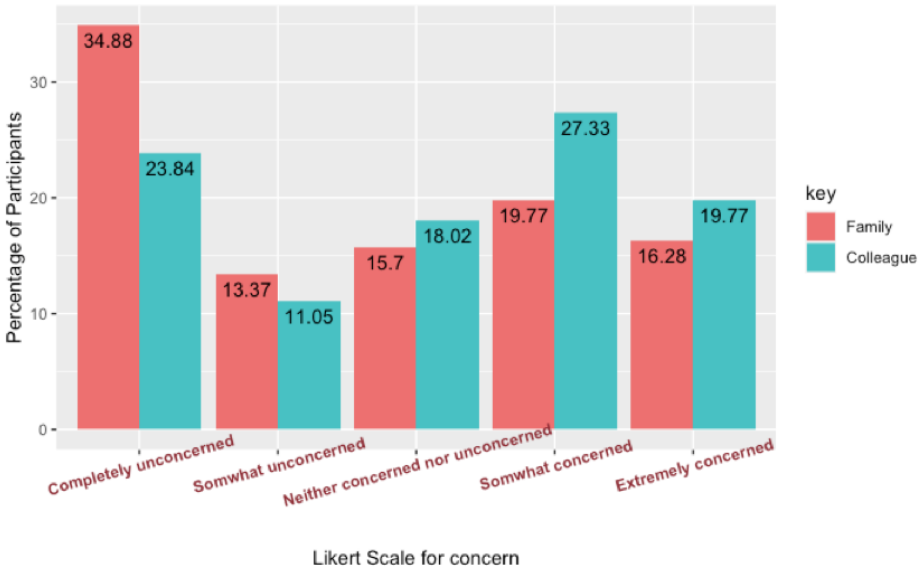

Figure 11: User concern if someone else (key) reads notification content from health and fitness apps.

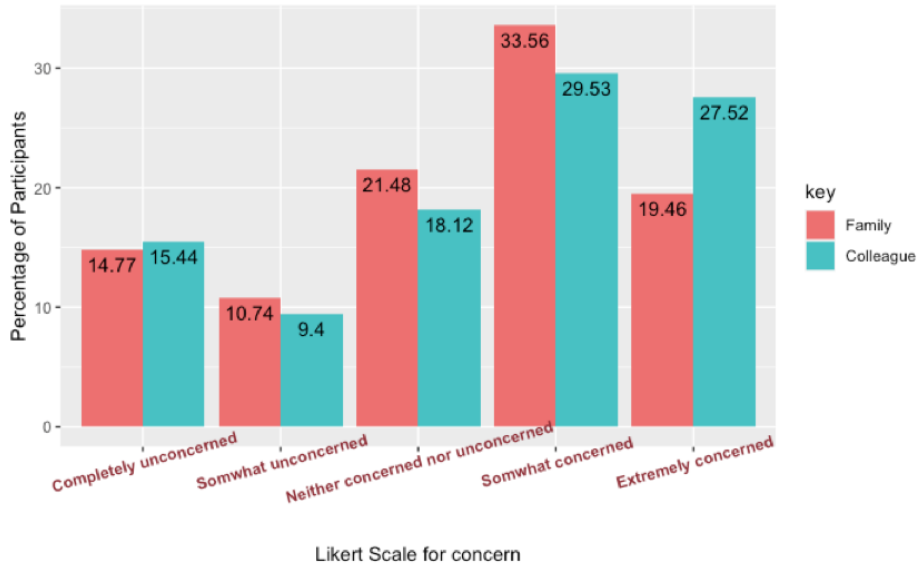

Figure 12: User concern if someone else (key) reads notification content from dating apps.

Some of the users mentioned the following reasons for their concerns if their family member viewed the notification content: "I do not use my phone for sensitive reasons, it is just a communication device to keep me in touch with others and allow them to reach me. Anything that is of a nature that I would not be happy others seeing I take care of at home.", "I'm a private person, so I wouldn't want them seeing much.", "Sometimes I get saucy messages I wouldn't want them to see.", "My messages and financial data I feel are very private and want to keep them to myself for the most part.", "Mainly concerned about my parents seeing how I speak to other people casually.", "I would be concerned in general if anybody was accessing my information without my consent. Especially banking information.", "My messages and financial data I feel are very private and want to keep them to myself for the most part.", "There is nothing that they wouldn't already know that is going on in my life.", "My family is pretty cool and I would be ok with them seeing most of my notifications.", "some message are watching my partner misunderstanding in my life.", "i would be concerned if they read a message that was personal such as a message from a dating site", "I have lots of personal things to maintain.", etc.

Some of the users mentioned the following reasons for their concerns if their colleague viewed the notification content: "I have nothing to be worried about that would get delivered to my phone.", " Same reason, sometimes I get saucy messages I wouldn't want them (colleagues) to read.", "I am not as close to colleagues as family so this would be extremely concerning as I would feel all of the above (app categories) would be an invasion of privacy.", "i dont want work people seeing my phone items", " I say things on social media I would not say at work.", "I think , my family members just reads the content of my phone notification or something without my permission then it is intrusive and the shouldn't be doing it. They should respect my privacy.", "Well, while I may have nothing to hide, I certainly don't want a colleague looking at my banking account.", "I don't any anything that I would be concerned that anyone would see.", "I really wouldn't like them reading my notifications, but I also don't think they'd see anything bad.", "I would not want anyone outside of immediate family or trusted friends and loved ones to see notification information on my phone.", etc.

Other users who were less concerned or unconcerned mentioned reasons like "I am an open book and my friends and family know just about everything about me.", "Again, I have nothing to hide.", "I don't have anything I would object to others seeing", "Most of my messages other people would know the people, and I wouldn't say much that I wouldn't tell them anyway. My e-mails should be fine, unless I potentially get a SPAM e-mail I didn't want.", etc.

The sensitivity of content from different notifications depends upon:

1. Notifications delivered in presence of colleagues is more private than notification received in presence of family members for all types of apps.

2. Content from Banking and Payment Apps is seen as most sensitive by smartphone users (based on mean scores). Content from Calendar apps is seen as least sensitive.

Table 6: User concern mean score if notification content from different app categories is read by a family member or colleague.

App Categories	Family Member	Colleague
Instant messaging	3.37	3.56
Social media	3.31	3.43
Calendar	2.63	2.96
E-mail	3.23	3.50
Banking and payments	3.48	3.68
Health and fitness	2.87	3.16
Dating	3.37	3.45

3. In the context of surroundings of family members, the type of apps whose content is marked as somewhat sensitive or extremely sensitive most times is for Dating Apps (53% respondents). This is followed by no. of respondents for Banking Payments apps (52%) and Instant Messaging (49%).

4. In the context of surroundings of colleagues, the type of apps whose content is marked as somewhat sensitive or extremely sensitive most times is for Banking and Payment Apps (65% respondents). This is followed by no. of respondents for Instant Messaging apps (64%) and Dating Apps (57%).

4.8 Mobile Users' Privacy Concern Score

To asses smartphone users' information privacy concerns, we took the instrument "Measuring mobile users' concerns for information privacy"- MUIPC (Xu et al. 2008 and Xu, Heng, et al. 2012), which consists of a 9- item and 7-point Likert scale. However, for our study we considered, only part of the original version, a 3-item scale for 'Perceived Surveillance' and 3-item scale for 'perceived intrusion'.

Perceived Surveillance: Solove (2006) has defined surveillance as "the watching, listening to, or recording of an individual's activities (p.490)." Malhotra et al. (2004) suggest that the practice of data collection, whether legitimate or illegitimate, "is the starting point of various information privacy concerns (p.338)." The rapid advancement of technology has led to more powerful means of surveillance. Smartphone apps can collect personally invasive data e.g., identity, upcoming schedule, time spent on different apps, contact lists, real-time location, etc. because smartphones contain various functions such as web browsers, emails, photo albums, games, calendars, and contact lists,etc. Additionally, the aggressive data collection activities by mobile apps and operating systems induce the perception of intensive data logging and the impression of being constantly monitoring of user behavior through smartphones by vendors.

In our study, the mean and median score of 'Perceived Surveillance' was 15.68

and 16, respectively. Smartphone users who reported no negative experiences with notifications had 14.66 score of 'Perceive Surveillance', as compared to 17.6 for the other extreme of smartphone users, who had more than 20 negative experiences, as seen in Table 7.

Table 7: Perceived Surveillance

Occurrences of negative Experiences	Mean Score	Median Score
0	14.73	15.0
1-2	15.51	16.0
3-5	16.20	16.0
6-10	16.73	18.0
11-20	17.00	18.0
More than 20	17.60	18.0

Perceived Intrusion: The notion of intrusion has often been connected to the concept of personal space (Solove 2006). The notion of personal space, in today's computing environment, has expanded to incorporate realms of both physical and informational space, due to the powerful technological advancements. Because it is highly possible to have malware even from mobile app stores (Dignan 2011), users may resist mobile apps for the fear that the malicious apps may interrupt their activities through the unwanted presence.

In our study, the mean and median score of 'Perceived Intrusion' was 15.48 and 16, respectively. Smartphone users who reported no negative experiences with notifications had 14.34 score of 'Perceive Intrusion', as compared to 18 for the other extreme of smartphone users, who had more than 20 negative experiences, as seen in Table 8.

Table 8: Perceived Intrusion

Occurrences of negative Experiences	Mean Score	Median Score
0	14.72	15.0
1-2	15.51	16
3-5	16.20	16.0
6-10	16.73	18.0
11-20	17.00	18.0
More than 20	17.60	18.0

To validate the association between the two aspects, we analysed the correlation of 'Occurrences of Negative Experiences' with smartphone notifications and 'MUIPC' scale items, and is shown in Table 12. It can be seen that scale items "Q4:I feel that, as a result of my using mobile apps, others know about me more than I am comfortable with." is correlated (0.23) with statistically significant p-value of 0.018 and scale item "Q6: I feel that, as a result of my using mobile apps, information about me is out there that, if used, will invade

my privacy." is correlated (0.24) with p-value as 0.014. It can be seen that smartphone users who report more occurrences of negative experiences with smartphone notifications report a higher concern for their information privacy.

Table 9: Correlation analysis of 'Occurrences of Negative Experiences' with smartphone notifications and 'MUIPC' scale items

Scale Items	Correlation Coefficient	p-value
Q1: I believe that the location of my mobile device is monitored at least part of the time.	0.16	0.11
Q2: I am concerned that mobile apps are collecting too much information about me.	0.11	0.27
Q3: I am concerned that mobile apps may monitor my activities on my mobile device.	0.15	0.12
Q4: I feel that, as a result of my using mobile apps, others know about me more than I am comfortable with.	0.23	0.018
Q5: I believe that, as a result of my using mobile apps, information about me that I consider private is now more readily available to others than I would want.	0.14	0.15
Q6: I feel that, as a result of my using mobile apps, information about me is out there that, if used, will invade my privacy.	0.24	0.014

4.9 Technical Efficacy Score

Due to unequal access to and adoption of smartphones, a significant amount of individuals are at a disadvantage due to experiencing difficulties in using a smartphone, therefore may be disadvantaged in the modern digitized societies. Hence, it is important to understand if people who encounter digital difficulties are at more risk of negative experiences due to notifications. Hence, we quantify how much someone is encounters digital difficulties or experience problems in using a smartphone.

A validated scale developed by Anrijs S et al (2020) is used for our analysis. We have chosen 5-items of 'General Digital Difficulties (GDD)' from the original scale. It is a 5-point Likert Scale with score range from 5 to 25, where higher score value means the user reports facing more digital difficulties than a user with lesser score. The mean and median score in our analysis was 13.44 and 15, respectively, with 7.10 as the standard deviation. The individual scores for each

of the scale items are reported in Table 10. Inferences can be drawn between the number of negative experiences and the digital disadvantages faced by users from the Table 11. It can be seen that the users who do not face any negative experience with notifications face less difficulties in operating digital devices as compared to people who have faced at least one negative experience.

Table 10: Digital Difficulties Score

Scale Items	Mean score	SD
In general, I often have difficulty when using my smartphone, apps, websites, or computer programs.	2.64	1.54
In general, I am not able to solve questions or problems on my own when using my smartphone, apps, websites, or computer programs.	2.69	1.51
In general, I need support when trying out something new on my smartphone or computer.	2.74	1.61
In general, I find it hard to adjust settings of my smartphone, apps, websites, or computer programs (for example, privacy or safety settings).	2.72	1.58
In general, I often have questions or problems when using my smartphone, apps, websites or computer programs after an update has been done.	2.66	1.49

Table 11: Digital difficulties and association with Negative Experiences due to smartphone notifications.

Occurrences of negative experiences	Mean score	Median Score
0	9.89	6.00
1-2	13.24	14.00
3-5	16.92	18.00
6-10	17.92	19.00
11-20	14.75	15.50
More than 20	10.00	6.50

Table 12: Correlation analysis of 'Occurrences of Negative Experiences' with smartphone notifications and 'MUIPC' scale items

Scale Items	Correlation Coefficient	p-value
Q1: In general, I often have difficulty when using my smartphone, apps, websites, or computer programs.	0.29	0.0024
Q2: In general, I am not able to solve questions or problems on my own when using my smartphone, apps, websites, or computer programs.	0.27	0.0058
Q3: In general, I need support when trying out something new on my smartphone or computer.	0.28	0.0047
Q4: In general, I find it hard to adjust settings of my smartphone, apps, websites, or computer programs (for example, privacy or safety settings).	0.25	0.012
Q5: In general, I often have questions or problems when using my smartphone, apps, websites or computer programs after an update has been done.	0.23	0.018

Appendix A Questionnaire

The following questionnaire has been developed for conducting the survey.

I. **Introduction**

(1) This question will record the recipient's browser information. It will not be displayed to the user.

(2) We care about the quality of our data. In order for us to get the most accurate measures of your knowledge and opinions, it is important that you thoughtfully provide your best answers to each question in this study.

Will you provide your best answers to each question in this study?

i. I will provide my best answers.

ii. I will not provide my best answers.

iii. I can not promise either way.

II. **Background**

(1) What is the Operating System (OS) of your phone?
(a) Android
(b) iOS
(c) Other. (Please specify:) [text box]

(2) Does your device use any type of lock (e.g., PIN, password, pattern, fingerprint, faceID, etc.)?
   i. Yes
   ii. No
   iii. Don't know

(3) Who other than you can unlock your device? (Select all that apply.)
   i. Parents
   ii. Spouse
   iii. Siblings
   iv. Friends
   v. Children older than 13
   vi. Other family members
   vii. Colleagues
   viii. Other. (Please specify:) [text box]

III. **Notifications and smartphone features**

(1) How many notifications have you received in the last hour? NOTE: Include all types of notifications (i.e. app icon badges, notification center, lock screen, and banners).
   i. 0
   ii. 1 to 9
   iii. 10 to 19
   iv. 20 to 29
   v. 30 or more

(2) On a typical day, how frequently do you pick up your phone to check, clear, or address notifications?
   i. Once in about 5 minutes
   ii. Once in about 15 minutes
   iii. Once in about 30 minutes
   iv. Once in about 1 hour
   v. Once in about 3 hours
   vi. Once in about 6 hours
   vii. Once in about 12 hours
   viii. Once in about 24 hours
   ix. Whenever a notification is delivered
   x. Something else. (Please specify:) [text box]

(3) Does your screen wake up when a notification is delivered?
   i. Never
   ii. Sometimes

iii. About half the time
iv. Most of the time
v. Always
vi. Do not know

(4) For each of the following actions, mention how many hours in a typical day (from 0 to 24) you use it.
i. Use Do Not Disturb (DND) Mode [a list of numbers from 0 to 24]
ii. Use Silent mode [a list of numbers from 0 to 24]
iii. Switch off the device [a list of numbers from 0 to 24]
iv. Use Airplane mode [a list of numbers from 0 to 24]
v. Use notification management apps [a list of numbers from 0 to 24]

(5) Mention the most frequently used Google service or product on your primary smartphone device. To ensure that you are participating attentively, please select the 'Translate' option. [Attention Check Question]
i. Docs
ii. Hangouts
iii. Maps
iv. Photos
v. Scholar
vi. Sheets
vii. Slides
viii. Translate
ix. Other. (Please mention:) [Text Box]

(6) Please explain your reasons for the answers to the previous question. (Optional) [an essay type text box]

IV. **Device sharing behaviour**

(1) How frequently can someone else view notifications on your phone in any of the following places? For each of the following, choose one from: Never, Few times a month, Few times a week, Once a day, Few times a day
i. Home
ii. Public Transport
iii. Cafeterias and restaurants
iv. Meetings
v. Seminars and presentations
vi. Stores and markets

vii. Classes
viii. Others. (Please specify:) [text box]

(2) For the following question, choose one option from: Never, Less than once a week, Few times a week, Multiple times a week, Once a day, Few times a day, Multiple times a day and N/A.
How frequently do you share your phone with the following people:

i. Spouse
ii. Siblings
iii. Parents
iv. Children older than 13
v. Friends
vi. Other family members
vii. Colleagues
viii. Strangers

(3) For the following question, choose one option from: Never, Rarely, Sometimes, Always and N/A.
Do you clear notifications from screen before handing over your phone to the following people::

i. Spouse
ii. Siblings
iii. Parents
iv. Children older than 13
v. Friends
vi. Other family members
vii. Colleagues
viii. Strangers

(4) When you hand over your smartphone to someone else, which of the following actions do you take? (Select all that apply.)

i. Nothing
ii. Close running applications
iii. Clear notifications
iv. Enable guest mode or second space
v. Enable app locks
vi. Change accessibility settings
vii. Watch over the other person's use of the phone
viii. Check all the applications used by the person
ix. Other. (Please specify:)[text box]

V. **Last Notification** Think about the latest notification that you received on your smartphone. Please answer the following questions with respect to that notification.

(1) Which app sent the notification? [text box]

(2) How quickly did you address the notification after you first saw it?
   i. within a minute
   ii. within 5 minute
   iii. within 30 minute
   iv. within an hour
   v. within 6 hours
   vi. within 12 hours
   vii. within 24 hours
   viii. Other. (Please specify:) [Text box]

(3) What action did you take when you first became aware that you had received this notification?
   i. Read the notification preview (title)
   ii. Read the notification content
   iii. Cleared it from the phone lock screen
   iv. Cleared it from the notification center/ drawer
   v. Opened the relevant app to address the notification
   vi. Did not do anything
   vii. Prevented further notifications from the app (Please tell us how:) [Text box]
   viii. Other. (Please specify:) [Text box]

(4) How do you receive notifications from this app? (Select all that apply.)
   i. Lock Screen
   ii. Notification drawer
   iii. Floating notification
   iv. App Badge
   v. Do not know
   vi. Other. (Please specify:) [Text box]

(5) How concerned would you be if someone else viewed this notification? [Choose from a 5-point Likert Scale ranging from Extremely concerned to Extremely unconcerned]

(6) Did this notification include information pertaining to another person?
   i. Yes
   ii. No

(7) How concerned do you think the person would be if the content of the notification was seen by someone other than you? [Choose from a 5-point Likert Scale ranging from Extremely concerned to Extremely unconcerned]

VI. **Negative Experience with Notifications**

(1) How many times have you experienced negative experiences related to notifications?
   i. 0
   ii. 1-2
   iii. 3-5
   iv. 6-10
   v. 11-20
   vi. More than 20

(2) Of the negative experiences related to notifications that you have encountered, please tell us a bit about the most negative experience. [text box]

(3) What caused the negative experience?
   i. I had given my phone to someone else when the notification arrived.
   ii. I left the phone screen unlocked.
   iii. I forgot to take appropriate actions to silence the notification.
   iv. The notification included sensitive content. (Please specify:) [text box]
   v. Others. (Please specify:) [text box]

VII. **Measuring mobile users' concerns for information privacy** [29]

(1) Please indicate your level of agreement with the following statements: [Choose one option from 7 point Likert-Scale ranging from Strongly Agree to Strongly Disagree.]
   i. I believe that the location of my mobile device is monitored at least part of the time.
   ii. I am concerned that mobile apps are collecting too much information about me.
   iii. I am concerned that mobile apps may monitor my activities on my mobile device.
   iv. I feel that, as a result of my using mobile apps, others know about me more than I am comfortable with.
   v. I should select somewhat agree for this question.
   vi. I believe that, as a result of my using mobile apps, information about me that I consider private is now more readily available to others than I would want.
   vii. I feel that, as a result of my using mobile apps, information about me is out there that, if used, will invade my privacy.

VIII. **Technical Efficacy** [30]

(1) Please indicate your level of agreement with the following statements: [Choose one option from: Never, Rarely, Sometimes, Always and N/A.]

i. In general, I often have difficulty when using my smartphone, apps, websites, or computer programs.

ii. In general, I am not able to solve questions or problems on my own when using my smartphone, apps, websites, or computer programs.

iii. In general, I need support when trying out something new on my smartphone or computer.

iv. In general, I find it hard to adjust settings of my smartphone, apps, websites, or computer programs (for example, privacy or safety settings).

v. In general, I often have questions or problems when using my smartphone, apps, websites or computer programs after an update has been done.

IX. **Demographics**

(1) What is your year of birth?

(2) What is your gender?

(3) What is your ethnic background?

(4) What is the highest level of education you have completed?

(5) What is your current employment status?

(6) What is your profession?

(7) What is your field of study?

(8) What is your current annual household income before taxes?

(9) How many years have you lived in the United States of America or India?

(10) Including yourself, how many people live in your household?

(11) How many children below the age of 18 live in your household?

(12) What is your current marital status?

X. **Closing**

(1) Is there anything else you would like to tell us?

Appendix B Study Information Sheet

INDIANA UNIVERSITY STUDY INFORMATION SHEET
for
Preferences regarding Smartphone Notifications

About this research

You are being asked to participate in a research study. Scientists do research to answer important questions which might help change or improve the way we do things in the future.

This form will give you information about the study to help you decide whether you want to participate. Please read this form, and ask any questions you have, before agreeing to be in the study.

Taking part in this study is voluntary.

You may choose not to take part or may leave the study at any time. Leaving the study will not result in any penalty or loss of benefits to which you are entitled. Your decision whether or not to participate in this study will not affect your current or future relations with Indiana University, Bloomington.

This research is intended for individuals 18 years of age or older. If you are under age 18, do not complete the study.

Why is this study being done?

The purpose of this study is to investigate people's experiences with notifications they receive on their smartphones. You were selected as a possible participant because you accepted our invitation to participate in the study. The study is being conducted by research scholar Priyanka Verma from BITS Pilani, India and Prof. Sameer Patil from Indiana University Bloomington, USA.

What will happen during the study?

This study consists of a questionnaire to be completed online. Completing the questionnaire takes about 10-15 minutes.

What are the risks and benefits of taking part in this study?

The risks of participating in this research are minimal. However, you may experience a small amount of stress or discomfort while contemplating your responses. Your responses are confidential and will be accessed only by our research team. We will not ask for personally identifying information.

We do not expect you to benefit directly from taking part in this study, but we hope to derive insight that will help improve the user experience of smartphone notifications.

How will my information be protected?

All research includes at least a small risk of loss of confidentiality. Efforts will be made to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Your identity will be held in confidence in reports in which the study may be published. The information will be stored securely on encrypted hard drives during analysis and then moved to the Scholarly Data Archive at IU. The data will be accessible only to those conducting this study.

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the study investigator and his/her research associates, the Indiana University Institutional Review Board or its designees, and any state or federal agencies who may need to access your research records (as allowed by law).

Will I be paid for participation?

For your participation, you will be paid $1.80 via Amazon Mechanical Turk. Note that receiving payment requires that you consent to participate, complete the study attentively, and correctly enter the completion code on Amazon Mechanical code.

Who should I call with questions or problems?

For questions about the study, contact the researchers: Priyanka Verma ¡prverma@iu.edu¿ or Sameer Patil ¡patil@indiana.edu¿.

For questions about your rights as a research participant or to discuss problems, complaints or concerns about a research study, or to obtain information, or offer input, please contact the IU Human Subjects Office at 800-696-2949 or at irb@iu.edu.

Thank you for agreeing to participate in our research. Before you begin, please note that the data you provide may be collected and used by Amazon as per its privacy agreement. Following mTurk policies, we may reject your work if the HIT was not completed correctly or the instructions were not followed. You must be 18 or older to participate in this research.

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