

Preferred Notification Modalities Depending on the Location and the Location-Based Activity

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ABSTRACT

Smartphones offer different modalities to inform about incoming notifications. They are perceived differently in terms of pleasantness and disruptiveness, depending on the receptivity and interruptibility of the user, among others. Contextual factors such as the user's location, activity, and task engagement level further influence this perception. Within a lab study with 40 tech-savvy participants, we investigated suitable notification modalities for different place types. We found that a user's receptivity, the disruptiveness of a notification, and the task engagement correlate and that they differ per place type with statistical significance and small to large effect sizes. Due to their unobtrusive nature, silent mode and vibration are preferred notification modalities at all places – silent mode especially at "do not disturb" locations ("library", "movie theater"), at places where users tend to be in company ("café", "restaurant"), or where users have to focus ("university", "work"). Ringtone is considered obtrusive and undesired and is only tolerated at a few places at which users tend to be alone ("home") or which are rather loud so that the auditory alert does not disturb others too much ("gas station").

CCS CONCEPTS

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

KEYWORDS

Smartphone Notifications, Place Types, Location-Based Activity, Preferred Notification Modality

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1 INTRODUCTION

The perception of notifications depends on multiple contextual factors such as the smartphone position, the user's location, and their activity [3]. This paper investigates the perception of notifications and the preferences for different notification modalities depending on the location of the user and the location-based activity. Notification modalities include three alerting methods: auditory cues (e.g., ringtone), haptic cues (e.g., vibration), and visual (e.g., notification LED). Locations can be described in different formats: as GPS coordinates [4], as Bluetooth or WiFi fingerprints [4, 17], or as place types [17]. Though, semantic interpretation that allows inferences of activities is only available for annotated locations such as place types. Jones et al. argue that (un)common activities are another factor that should be considered when investigating places [9]. Findings from literature emphasize a relation between a user's location and the activity performed at this location [10]. Such activities are also called "location-based activities".

To infer location-based activities, it is recommendable to rely on a location representation with semantic meaning, e.g., place types. The semantic meaning of a place can be provided by the user [17] or inferred automatically from sensor measurements, e.g., using the Google Places API [6]. From the semantic meaning of a place, one or more activities can be inferred that are representative for this location, for example, "watching a movie" at the location "movie theater" based on common knowledge. Location-based activities can also be influenced by the social context of a user which can relate to the user location as shown in [5]. Depending on the location-based activity, the corresponding level of engagement, the disruptiveness of a notification, a user's receptivity and

interruptibility might vary [6, 17] which also influences the suitability of or preference for a certain notification modality [3]. We will investigate place type-specific user preferences and relations between notification perception and place type.

2 RELATED WORK

Since our focus is on notification perception, it is reasonable to examine related work in the areas of receptivity and interruptibility detection, especially on mobile phones and in ubiquitous environments. There is a large amount of literature that investigated breakpoints and activity changes [14, 15]. Switching from one task to another is considered a situation with increased user receptivity [7] and a suitable moment for interruptions [1, 8]. These findings suggest relations between the interruptibility of the user and their current activity and task engagement – and possibly also between the user’s receptivity for smartphone notifications. Not only the engagement with a task but the nature of the task itself influences the user and their interruptibility. Park et al. concluded that users do not want to be interrupted while being socially engaged [16]. The social context is a property that is related to the location of the user [5] which for itself proved to be a feature related to a user’s interruptibility [6]. Social context, activity, and location were considered together in a set of features used for interruptibility detection [17], for identifying or predicting user preferences for notification reception [12, 13], and for selection of suitable notification modalities [3]. Due to their extensive consideration in literature, we will focus on location and location-based activities and investigate their influence on a user’s perception of notifications.

3 USER STUDY

The objective of the study was to get a first impression about preferences for notification modalities depending on the place type and location-based activity.

Design Decisions

We decided to run the study in a laboratory setting to have more control about external interruptions and to increase the internal validity. The study followed a mixed design: each participant experienced each location (within-subject), but was informed about incoming notifications at a certain location either via ringtone or vibration (between-subject). The notification modality changed at each location, i.e., the first group experienced vibration at place type 1, 3, 5, etc. and ringtone at place type 2, 4, 6, etc.; the second group vice versa. Each participant was interrupted by a notification at the same place and during the same location-based activity with a restriction of one interruption per place type.

Table 1: Overview of interview questions.

- On a scale from 1 to 7 with 1 being "not unpleasant at all" and 7 being "very unpleasant": How unpleasant was the reception of the notification?
- On a scale from 1 to 7 with 1 being "not unpleasant at all" and 7 being "very unpleasant": How unpleasant was it to be interrupted during the location-based activity? Why?
- On a scale from 1 to 7 with 1 being "not engaged at all" and 7 being "highly engaged": How engaged were you in the location-based activity?
- Would you have preferred a different notification modality? (yes/no) Why?

Procedure

We informed the study participants about their tasks and provided an example scenario (cf. Subsection "Scenarios"). If there were no questions, we asked them to sign a consent form and handed out the smartphone. The scenarios of the study were designed to fit into an exemplary daily schedule of a student having a student job in a company. We considered the days Friday to Sunday and let the participant experience common activities, each represented by a scenario. After each scenario, we ran a short structured interview to assess the participant’s sentiment towards the interruption (cf. Table 1). At the end, we assessed demographic data.

Scenarios

At first, we provided an introduction:

"In this study, you will visit different locations introduced by the scenarios. We will ask you to explain the activities you perform at these locations just like you would perform them in everyday life. Please use the first-person perspective and explain exactly which activities you perform. Please say at least three sentences about location-based activities for each place type."

In addition, we provided a short example scenario containing a place type printed in *italics* (swimming pool), an objective (meet friends), a beginning and an end, plus possible activities in brackets of which one will trigger an interruptive notification:

"Scenario: You are at home and want to go to the *swimming pool* to meet friends." Start: You leave your home. Activities: go to the swimming pool by bike, be at the swimming pool (look for friends, go swimming). End: You leave the swimming pool."

We also provided an exemplary response to facilitate the participants understanding of how to answer.

"I take my bike and go to the swimming pool. After arrival, I pay the entrance fee and look for a changing room to put on my bathing togs. Next, I look for my friends. After finding them, I place my towel next to them. After a short chat with my friends, I decide to go swimming. After swimming a few lengths, I leave the pool."

Table 2: Considered place types and location-based activities.

Place Type	Location-Based Activity
<i>Bakery</i>	Ordering food
<i>Bank</i>	Withdrawing money
<i>Bar</i>	Drinking beverages
<i>Bus / Subway Station</i>	Waiting
<i>Café</i>	Chatting with a friend
<i>Clothing Store</i>	Trying on new clothes
<i>Gas Station</i>	Refueling the car
<i>Grocery Store</i>	Looking for groceries
<i>Gym</i>	Performing weight training
<i>Home</i>	Cooking food
<i>Library</i>	Studying
<i>Meal Takeaway</i>	Ordering food
<i>Movie Theater</i>	Watching a movie
<i>Park</i>	Relaxing on a picnic blanket
<i>Parking</i>	Parking a car
<i>Post Office</i>	Waiting in line
<i>Restaurant</i>	Eating food
<i>University</i>	Attending a lecture
<i>Work</i>	Giving a presentation

In this example scenario, an interruption might have occurred during the search for the friends, e.g., because they sent a message indicating their position.

Place Types and Location-Based Activities

The selected places and activities are based related work [5, 6]. We decided to merge places with similar location-based activities to reduce the number of test cases in the following study: "shopping mall" was included into "clothing store", "grocery store" included into "store", and "club" included into "bar". In addition, we considered "home" and "work" [5, 17]. We selected representative activities based on common knowledge and under consideration of the probability of activities being performed alone or in company [5]. Table 2 gives an overview of all place types and location-based activities that were included into our scenarios.

Participants

We recruited 40 volunteers, 19 of them female and 21 of them male. Most of them were current or former computer science students or working in IT-related fields. The participants were aged between 19 and 41 (\bar{x} 26). Among them, we raffled two €10 Amazon gift coupons.

4 RESULTS

Receptivity

Receptivity refers to the responses given to the first item of the questionnaire ("How unpleasant was the reception of the notification?", cf. Table 1 and 3), ranging from 1

("not unpleasant at all") to 7 ("very unpleasant"), i.e., a low value represents a high receptivity.

It is visible that our participants are more receptive for smartphone notifications at locations where they have to perform rather actionless activities such as waiting ("bank", "bus / subway station", "store", "gas station") or relaxing ("bar", "home"). They are rather not perceptive for smartphone notifications at places where disturbances are not generally tolerated ("library", "movie theater", "work"). It is also visible that for some places the receptivity depends on the notification modality. In general, ringtone is perceived as more unpleasant and many participants are not willing to receive notifications at the "post office", "restaurant", or "university" if the notification arrival is announced by the ringtone instead of vibration.

Disruptiveness

Disruptiveness refers to the responses given to the second item of the questionnaire ("How unpleasant was it to be interrupted during the location-based activity? Why?", cf. Table 1 and 3), ranging from 1 ("not unpleasant at all") to 7 ("very unpleasant"), i.e., a low value represents a low disruptiveness.

It is visible that our participants perceive interruptions as less disruptive at locations where they have to perform rather actionless activities such as waiting ("bank", "bus / subway station", "post office", "clothing store", "grocery store", "gas station") or relaxing ("bar", "home") – fairly similar to places at which the receptivity is high. They are rather not interruptible at places where disturbances are not tolerated ("library", "movie theater", "work"). It is also visible that for some places the disruptiveness depends on the notification modality. In general, ringtone is perceived as more unpleasant, especially at places where participants are not willing to be interrupted by an incoming smartphone notification announced via ringtone, e.g., at the "gym", "restaurant", or "university".

Task Engagement

Last, we investigated the task engagement represented by the responses given to the third item of the questionnaire ("How engaged were you in the location-based activity?", cf. Table 1 and 3), ranging from 1 ("not engaged at all") to 7 ("highly engaged").

It is visible that our participants show low task engagement while waiting ("bank", "bus / train station", "post office", "grocery store", "gas station") or relaxing ("bar", "home", "park"). They were rather engaged in activities that require concentration and focus (to learn at the "library", watch a movie at the "movie theater", park a car at a "parking" lot, or do their job at "work").

Table 3: Ratings for receptivity, disruptiveness, and task engagement depending on a specific place type and location-based activity. Statistically significant results are marked: * $p < 0.05$; ** $p < 0.01$; * $p < 0.001$**

Place Type	Modality	Receptivity	Corrected p Value	Disruptiveness	Corrected p Value	Task Engagement
<i>Bakery</i>	Vibration Ringtone	2,45 ($\pm 1,5$) 3,60 ($\pm 1,57$)	0.494	3.20 (± 1.58) 4.55 (± 1.91)	0.494	6.75 (± 0.50)
<i>Bank</i>	Vibration Ringtone	1,80 ($\pm 1,06$) 2,45 ($\pm 1,07$)	1.000	1.95 (± 1.40) 2.40 (± 1.82)	1.000	4.10 (± 1.60)
<i>Bar</i>	Vibration Ringtone	1,60 ($\pm 1,19$) 2,65 ($\pm 2,08$)	1.000	2.00 (± 1.41) 2.60 (± 1.88)	1.000	3.08 (± 1.35)
<i>Bus / Subway Station</i>	Vibration Ringtone	1,25 ($\pm 0,72$) 2,25 ($\pm 1,55$)	0.760	1.30 (± 0.73) 1.35 (± 1.14)	1.000	3.50 (± 1.75)
<i>Café</i>	Vibration Ringtone	3,40 ($\pm 1,64$) 4,85 ($\pm 1,50$)	0.171	4.25 (± 1.86) 4.95 (± 1.24)	1.000	5.88 (± 0.97)
<i>Clothing Store</i>	Vibration Ringtone	1,95 ($\pm 1,44$) 2,85 ($\pm 1,75$)	1.000	2.30 (± 1.84) 2.80 (± 1.74)	1.000	4.75 (± 1.57)
<i>Gas Station</i>	Vibration Ringtone	1,35 ($\pm 0,67$) 1,90 ($\pm 1,29$)	1.000	1.45 (± 0.83) 1.50 (± 0.83)	1.000	5.38 (± 1.43)
<i>Grocery Store</i>	Vibration Ringtone	1,90 ($\pm 1,29$) 2,95 ($\pm 1,79$)	1.000	2.35 (± 1.50) 2.30 (± 1.22)	1.000	1.23 (± 0.53)
<i>Gym</i>	Vibration Ringtone	2,10 ($\pm 1,14$) 4,60 ($\pm 1,85$)	<0.001***	3.25 (± 1.97) 4.80 (± 2.12)	0.285	3.93 (± 1.54)
<i>Home</i>	Vibration Ringtone	1,75 ($\pm 1,07$) 1,40 ($\pm 0,68$)	1.000	2.25 (± 1.52) 1.85 (± 1.50)	1.000	5.03 (± 1.61)
<i>Library</i>	Vibration Ringtone	4,80 ($\pm 1,85$) 6,30 ($\pm 1,03$)	0.133	5.10 (± 1.62) 5.80 (± 1.40)	1.000	3.98 (± 1.33)
<i>Meal Takeaway</i>	Vibration Ringtone	2,10 ($\pm 1,33$) 3,75 ($\pm 2,05$)	0.190	2.50 (± 1.64) 3.40 (± 1.93)	1.000	2.40 (± 1.66)
<i>Movie Theater</i>	Vibration Ringtone	4,75 ($\pm 1,97$) 6,75 ($\pm 0,55$)	0.019*	5.55 (± 1.76) 6.65 (± 0.67)	0.190	5.45 (± 1.38)
<i>Park</i>	Vibration Ringtone	2,05 ($\pm 1,43$) 3,35 ($\pm 2,23$)	1.000	2.60 (± 1.93) 3.65 (± 2.28)	1.000	1.30 (± 0.61)
<i>Parking</i>	Vibration Ringtone	3,50 ($\pm 1,53$) 4,00 ($\pm 2,00$)	1.000	4.30 (± 1.98) 4.65 (± 1.63)	1.000	4.53 (± 1.50)
<i>Post Office</i>	Vibration Ringtone	1,55 ($\pm 0,94$) 3,55 ($\pm 1,61$)	<0.001***	1.15 (± 0.37) 1.90 (± 1.33)	1.000	3.18 (± 1.15)
<i>Restaurant</i>	Vibration Ringtone	3,35 ($\pm 1,81$) 5,35 ($\pm 1,50$)	0.019*	4.20 (± 1.67) 5.05 (± 1.64)	1.000	2.58 (± 1.34)
<i>University</i>	Vibration Ringtone	3,15 ($\pm 1,66$) 5,90 ($\pm 0,85$)	<0.001***	3.80 (± 2.02) 4.60 (± 1.79)	1.000	4.35 (± 1.35)
<i>Work</i>	Vibration Ringtone	5,90 ($\pm 1,52$) 6,80 ($\pm 0,52$)	1.000	6.65 (± 0.81) 6.75 (± 0.64)	1.000	3.85 (± 1.17)

Statistical Analysis

To verify if differences between the notification modalities ringtone and vibration are statistically significant for *receptivity* and *disruptiveness*, we ran statistical tests. Since the data was not normally distributed, we chose the parameter-free Mann-Whitney U test. To avoid an inflation of type I errors, p values were corrected using

the Holm-Bonferroni method. We reported the p value that resulted from each test together with an indicator for statistical significance (cf. Table 3).

In terms of receptivity, statistical tests emphasize a statistically significant difference between ringtone and vibration for "gym", "movie theater", "post office", "restaurant", and "university". These are mostly places where other people are present who might be disturbed

by a ringtone, but would probably not notice or mind the vibration sound. Absence of statistical significance for other place types such as "library" might be caused by a comparably negative effect of both vibration and ringtone on the participant depending on the location or the location-based activity.

Concerning disruptiveness, statistical tests did not reveal any significant difference. A reason might be that our participants felt disrupted by both vibration and ringtone independent from the location or activity. Though, it is also possible that opinions vary too much among participants or that the sample was not representative enough or too small to find any effects.

Correlations Among Receptivity, Disruptiveness, and Task Engagement

Responses for receptivity, disruptiveness and task engagement (cf. Table 3) suggest correlations among these concepts. An analysis based on Pearson's correlation coefficient (cf. Table 4) confirms statistically significant correlations and, according to Cohen [2], large ($r > 0.5$) and medium effect sizes ($r > 0.3$).

These correlations seem reasonable since the engagement with a task influences the sentiment towards a disruption during the task and the willingness to be interrupted. Hence, it is comprehensible that the places at which our participants tend to be more receptive are also those with a lower disruptiveness and a lower task engagement, respectively. The same applies the other way around: participants tend to decline the reception of notifications if the disruptiveness is high and they are highly engaged in their location-based activity.

Correlations Between Place Type and Perception-Related Concepts

To investigate if the values for receptivity, disruptiveness, and task engagement vary with statistical significance between different place types, we performed a multivariate analysis of variance (MANOVA) (cf. Table 5). The results of the analysis confirm statistically significant differences with $p < 0.01$ and, according to Cohen [2], large effect sizes with a partial $\eta^2 > 0.14$. This means that the task engagement level varies among different location-based activities and that the participants' receptivity and the perceived disruptiveness also vary at different locations. If we include the notification modality in addition to the place type, we can see that the effect sizes increase even more. This might indicate an effect of the notification modality, leading to the conclusion that both place type and notification modality should be considered when investigating receptivity, disruptiveness, or task engagement.

Table 4: Correlations between receptivity (R), disruptiveness (D), and task engagement (T). Statistically significant results are marked: * $p < 0.05$; ** $p < 0.01$; * $p < 0.001$**

		Correlation Coefficient r	p Value
R	D	0.828	<0.001***
R	T	0.494	<0.001***
D	T	0.616	<0.001***

Table 5: Results of the MANOVA performed to analyze the differences of values for receptivity (R), disruptiveness (D), and task engagement (T) depending on the place type only or depending on the place type in combination with the notification modality. Statistically significant results are marked: * $p < 0.05$; ** $p < 0.01$; * $p < 0.001$**

Place type only			
	F Value	p Value	Partial η^2
<i>R</i>	31.413	<0.001***	0.433
<i>D</i>	39.830	<0.001***	0.492
<i>T</i>	48.248	<0.001***	0.540
Place type and notification modality			
	F Value	p Value	Partial η^2
<i>R</i>	23.888	<0.001***	0.550
<i>D</i>	21.327	<0.001***	0.522
<i>T</i>	24.256	<0.001***	0.554

Preferred Notification Modality

Lastly, we investigated the preference for a notification modality depending on the place type and the activity. 76.32% of participants who received ringtone alerts would have preferred a different modality especially at the "library", "movie theater", "restaurant", "university", and "work" since ringtone is perceived obtrusive, interrupting, annoying, inadequate in public, and inappropriate when being in company. For vibration, 49.74% of all participants would have preferred the silent mode since vibration was still too disruptive at places such as "library", "movie theater", or "work" where users do not want themselves or others to be disturbed.

Limitations

Our investigations showed that smartphone users have different preferences for notification modalities depending on a general habit of the user, their current location, activity, and task engagement. However, visited places and related activities can vary among individuals. On the one hand, personal characteristics and hobbies might also have an influence. Our sample consisted of digital natives only. It is possible that other participants perform alternative activities and that they have different preferences. Older participants such as hearing-impaired elderly people or pensioners might prefer ringtone as notification modality as it is easier to perceive and as

they might not be in environments such as "work" where the ringtone can disturb others. On the other hand, we only considered one exemplary activity per place type. We recommend to run a field experiment with participants undergoing daily activities to assess further location-based activities and to verify if our results are reproducible. For now, our findings can serve as a basis for an automatic selection of a suitable notification modality that can be enhanced by further information about user activities or be customized to personal preferences.

5 SUMMARY

We conducted a lab study to gain first insights into smartphone users' preferred notification modality depending on the location and activity. Our results indicate that users are usually receptive for notifications alerted by vibration, independent from the place type, since vibration tend to be the default modality and due to its compromise between unobtrusiveness and perceptibility. Ringtone is perceived rather unpleasant for many places types, but also tolerated at noisy or outdoor environments or when users are alone. At the places "café", "gym", "library", "movie theater", "parking", "restaurant", "university", and "work" users are rather not receptive for any notification and prefer the silent mode.

We found correlations between the three concepts that are related to the perception of a notification. If a user's receptivity is high then the perceived disruptiveness of a notification is rather low, i.e., if the user is willing to receive a smartphone notification then they are also willing to be disturbed by it. If the user is highly engaged in the primary task then they are not receptive for smartphone notifications and consider them disruptive, i.e., if the user is highly engaged in a task then they are not willing to shift their attention from this task to a smartphone notification or any related interruption.

As shown by the results of a MANOVA analysis, receptivity, disruptiveness, and task engagement of our participants vary with statistical significance depending on the place type. This can be explained with the nature of these locations and activities: place types differ in environmental factors, social context, and location-based activities, among others, while the activities themselves vary in task engagement and, possibly, also social context. These factors influence the willingness of smartphone user's to receive notifications and their preference for different notification modalities. Another influencing factor seems to be the importance of a notification as concluded by Mashhadi et al. [11]. Hence, further subjective factors should be considered when investigating the preferred notification modality and the user's perception of smartphone notifications.

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