# Investigating The Perceptibility of Different Notification Types on Smartphones Depending on the Smartphone Position

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## Abstract
Smartphones keep their users up to date by notifying them about new messages or phone calls, among others. They offer different notification types such as ringtone, vibration and LED. However, users do not always perceive incoming notifications. Within a lab study with 36 subjects we investigated the perceptibility of these notification types depending on different smartphone positions: on the table, in the trouser pocket or in the backpack. Our results show that vibration and ringtone are perceived best at all positions. There is a statistically significant difference between these types and LED which was only perceived while the phone was on the table – if perceived at all. Users felt that vibration is most pleasant than the ringtone due to habit, lower obtrusiveness, lower disturbance, and lower distraction. Qualitative feedback reveals that the habits of the user, their (social) context, and their current task also influence the suitability of the notification type. We conclude that the best solution would be an automatic notification type selection that uses mostly vibration, though ringtone for important notifications and LED for unimportant notifications or those received while being surrounded by other people.

## Author Keywords
Smartphone; Notification Types; Smartphone Position

## ACM Classification Keywords
H.5.2 [User Interfaces]

## Introduction

Smartphones are an essential part of our everyday lives. They keep us up to date about incoming messages, email, calls or news, among others. Smartphones offer different notification types to inform us, e.g. ringtone, vibration, LED, display light, camera flashlight, or smartwatch vibration. However, it is not always possible to notice a notification as a vibration might be overheard or the blink of a notification LED might be overseen. The perceptibility might differ depending on the smartphone position as the surrounding of the smartphone might inhibit the sound or visibility, e.g. a smartphone within a trouser pocket or backpack might be easier to be overheard due to the textile that surrounds the smartphone. A smartphone being hold in the hand or lying on the table might allow to spot the blink of a notification LED that would be invisible if the smartphone is out of sight.

We hypothize that there is a correlation between the perceptibility of a notification depending on its notification type and the smartphone position. We will focus on the notification types ringtone, vibration, and LED as they were used in related work [4]. Researchers already found out that vibration has a good perceptibility in-the-wild [1, 6] and that the suitability of a notification type depends on the user context and environment [5], e.g. ringtone and vibration are associated with important notifications whereas LED is rather used in meetings where disruptions needs to be avoided.

Different smartphone positions were also investigated in related work before [2, 3]. They include common positions such as lying on a table, being kept in a front trouser pocket, or being stored in a backpack. These are the smartphone positions we will focus on in this paper. We decided to not consider the smartphone to be held in the hand as this is usually the case when the smartphone is in use anyway and every notification would be perceived.

Within this paper we want to answer the following questions:

- How perceptible are smartphone notifications depending on the notification type and the smartphone position?
- Which notification type is most suitable for which smartphone position?
- Which notification type is most pleasant to the user?

## Study Design

We decided in favor of a lab experiment to have more control over external influences and to guarantee a high intenal validity. In case that statistically significant results are yielded in such a controlled environment, it is possible to go into the field as future work.

*Experimental conditions:*
We have two variables that are to be manipulated. On the one hand the notification types: ringtone, vibration and LED. On the other hand the smartphone positions: on the table, in the trouser front pocket and in the backpack. We decided to let every user experience all notification types, i.e. a within-subject condition. However, the smartphone position should be fix for each user, i.e. a between-subject condition. This shall create the feeling of having their own smartphone situated at a certain position. It is pretty unusual to have three smartphones at different positions or to have to move one smartphone to different positions while performing a task such as watching a movie.

To counteract carry-over effects, we randomized the order of the notification types, i.e. six possible orders. As each of these orders has to be conducted with each of the three positions, we end up with 18 different orders.

*Smartphone app:*
To be able to switch notification types without manually accessing the smartphone and to be able to send notifications at fix points in time for each subject, we created a smartphone app. The app is able to receive commands via HTTP requests from a server with a web interface. The webinterface allows to specify the content of the notification, which notification type shall be used and when the notification shall be displayed. The HTTP requests are received by the app which then sends out the respective notification. The smartphone display is always deactivated so that only the specified notification type indicates a new notification. The app tracks the time between sending the notification and the user reaction to the notification. The collected data is sent back to the server for storage, but also remains on the phone in case of a connection loss.

For the notification types we selected the following configuration:

| | |
|---|---|
| Ringtone | standard sound "Tejat" at full volume for approx. 250ms |
| Vibration | pattern of 300ms off, 400ms on, 300ms off, and again 400ms on. |
| LED | blinks for 500ms in green (color code #00FF00) and alternately stays off for 500ms |

*Scenario:*
The scenario is set to take place in a home environment. The smartphone user is supposed to relax while watching a movie. While watching the movie, several distractions might happen: the doorbell is ringing, someone is knocking on the door, the phone is ringing, you receive a message via smartphone. We klindly asked the user to watch the movie thoroughly so that they are able to recall the storyline afterwards. We also asked the user to react to distractions. If the phone is showing a notification the user should click on it. To avoid the smartphone to be overheard we selected a movie that does not require sound to be understood. We selected "DUSTIN"[1], a short animation movie about a dog and a roboter.

*Room setup:*
Due to convenience, we conducted the experiment in a university office. We aimed at creating a "at home" feeling by selecting a room with pleasant temperature, a window that allows natural light, and a comfortable seat, among others. In addition, we made sure that the room has a good WiFi connection to ensure a working data transfer between app and webserver.

*Procedure:*
Each subject was invited to the experiment room and asked to sit down and to make themself comfortable. First, we explained the scenario, i.e. watching a movie and remembering the storyline while underlying external distractions. Next, we asked the subject to sign a consent form. The movie was started and so was a timer that was responsible for sending notifications to the smartphone at fixed time intervals: after 1, 3 and 5 minutes. The user was watching the movie and, in parallel, reacted to incoming notifications whenever noticed. Each subject had 120 seconds to react to a notification before it was dismissed and labeled as "not perceived". After the movie had finished, the study leader reveals the true nature of the experiment. If the subject still gave their consent, we assessed demographic information. To conclude the experiment, we collected qualitative feedback. Each experiment took about 20 minutes in total.

[1] http://www.cgmeetup.net/home/dustin-short-film/

*Subjects:*
Each subject participated in the experiment voluntarily and without being paid. As mentioned before, we had 18 different experiment orders. Hence, we aimed for a number of subjects that is a multiple of 18. At the end, 36 subjects participated in the experiment, 12 of them female. Subjects were between 18 and 26 six years old. We focused on subjects that are part of the digital natives generation which are familiar with the use of smartphones in everyday life. We selected participants who own a smartphone and who use it on a daily basis.

## Results

*Perceptibility*
First of all, we want to investigate how perceptible smartphone notifications are depending on the notification type and the smartphone position. To do so, we consider the reaction times per user as shown in Table 1. Vibration and ringtone were noticed very often and fairly quickly. In contrast, LED was often not noticed at all, especially while the phone was out of sight, i.e. in the trouser pocket or backpack.

To verify if these differences are statistically significant, we ran statistical tests. As the data is not normally distributed, we chose the parameter-free Friedman test instead of the classicial t test. The results, as shown in Table 2, show that there is a statistically significant difference between the reaction times of vibration and LED as well as ringtone and LED for all positions. We could not find any significant differences between vibration and ringtone.

These results emphasize the high perceptibility of vibration and ringtone as notification types. We conclude that these notification types are to be used for notifications of high importance that should be noticed at any rate.

*Suitability*
Next, we investigate the most suitable notification type for each considered smartphone position.

The results depicted in Figure 1 show that vibration and ringtone are most prominent. They were noticed most of the time for each position, though most often when close to the user, i.e. in the trouser pocket or on the table. They were the only notification types that were perceived while the phone was stored in the backpack, even though not by each subject. LED, however, was barely noticed, even when the smartphone was lying on the table.

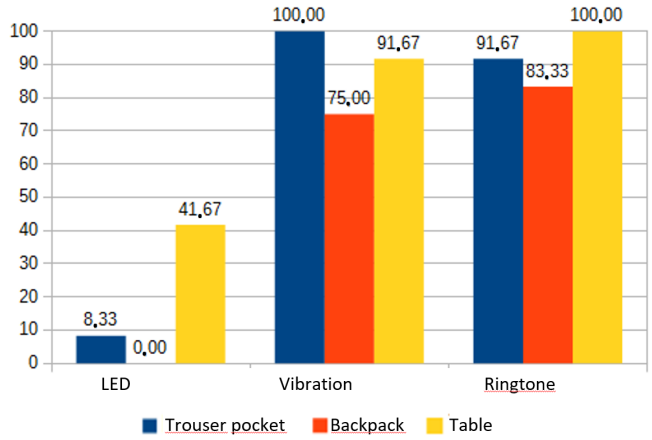


**Figure 1:** Overview of percentage of perceived notifications per notification type and smartphone position.

There are some outliers that probably occured by coincidence: One subject that were able to catch the blink of the LED while the phone was in the trouser pocket. Another one did not notice the vibration of the phone while it was lying on the table. A third subject did not hear the ringtone while the smartphone was in the trouser pocket.

**Table 1:** Reaction times in seconds for notifications depending on notification type and smartphone position.

| Notification Type | Position | Mean | Median | Standard Deviation |
|---|---|---|---|---|
| LED | Table | 103.2363 | 120 | 34.97664 |
| | Trouser Pocket | 115.9522 | 120 | 14.02182 |
| | Backpack | 120 | 120 | 0 |
| | *Average* | 113.0629 | 120 | 22.33264 |
| Vibration | Table | 16.0256 | 6.5785 | 32.7745 |
| | Trouser Pocket | 9.0828 | 8.4 | 2.39842 |
| | Backpack | 39.8143 | 14.2145 | 48.51569 |
| | *Average* | 21.6409 | 8.41 | 35.45812 |
| Ringtone | Table | 6.684 | 6.392 | 2.41601 |
| | Trouser Pocket | 19.0573 | 10.426 | 31.84418 |
| | Backpack | 30.0117 | 10.771 | 42.19942 |
| | *Average* | 18.5831 | 9.477 | 31.2033 |

**Table 2:** Results of the Friedman tests to investigate distinctions between the notification types per smartphone position. Significant results are printed bold.

| Notification Typ 1 | Notification Type 2 | Position | p value |
|---|---|---|---|
| LED | Vibration | Table | **.001** |
| | | Trouser Pocket | **.001** |
| | | Backpack | **.003** |
| | | *All* | **<.001** |
| LED | Ton | Table | **.001** |
| | | Trouser Pocket | **.001** |
| | | Backpack | **.002** |
| | | *All* | **.000** |
| Vibration | Ton | Table | .564 |
| | | Trouser Pocket | .564 |
| | | Backpack | .527 |
| | | *All* | .732 |

In a qualitative feedback round subjects stated that they have a preference of vibration over ringtone or the other way round depending on the context and importance of the notification.

We conclude that both vibration and ringtone are suitable for smartphone notifications at all positions. However, the importance of the notification and the context of the user, e.g. being at home vs. being in a meeting, should be taken into account. LED should only be used for notifications with normal or rather low importance and in contexts where sounds are not welcome, e.g. library or meeting.

*Pleasantness*
Last of all, we investigate which notification type is most pleasant to the user. We base this rating on the qualitative feedback of the subjects.

23 of the subjects stated that vibration was perceived as most pleasant. 10 of the subjects pledged for ringtone and only 3 for LED as most pleasant. The reasons for their decision can be summarized as one or more of the following aspects.

1. Habit: I use to have the phone in this mode
2. Annoyance, volume and obtrusiveness: it does not annoy or disturb people around me as much as other notification types; it is less obtrusive; it does not annoy me all the time
3. High perceptability, low distraction: I can still follow the movie in parallel; it is not as distracting as other notification types; I usually perceive it

We conclude that it is important to take into account the habits of the user, their (social) context, their current task and the importance of the notification when automatically selecting a notification type based on pleasantness.

## Summary and Conclusion

Within a lab experiment, we investigated the perceptibility, suitability and pleasantness of three different smartphone notification types (vibration, ringtone and LED) depending on three different smartphone positions (on the table, in the front trouser pocket and in the backpack).

Our results indicate that vibration and ringtone are best perceptible independent from the smartphone position. While vibration is considered most pleasant, ringtone is considered too annoying, disturbing and obtrusive for everyday use. Ringtone should only be used if the notification is very important and requires a quick and direct user interaction. Both are suitable notification types that allow perception of new notifications even while the smartphone is stored in the trouser pocket or backpack. LED, in contrast, is only perceptible while the phone is lying on the table. That is, LED is considered very unobtrusive and is therefore suitable for rather normal or unimportant notifications that do not need instant attention from the user.

Qualitative feedback reveals that the habits of the user, their (social) context, and their current task also influence the suitability of the notification type.

However, these results are only limited generazible. Our sample consisted of digital natives only. It is possible that older subjects would show different results, e.g. hearing-impaired elderies. Moreover, this was a laboratory setting and smartphones are usually used in the wild. It is necessary to run a field experiment underlying daily noises to verify if the results still hold true. Field experiments should also cover different user activities and might include everyday activities such as riding a bicycle, sitting in the train, attending a meeting, or meeting friends at a restaurant.

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