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What Makes a Notification Important? Investigation on Several Possible Features

Master's Thesis
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Zusammenfassung

Smartphone-Nutzer begegnen häufig dem Problem einer Überflutung an Benachrichtigungen. Wenn Benachrichtigungen wiederum abgeschaltet werden, ergibt sich die Problematik des Nichterhaltens von wichtigen Benachrichtigungen. Daher untersuchen wir die Leitfrage: Was macht eine Benachrichtigung wichtig? Hinsichtlich dieser Fragestellung zogen wir mehrere wahrscheinliche Faktoren in Betracht. Unsere Arbeit umfasst eine umfangreiche Recherche bisheriger Forschungen im Bereich mobiler Benachrichtigungen, um zu erfassen, welche Faktoren die Wichtigkeit von Benachrichtigungen beeinflussen können. Aus dieser Recherche entnahmen wir Faktoren, welche wir mit Hilfe einer Studie näher hinsichtlich ihrem Einfluss auf die Wichtigkeit von Benachrichtigungen erforschen wollten. Im Rahmen einer 4-wöchigen Studie, welche wöchentliche Interviews, tägliche Fragebögen und automatische Datensammlung via einer von uns entwickelten Applikation umfasste, sammelten wir Informationen über ein breites Spektrum an verschiedenen Faktoren, darunter: Zeit, Aktivität, Ort, Sentiment der Benachrichtigung, Emotion des Nutzers, Interessen des Nutzers, etc. Die 32 Teilnehmer unserer Studie lieferten uns wertvolles Wissen über die Wichtigkeit von Benachrichtigungen in Form von qualitativen und quantitativen Daten. Die Ergebnisse der Studie analysierten wir mit Hilfe statistischer Tests und wiesen damit mehrere Relationen zwischen verschiedenen Faktoren und der Wichtigkeit von Benachrichtigungen auf. Mit Hilfe der qualitativen Daten haben wir mehrere Hypothesen aufgestellt, welche wir durch Analyse der quantitativen Daten teilweise verifizieren konnten. Dabei haben wir festgestellt, dass bisherige bekannte Faktoren, wie Ort und Zeit, die Wichtigkeit beeinflussen, aber auch bisher wenig untersuchte Faktoren wie Emotionen der Nutzer und Sentiment der Benachrichtigungen einen Einfluss auf die Wichtigkeit von Benachrichtigungen haben. Außerdem haben wir verschiedene Arten von Wichtigkeiten festgestellt, und daher sollte bei zukünftigen Forschungen eine genaue Unterteilung der Wichtigkeit berücksichtigt werden, um detaillierte Effekte von verschiedenen Faktoren auf verschiedene Arten von Wichtigkeit zu erfassen. Insgesamt schließen wir daraus, dass mehrere Faktoren in Betracht gezogen werden müssen, um die Wichtigkeit einer Benachrichtigung zu bestimmen.

Abstract

Smartphone users frequently face the issue of being flooded by notifications. However, if notifications are muted, important notifications will not be relayed to the user. Therefore, we explore the central question: What makes a notification important? With respect to this issue, we explore several features. Our work contains an extensive literature research on previous works in the field of mobile notifications. This allowed us to apprehend which features could potentially influence the importance of a notification. We extracted several features which we wanted to investigate in the scope of a 4-week study. The study included weekly meetings, daily questionnaires and automatic data collection via an application implemented by us. During the study, we collected information about an extensive array of features, including: time, activity, location, sentiment of a notification, emotion of the user, interests of the user, etc. The 32 participants of our study provided us with vast information on the importance of notifications in the form of qualitative and quantitative data. The results of our study were analysed using statistical tests and exhibit relations between several features and the importance of notifications. We extracted several hypotheses from our qualitative data which we partially verified using our quantitative data. We noticed relations between well researched features and importance, like time and location. Additionally, we noticed that less researched features and importance, like user emotion and notification sentiment, showed to have a significant relation, too. Furthermore, we derived several kinds of importances from our qualitative data. Therefore, these different kinds of importances should be considered in future works in order to find influences of different features on different aspects of importance. Overall, we conclude several features need to be considered in order to derive the importance of notifications.

Acknowledgment

The finalisation of this work was only possible due to the support of several people and parties. Therefore, I want and need to express my gratitude to each of them.
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A vital part of this work is the user study, we conducted for four months. I wish to thank each participant for your support. The 4-week long user study was indeed long and I know some of you were extremely busy with work or research, rushing to meet deadlines. I appreciate your dedicated efforts in answering the questionnaires

and your thoughtful and honest replies during the interviews. A statistic, which did not make it into this work, was the ranking of who used the most expletives while talking about notifications. A clear head-to-head race between two of you became apparent during the transcription of the audio data. Closely followed by one who had no qualms in expressively enunciating their disdain towards system notifications. Thank you for reminding me of how significant research in this area is.
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Contents

1. Introduction

In the year 2015 1.86 billion people possessed a smartphone [112]. The number is supposed to grow by another billion people till 2020. This portable device has become an integral part of people's life. It allows easy access to a vast range of features, which include calling, taking photos, accessing the internet and so on. Smartphone users tend to always carry their device with them [75]. Different from stationary computers, the pervasiveness of smartphones can affect people in a more thorough way. In the following we want to focus on the aspect of notifications which smartphone users can practically receive at any time when carrying their devices.

1.1 Motivation

Due to the pervasiveness of smartphones we are exposed to notifications nearly at all times. Notifications can be useful in delegating information to the user. For instance, a user might receive a notification from the system to update their phone, which will remove several bugs, or a friend messages them on a messenger about an up-coming event they should attend. Notifications allow Google Maps to notify us about traffic jams on our way to work or they deliver interesting suggestions about videos to watch or articles to read. Therefore, notifications can help to lead the smartphone user to content which might be useful or interesting for them.
However, even before the penetration of global markets by smartphones researchers noticed the disruption caused by notifications when using stationary computers [13, 35, 47, 48]. The timing of an interruption can have negative effects on the user's emotional state and cause annoyance and frustration [1] and irrelevant notifications cause more frustration than those which do serve some purpose for the user [47]. Furthermore, notifications can reduce task performance [12]. Notifications which are irrelevant to the current task cause a greater disturbance as they require the user to change their train of thoughts and resettle back to the previous task thereafter. These negative effects are transferred to smartphones and due to the previously mentioned pervasiveness of this device, notifications can cause similar disruption at any time and at any place.
Many people underestimate the number of notifications they receive on smartphones. Weber et al. [107] conducted a study where their participants underestimated the amount of notifications they receive per day by more or equal to 50%,

meaning they received double as much as they expected. Their participants received between 60 and 200 notifications per day. In [82] the study participants received an average of 63.5 notifications per day. Their participants include students and workers in dominantly technical fields.
Lee et al. [58] researched the smartphone usage behaviour of 95 students at a Korean university. The average was at more than 400 notifications per day. They focused their research on technology addiction and smartphone overuse. Their results show that notifications can cause stress for the user. Yoon et al. [109] researched this issue of stress caused by notifications, too. For their research, they clustered their study participants into four groups depending on the qualitative data they collected: a *sensitive*, a *disoriented*, an *indifferent* and an *informed* group. Their research was mostly in regards to the usage of the KakaoTalk [1], a widely distributed messaging tool in Korea. The *sensitive* and *disoriented* group both felt stress because of notifications. The difference is that the *sensitive* group knew how to adjust notification settings. The *disoriented* group did not. The *sensitive* group would feel stress because of five reasons. The first was because of group chats which tend to be flooding. The sent notifications might be addressed at everyone so have potential to be relevant and are therefore not muted. Secondly, users were afraid of missing out on important pieces of information or emergencies. Third, the mental model of expected response norms differed. One group would expect the messenger to be a real-time chat, while the other viewed it as a mailbox where messages can be stored for later. This caused stress when people with different mental models interacted. Fourth, the messenger sent advertisement and spam. And lastly, the users felt stress when they were not able to tend to notifications despite knowing a notification has arrived. It is evident that smartphone users wish to receive relevant and important notifications. However, they have to face the abundance of additional notifications which exploit the user's attention. The flood of notifications can cause harm to smartphone users.

1.2 Objectives

We wish to research how different features affect the perception of notifications for smartphone users and what kind of notifications they like to receive. Fischer et al. [25] noticed in their research that the content of notifications is an important factor which influences the receptivity of smartphone users. Dependent on the content, users are tolerant of notifications despite arriving at unideal times. We believe many factors can influence the perception of notifications. Thus, we conduct a study in order to assess the influence of several features quantitatively and qualitatively. The main goal of this work is therefore to try to find an answer to our profound title question: *What Makes a Notification Important?*

1.3 Structure

The details of our research will be presented in this thesis. In the scope of this work we will first outline the basics of notifications and the needed techniques for our study in chapter 2. In chapter 3 we will give an overview of several features and

[1] https://www.kakaocorp.com/service/KakaoTalk

give information about existing research in this area. Then we select the features which we want to analyse in our work in chapter 4. Chapter 5 will outline our study design and chapter 6 will describe the implementation of the application which will be needed to gather the necessary data for our study. Following chapter 6, we will evaluate our results in chapter 7 and follow up with a discussion in chapter 8. We conclude our work in chapter 9 with a summary and an outline of potential future work.

2. Background

The main focus of this work will be on notifications on the Android Operating System (OS) [46]. This is due to the fact of Android OS being the most used smartphone OS with an 81.7% market share [103]. In the following we want to give a basic outline on the specifications of notifications on the Android OS. Additionally, we present the study techniques that will be used for our study.

2.1 Smartphone Notification

Notifications are used to notify a smartphone user about some content which an application or the system wants to deliver to the user. The notification can contain any information ranging from some facts about the current status to messages from other people or even content like news, weather information, video recommendations, etc. Applications can use notifications for any kind of content. It is possible to add images to a notification. Also, it is possible to add interactive tools to a notification so a user could engage with a notification beyond simply tapping on it or just swiping it away. Some applications use notifications as a controller of the respective application. The third notification in figure 2.1 is a notification by the *Blue Light Filter - Night Mode, Eye Care* application[1]. The notification itself is a toolbar which enables the usage of some functions of the application while it is closed. The fifth notification shown in figure 2.1 is another example of such an interactive notification. It displays a notification from the *Spotify Music* application[2] which allows interaction with the notification by adding elements to control the play of music.
Notifications are a very powerful tool to convey information and functions to a smartphone user. Notifications about ongoing events are usually *ongoing notifications*. These notifications show information about the respective ongoing event and cannot be removed. They remain for the duration of the respective event. The first notification in figure 2.1, which notifies the user that the device is charging via USB, is an example of such. In the following we want to get into detail how notifications work on the Android OS.

[1] https://play.google.com/store/apps/details?id=com.eyefilter.nightmode.bluelightfilter&hl=en
[2] https://play.google.com/store/apps/details?id=com.spotify.music&hl=en

2.1.1 Appearance of a Notification

In order to have a look at current notifications the user can swipe down the *status bar* to reach the *notification drawer*. In figure 2.1 we can see the *status bar* at the top, followed by a menu and lastly the *notification drawer* where current notifications are listed.
In order for the user to notice that notifications are available, several ways exist for a notification to appear on the screen as we illustrate in the following list:

Status Bar Notification A *status bar notification* [108] is a notification which appears in the *status bar* at the top of the screen. The notification will appear in the *notification area* of the *status bar* [46]. We usually see the icon of the application which notifies us. In figure 2.3a we can see the *status bar* marked in the red box. Two notifications can be noticed in the *notification area*. Till Android 4.4.4 (API level 20) the notification would also appear as a *ticker* in the *status bar*, which means a ticker text would scroll over the *status bar*. This was replaced in Android 5.0 (API level 21) by *heads-up notifications*.

Icon Notification An *icon notification* [108] will change the appearance of the icon of the respective application which is sending a notification. A *notification badge* will appear at the icon of the respective application. Figure 2.3b depicts such a *notification badge*. In this example we were notified that the application *WhatsApp* Messenger[3] has one notification for the user. Starting from Android 8.0 (API level 26) it is possible to long-press the icon and receive a preview of the notification.

Heads-Up Notification A *heads-up notification* [46] will appear at the top of the screen in the foreground. This means it will be on top of the *status bar* and cover the top of the opened applications if an app is used in foreground. This kind of notification can appear when the phone is active and unlocked. Figure 2.3c displays a *heads-up notification*. This feature was introduced in Android 5.0 (API level 21).

Popup Notification A *popup notification* [108] will appear on the screen in the foreground and block parts of the view on the screen. As an example, *WhatsApp* offers this feature, which can be seen in figure 2.3d. The incoming message will block the screen and the user may answer immediately, view the message or close the notification.

Lock Screen Notification Starting from Android 5.0 (API level 21) Android allows notifications on the *lock screen*. Figure 2.3e depicts a notification appearing on the *lock screen*. This feature can pose privacy issues because notifications displayed on the *lock screen* can be accessed without any passwords by anyone. Therefore, it is possible to declare in the notification settings whether the content of a notification should be displayed if *lock screen notifications* are enabled.

[3] https://play.google.com/store/apps/details?id=com.whatsapp&hl=en

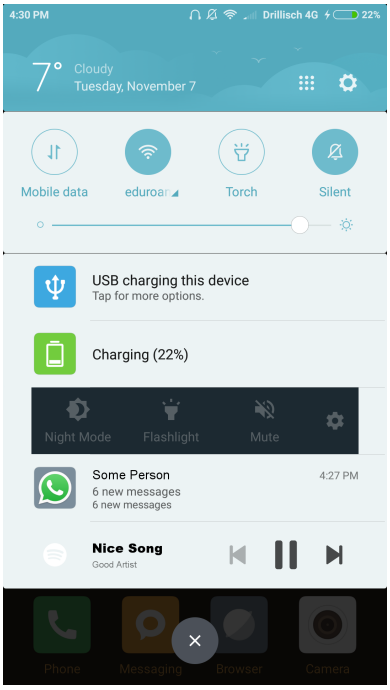


Figure 2.1: Example of notifications in the notification drawer

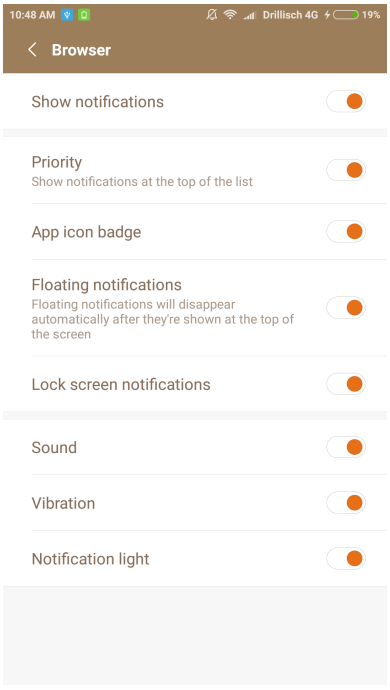
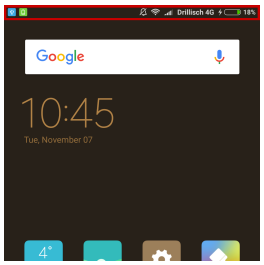
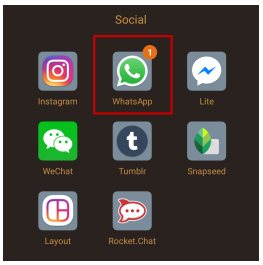


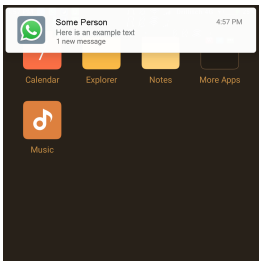
Figure 2.2: Example of settings for the notifications of an application



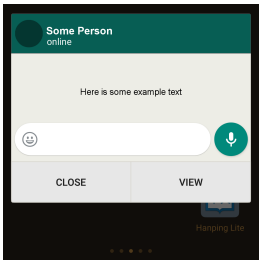
(a) Example of the status bar as envisioned in the marked area



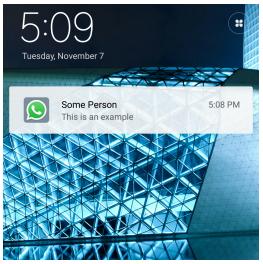
(b) Example of a notification badge as envisioned in the marked area



(c) Example of a floating notification at the top of the image



(d) Example of a popup notification



(e) Example of a lock screen notification

Figure 2.3: Five different ways a notification may appear on the screen

2.1.2 Notification Settings

An Android user has several options to adjust the way an application notifies them about incoming notifications. Such adjustments can be seen in figure 2.2. We can see that the user can choose whether they want to receive any notifications by an application or not. In the following we refer to this option of turning off notifications of an application as *blacklisting*. *Whitelisting* on the other hand is the opposite of *blacklisting* and refers to allowing notifications of an application to be sent. Also, we notice the user can adjust whether notifications of an application should appear with *priority*. This means if the notification of this respective application appears in the *notification drawer* along with notifications from applications which were not marked as *priority*, then the notifications of the *prioritized* application will appear at the top of the list. Next, the user can adjust the way a notification should appear. They can choose between most of the options mentioned in subsection 2.1.1 depending on the Android version. The last block in figure 2.2 allows the user to choose the *notification mode*. The *notification mode* is the *external signal* with which the user may be notified about the arrival of an incoming notification. The three possible modes are as follows:

Sound If enabled, an incoming notification will cause an alert sound to gain the user's attention. *Sound* can easily gain the user's attention but might disturb other people as well [54].

Vibration If *vibration* is turned on, an incoming notification will cause the phone to vibrate. Depending on the location of the phone, the phone might either cause noise, e.g. on a table, which can be perceived by others as well or only disturbs the user, e.g. in the trouser pocket. *Vibration* will not disturb the surrounding environment as much as *sound* [54].

Notification Light *Notification light* will let the phone notify the user about an incoming notification by using an LED signal. This *notification mode* poses the least disturbance to other people [54].

A smartphone user can choose a subset of these *notification modes*, including all or none of them. Android version 8.0 (API level 26) allows developers to implement several *notification channels*. These *notification channels* allow different categorizations of different notifications. The user can adjust the *notification settings* of each *notification channel*.
The *notification mode* can be overwritten by the *ringer mode*. In figure 2.1 we can see a menu with several toggle buttons under the *status bar*. The button to the right, which states *silent*, allows the user to choose the *ringer mode*. Many phone models offer a menu that appears after swiping down from the *status bar*. This menu usually includes a button for the *ringer mode*. The *ringer mode* allows three settings:

Silent The phone will not cause any *sound* or *vibration* even if the *notification settings* are set to any of these two choices. *Notification light* will continue to work.

Vibration If the *ringer mode* is set to *vibration*, incoming notifications which were set to *sound* will cause a *vibration* at most but no *sound*. The other *notification modes* will continue to work.

Sound *Sound* will allow all notifications to be delivered as set in their respective notification settings.

The *ringer mode* comes in handy if the user is in a certain environment that calls for specific grades of disturbance tolerance. For instance, during a meeting a user would likely change the *ringer mode* to *silent* so nobody else will be disturbed.

2.1.3 User Interaction

When a notification appears, the user has several ways to interact with the notification. They may *accept* the notification or *delete* it. In the following, *accept* means the user tends to the notification and thus, opens the respective application. *Deleting* on the other hand means the user disregards the notification and does not tend to it. After either action the notification will be *removed* from the *notification drawer* with the exception of *ongoing notifications*, which cannot be *removed* by the user. For either case several methods exist.

Acceptance

via Notification Drawer The user may enter the *notification drawer* and taps on the notification they wish to *accept*. After this interaction the respective application will be started as a foreground process, so the user can directly interact with the application.

via Application Alternatively, the user can tap on the icon of the respective application. *Notifications*, which are not *ongoing*, will disappear after this action.

via Heads-Up, Popup or Lock Screen Notification If any of these notifications are enabled, the user may tap on these to *accept* the notification. In case of the *lock screen notification* the user might need to unlock the device with a code before the respective application will startup on the device.

Deletion

Single Deletion via Notification Drawer The user may enter the *notification drawer* and swipe one notification to the right. This will *delete* the notification.

Clear All via Notification Drawer Additionally, the user can enter the *notification drawer* and tap on the *clear all button*. This button is usually at the bottom of the *notification drawer*. In figure 2.1 the x-Button at the bottom is the *clear all button*.

Internal Deletion An application can cancel its notifications.

External Deletion In some cases the notification may also appear on other devices, e.g. a new message of a messenger, which might also be installed on a laptop. The notification will usually disappear if the user has *removed* the notification on another device. However, some applications do have synchronization issues.

As mentioned before, notifications also allow more sophisticated interactions, e.g. the usage as a controller for an application. Additionally, starting from Android version 5.0 (API level 21) long-pressing a notifications allows the user to access the *notification settings* of the application which sent the notification. Furthermore, the user can access an expanded version of a notification, the *big view notification*. Expanding a notification varies slightly depending on the phone model. Most manufacturers allow expansion by pulling a notification downwards with one finger. The MIUI, a firmware based on Android OS by Xiaomi for its products, allows expansion by pulling a notification downwards with two fingers.

2.1.4 Notification Structure

A notification typically contains a *small icon*, a *notification title* and a *notification text* [41]. If we look at the notifications in figure 2.1, we can see that most of them contain an icon to the left, a title written in bold and a text. Before Android 5.0 (API level 21), developers were also able to make use of the *notification ticker* and set a text that should scroll over the *status bar*. Setting up the *small icon*, *notification title* and *notification text* is the most common structure. Though, as mentioned before, some applications might use the notification for more sophisticated features such as allowing the user to control the application via a notification or show the status of a progress with a *progress bar*. Android offers several elements which a developer can include in their notification.
Internally, a notification will be associated with a *PendingIntent* [41]. This *PendingIntent* defines the action of the notification. The *PendingIntent* contains an *Intent* that will start an *Activity* in the respective application if the user taps on the notification.

2.1.5 Notification Listener Service

In order to collect the incoming notifications of a smartphone user, a developer may use the *Notification Listener Service* [45]. The *Notification Listener Service* was introduced with Android 4.3 (API level 18). This service allows an application to receive calls from the system when a notification is posted, removed or a change in ranking of a notification occurred. In order to use this service, a developer needs to declare the service in the *manifest file* of the respective application including an *intent filter*. Additionally, the `BIND_NOTIFICATION_LISTENER_SERVICE` permission is required. The user needs to allow an application to access the notifications on the phone. Then a developer can implement the *Notification Listener Service*.

2.2 Study Techniques

In the scope of this work we will combine several study techniques to assess the needs and natural behaviour of smartphone users. More details of our study will be discussed in chapter 5. At this point we want to give a basic understanding of commonly used techniques in the *human computer interaction* field.

2.2.1 Interview

Interviews are an effective way to learn about the thoughts of different parties about an issue [6]. During an interview the interviewer will ask the interviewee questions face-to-face and engage in a dialogue. They can be structured in three different ways:

Structured Interview A *structured interview* is quite rigid in its form. It contains pre-defined questions and the interviewee is supposed to answer these accordingly. It allows no flexibility on the interviewers side. Therefore, the interviewer cannot react to unexpected responses and raise further questions. On the positive side, they are convenient and easy to handle, especially on a large scale.

Semi-Structured Interview *Semi-structured interviews* offer more flexibility than *structured interviews*. The interviewer will likely prepare questions to ask the interviewee. However, these can be adjusted to the situation and allow more exploration of newly addressed topics.

Unstructured Interview *Unstructured interviews* require minuscule preparation. Often, only the given topic is provided. This kind of interview is useful if barely any prior knowledge is available.

2.2.2 Questionnaires

Other than interviews, questionnaires do not require a face-to-face dialogue. They are useful for large-scale surveys. However, due to the lack of direct interpersonal communication, the design of a questionnaire tends to be difficult as questions need to be understandable and unambiguous.
A frequently used evaluation scale is the *Likert scale* [62] that allows the user to rate their agreement with a statement.

2.2.3 Wizard of Oz

For a *Wizard of Oz* study [53] a piece of software is provided to users. The users are able to engage with the software and it seemingly works. However, a human is simulating functions of the software in the background. This technique allows to test a user's behaviour with systems which might be hard to implement.

2.2.4 Experience Sampling Method

Experience Sampling Method [31], short ESM, allows researchers to gain an understanding of a user's natural context. Throughout the day questionnaires will be triggered, e.g. on a smartphone, to assess the user's current context. The questionnaire can contain any questions in regards to the research topic.

3. Feature Overview

Within the scope of this work, we want to define two categories of features which might influence the user's perception of a notification. One would be *extrinsic features* which cannot directly be derived from the notification or activities and settings of the phone itself. *Extrinsic features* are those which are the context of the smartphone and its user. These can either be sensed using sensors, e.g. the *location* of the user, or provided by the user via an inquiry. On the other side we also define *intrinsic features* as those features which can be derived from the notification or phone settings themselves, e.g. the application sending a notification. These features are often more static compared to *extrinsic features* which describe the ever-evolving context and situation of user and smartphone.

3.1 Extrinsic Features

In the following we want to define what we mean by each *extrinsic feature*:

Time The feature *time* describes when an event in regards to a notification occurred, e.g. when it was triggered or when it was deleted. This feature has different variations in different papers. Hudson et al. [38] and Fisher et al. [26] assessed *time* hourly. Some categorize *time* into *morning*, *afternoon*, *evening* and *night* or similar categories [66, 69]. Some works have been differentiating between workdays and weekends [78] and considered the time into the experiment [78]. Also, some works regard time relative to the ongoing activity, e.g. if the user just started an activity or if the user is already in the middle of an activity [1].

Activity The *activity* of a user is their ongoing occupation at the time, the notification arrives [33]. Currently, it is difficult to derive the exact *activity* of a user based on sensors alone. We can determine whether a user is *still*, *walking*, *running*, *cycling* or in a *vehicle* [70] but it is hardly possible to determine details automatically. For instance, when a user is *still* we can hardly determine whether they are currently *leisurely* reading a book or reading a report for *work*. When the smartphone is *still* the phone could be lying on a surface

or the user is actually not moving. Mehrotra et al. [71] used an ESM study and categorized the results into six categories: *work*, *communication*, *traveling*, *maintenance/personal*, *leisure* and *idle*. Additionally, some works focus on activity breakpoints, meaning moments when the activity changes [74].

Activity Engagement The *activity engagement* describes the immersion of the user into the ongoing activity.

Formality of an Activity The *formality of an activity* describes how *casual* or how *formal* a situation is. A *casual* situation could be a gathering with friends or relaxing at home. A *formal* situation on the other side could be a meeting with a supervisor or attending lectures.

Meaningfulness/Emotionality of an Activity An *activity* can be *meaningful* or *emotional* if an activity is of personal value for a person. For example, a Christian with strong religious believes might think of going to church as *meaningful* while some atheists do not. Or talking with a friend about personal experiences during a really hard time can be very *meaningful* and *emotional* while on the other side chatting with a friend about what they ate for breakfast might not be as *meaningful* or *emotional*.

User Personality The *personality of a person* is defined by the user's features which stay mostly constant in regards to different aspects like thinking and behaviour [80]. Personality studies look into regularity in behaviour patterns and feelings. The *Big Five* [80] is a five-factor model which tries to describe personality traits. The two traits which will be relevant for this work, will be *neuroticism* and *extraversion*. *Neuroticism* describes the emotional stability. Some people tend to be more emotional and have stronger emotional responses than other people who tend to be more stable. *Extraversion* describes the need to engage with other people. Extroverted people tend to look for more frequent and intense social interaction while introverted people do not need frequent external stimulation.

User Interest In literature *interest* has two definitions [101]. *Interest* can be an emotion which is described as *situational interest*. Secondly, *interest* can be another part of a person's personality and individual hobbies and goals. The second definition encompasses all kinds of *individual interests* a user can have, including hobbies, passions, etc. *User interest* mainly refers to the second definition in this work. However, the two kinds of interest are interrelated [32, 92, 96] which is why the situational interest as an emotion will also be considered in support of the individual interests.

Phone Location The *phone location* relates the position of the phone to the user. The phone might be in a pocket, in the user's hand or on a table [63, 26].

Social Situation The *social situation* describes whether a user is *alone* or in *company* [78, 38]. Previous works have often only assessed the *surrounding sound* which we include here as it is difficult to precisely assess the exact *social situation* with only the phone.

Social Expectation Living in a society we adhere to certain*social expectations* [4] which have an influence on how we react to notifications. *Social expectations*

are related to the *social situation*. People will behave differently in company because of social frameworks like etiquette and consideration towards others. But those expectations also persist when the user is not in company, e.g. the expectation of an answer to a message.

Location The *location* differs to *phone location* by referring to the location of a user and can be assessed as GPS coordinates [91] or in more generic categories. In previous works several categories have been used for *locations*. Mostly, *work*, *home* and *other* [69, 70, 78] have been assessed. A more differentiating approach could offer a more precise detection of user interruptibility as the category *other* can refer to a vast amount of spaces [20].

User Emotion The *user emotion* is the emotional state of a user. Scherer et al. [94] describes *emotion* as the change of state of five different organismic subsystems. This change occurs as reaction to internal or external triggers. Therefore, *emotions* are short-lived compared to *mood* which lasts for a longer period of time. Pejovic et al. [78] considered the emotions *happy*, *sad*, *angry*, *frightened* and *neutral* and let the subjects evaluate how intense they felt these emotions at the moment. Schulze et al. [98] on the other side used these pairwise categorizations: Negative, unpleasant – positive, pleasant; Powerlessness, submissiveness – control, dominance; Calmness, thoughtfulness – agitation, activity; Familiarity, expectedness – surprise, unpredicted.

User Mood The *user mood* [86] is different from the *user emotion* in the way it does not necessarily need a stimulus or trigger. *Mood* is generally longer-lasting compared to *emotion*.

Proximity The *proximity* sensor of smartphones can detect the distance towards nearby objects. Mehrotra et al. [70] use the proximity sensor to detect whether the user was near the phone in the past minute.

Future Activity *Future activities* are *activities* which the user will do in the future. So far, there have been works which considered calendar entries [91, 98]. However, there are currently no other ways to derive *future activities* and it will be hard to derive if the calendar application is not used reliably by the user.

Luminosity The surrounding *luminosity* is the brightness of the surrounding of a phone and can be sensed by a smartphone [71].

3.2 Intrinsic Features

The following list defines each *intrinsic feature*.

Application Name The *name of the application* refers to the official name of an application, which caused a notification [70, 71].

Application Category The *category of the application* refers to the category of the application, which caused the notification [93]. In different works, the categorization can vary. Sahami et al. [93] noticed that the users of their

study used applications of 30 different categories of the Google Play marketplace. They removed several categories, which were only used by very few of their subjects, and derived new categories, resulting in 14 categories for their work. While their categorization was quite fine-grained, other works included fewer categorizations like *messengers*, *email*, *social* and *other* [82]. Mehrotra et al. [70] combined *application category* with *other party of the notification* meaning they considered categories like *Chat Social*, *Chat Work*, *Chat Family* and *Chat Other*, etc.

Notification Content In our work the *content of the notification*, which was triggered, includes the notification title, ticker and body. Many works only assess the notification title [69, 70]. The *notification content* can contain private information.

Notification Frequency The *frequency* refers to the amount of notifications an application causes in a certain time [82].

Notification Reminder Frequency We define the *notification reminder frequency* as the frequency with which an application causes the *same* notification.

Notification Sentiment With *notification sentiment* we refer to the emotion which the content of a notification expresses.

Other Party involved in the Notification This feature describes the party, which caused the notification. In case of a notification being by the *application category Communication*, this feature refers to the sender of the message. Hereby, previous works usually categorized them as *family*, *friends*, *work*, *other* or similar [70, 4]. If the notification was not caused by incoming messages of a communication application, then the notification is often triggered by the *system*, *service provider* or *other* [71].

Urgency of a Notification This indicates whether the notification contains information which needs to be handled soon [71].

Notification Relevance The *notification relevance* indicates whether the notification contains information which is relevant to the current situation of the user. While categorized as an *intrinsic feature* because it majorly depends on the *notification content*, this feature heavily depends on *extrinsic features* like the *activity* or *location*.

Internet Connectivity This feature indicates whether the smartphone is currently connected to the internet or not [70].

Notification Mode The *notification mode* refers to the modality of the individual notification [70, 91]. Usually notifications cause a *sound*, *vibration* or *optical signal* like *LED signal* [54, 98] (see subsection 2.1.2).

Concurrent Applications We define *concurrent applications* as applications which are active upon arrival of a notification.

Notification Pleasureability The *notification pleasureability* specifies whether the notification contains information which is enjoyable to the user [4].

Ringer Mode The *ringer mode* refers to the generic smartphone setting of the user about how the phone should notify the user [70]. Usually the phone offers *sound*, *vibration* and *silent* (see subsection 2.1.2).

Battery Level The *battery level* indicates the left energy of the smartphone.

Concurrent Notifications In our work we define *concurrent notifications* as how many and which other notifications are present upon the arrival of a notification.

Contrast Level The *contrast level* refers to the dimness of the smartphone display.

Application Usage Frequency We define the *application usage frequency* as how often the user uses the application which causes the notification.

Past User Reaction The *past user reaction* refers to how the user handled the notifications of the interrupting application in the past [69]. This can be in regards to acceptance and time till the notification was attended.

Phone Attendance This indicates whether the phone has been used in the past few minutes or not [70].

Since we focus on Android we exclude the feature *ringer switch*. On iOS-Systems a switch is offered, which can turn off notifications completely by pressing a certain button.

3.3 Previous Research

Tables A.1, A.2 and A.3 show which *extrinsic* and *intrinsic* features have been examined together so far.

Several works have used several features at once to examine whether they were suitable features to derive information about the effect of a notification on a smartphone user. Therefore, those works appear in several cells of the three tables A.1, A.2, A.3, e.g. Mehrotra et al. [70] have collected several features to determine which of them were helpful in determining the acceptance by the user. They have categorized the other parties of triggered notifications by communication applications into *work*, *social*, *family* and *other*. In their study they let the user label their contacts for this categorization. Also, they used the three types of locations *work*, *home* and *other*. By using Google's Activity Recognition library they were able to classify whether the user was *still*, *on foot*, *running*, *on bicycle* or in a *vehicle*. In addition, they collected several other features and created a ranking of which features allowed a high information gain in regards to acceptance of the notification. In regards to the *social situation*, they have sensed the *surrounding sound*.
Looking at the tables A.1, A.2 and A.3 it is apparent that certain features have had more attention by the scientific community than others. We first want to give an insight to the *extrinsic features* and then to the *intrinsic features*.

3.3.1 Previous Research on Extrinsic Features

3.3.1.1 Previous Research on Time

Depending on the *time* of the day or week the perception of a notification can change. A weather information notification for example is usually more useful in the morning than at night when it is unlikely for the user to go out. Time is assessed with nearly all intrinsic features we consider in our work, which is noticeable in table A.1. The mentioned works all noticed a relation between time and interruptibility of a user. Pejovic et al. [78] implemented a system which would send notifications depending on different features, amongst those time, and noticed that when only time was used, their system was most precise compared to using only *activity* or *location*. For activity, they only used smartphone sensors which were not sufficient. Mashhadi et al. [66] noticed in their work that people tend to prefer notifications in the morning and in the evening.

3.3.1.2 Previous Research on Activity

The table A.1 shows that in regards to interruptibility the user *activity* has been examined thoroughly. There have been many researches which have proven that notifications can have a negative effect on a user's efficiency and emotion during an activity [1, 35, 82, 93]. Therefore, it is sensible to determine which notifications are currently important to the user. The activity itself is a useful feature, e.g. messages from co-workers or the boss during work are often important even if they can cause stress.
Frequently, the assessment of the activity is quite basic: Classification of whether the user is sitting, standing, walking, walking up stairs, walking down stairs or a subset thereof. These activities were either assessed in an obtrusive way by using motion accelerometers at the ankles of the user [33] or unobtrusively by using the acceleration and balance sensor of a smartphone. However, Pejovic et al. [78] figured that they were not successfully able to reliably determine change in activities based on the smartphone accelerometer alone. Another possibility is to use the Google Activity Recognition API in order to assess whether the user is *not in motion*, *moving by feet*, *moving by bicycle* or *moving in a vehicle*. Mehrotra et al. [71] have inquired the specific activity by using an ESM study where they attached a questionnaire to notifications including a request to specify the activity the user was engaged in at arrival of the notification. Depending on these differences the interruptibility of a user can change greatly.
The activity has often been examined in combination with direct information of the application, e.g. *application name* or *application category*, the *other party of the notification*, the *notification mode* and information in regards to the *notification content*, including *relevance* and *urgency* (see table A.1). Ho et al. [33] examine the interruptibility of people during activity breakpoints. This means when they switch between the activities of *sitting*, *standing* and *walking*. They chose to give their study participants accelerometers which they had to put on in order to measure the activity. The results of their studies show that participants often do prefer notifications at activity breakpoints rather than at random times. However, there are some exceptions, e.g. when someone is in a meeting and has to stand up several times for a presentation.

3.3.1.3 Previous Research on Activity Engagement

When a user indulges in an *activity*, the level of their immersion can have an influence on their interruptibility [79]. Pejovic et al. [79] conducted an ESM study to inquire how users currently felt about their ongoing activity according to these five parameters: *interesting*, *challenging*, *concentrated*, *important* and *skilled*. Depending on these, the perceived interruption was different. The more challenging the task was, the less interruptible was the user according to their own assessment. In their work they examined *activity engagement* in general.
Mehrotra et al. [71] also assessed several *intrinsic* and *extrinsic* features, including activity engagement. They noticed that *notification mode*, certain *activities* and slightly the *task complexity* influence the time till the user sees the notification. When *notifications* arrived in vibration mode, the user would react the fastest. The *task complexity* had a positive influence on the *seen time*. They argue that users tend to be more alert when the complexity of their ongoing task rises. Statistically, the *completion level* had no influence. The engagement had an impact on the user's affective state. A user who is strongly concentrating on their task will be more frustrated by an interruption [71].

3.3.1.4 Previous Research on Formality of an Activity

We derived the feature *formality of an activity* from Schulze et al.'s work [98] which focuses on different types of conversations. Amongst these conversations were *formal* conversations and *casual* ones. We want to expand the factor formality to all kinds of activity. Some works have observed user behaviour during formal situations, e.g. during meetings [91]. However, as far as to our knowledge no research on the formality of activities in general have been conducted. Different types of activities can be formal, e.g. a business dinner, attending a lecture, visiting an opera concert, riding a taxi with business partners, etc.

3.3.1.5 Previous Research on Meaningfulness or Emotionality of an Activity

The *meaningfulness and emotionality of an activity* are derived from Schulze et al.'s work [98] as well. They noticed that many people do not want to be disturbed during *meaningful* or *emotional* conversations. We suspect that not only during communication but also during other meaningful activities, people might be less prone to accept notifications. As an example, a passionate dancer might perceive notifications as less important during dance practices.

3.3.1.6 Previous Research on User Personality

In table A.2 we see that the *user personality* has not been researched a lot so far. Mehrotra et al. [71] however, did notice that the user personality amongst other features influences the time till a notification is seen and till a notification is handled. The user personality can be assessed using previously developed questionnaires such as the 50 item Big Five Factor Markers from the International Personality Item Pool $IPIP$ [27] as used by Mehrotra et al. [71] or the ten item personality inventory by Gosling et al. [29].

3.3.1.7 Previous Research on User Interest

Fischer et al. [25] have examined the feature *interest* in regards to *time* and *notification content*. Their study shows that even during bad timing users tend to be receptive to notifications which suit their interests. This feature might be useful in regards to news applications which often get completely blacklisted by users [93], so these applications cannot send any notifications at all.

3.3.1.8 Previous Research on Phone Location

Fisher et al. [26] has considered the *phone location* amongst other features to implement a system which would detect interruptibility of a user. Together with the other features the consideration of the phone location greatly improved the detection of the user's interruptibility.

3.3.1.9 Previous Research on Social Situation

A very much researched feature is the *social situation*, albeit we also considered works which only recorded the surrounding sound for this feature. Pejovic et al. [78] differentiate in their work between *alone* and *not alone* and assess this information by using an ESM study. A thorough analysis of the social situation can have severe privacy implications as several participants in a study by Schulze et al. [98] stated, they do not want to be recorded by other people's phones. On the other side Schulze et al. [98] also detected a certain link between interruptibility and certain types of conversation compared to each other and compared to no conversation.
Depending on the social situation of the user the perception of the importance of a notification might change. If users are alone, they might be more willing to receive a notification which contains trivial information [38]. However, if a user is engaging in a conversation with someone else, they quite likely do not wish to be disturbed. Whether someone is in company can be determined by recording audio and classifying whether someone is talking or not. Then the recognition needs to be very noise-resistent as smartphones accompany the user to many places which can be both noisy or quiet spaces. Hudson et al. [38] assessed the social situation of office workers who occupy a room for themselves. So usually it will be quiet in the room but when they have company, the noise level rises.
Some information can also be inferred from the place. Restaurants for example are social places where it is likely that one has company. Kern et al. [54] suggest that not only the personal but also the social interruptibility should be taken into account. The modality of the notification is therefore quite important as e.g. an audio signal would interrupt not only the mobile user but also their environment. On the other side a visual signal would only interrupt the user. The social situation relates to the current activity and location of the user. In their experiment Kern et al. [54] use sensors to determine the social situation of a subject and use the ground truth data to derive the interruptibility. Therefore, they sense the activity using the classes *sitting*, *standing*, *walking*, *walking upstairs*, *walking downstairs* and *running* using an accelerometer. Also, they analyse audio input and classify the situation into the classes *street*, *restaurant*, *lecture* and *conversation*. Their results had a tendency to derive more false negatives, meaning the system would rather classify a situation as non-interruptible than interruptible even if the user could be interrupted.

3.3.1.10 Previous Research on Social Expectation

Society exerts a certain pressure on people so they will not take a huge amount of time till they answer a message [7]. So far some works have noticed in their qualitative data that smartphone users felt some kind of pressure to answer certain messages as soon as possible [82, 83], e.g. many people perceive WhatsApp as an application where fast, even instant, replies should be the norm. Sometimes, a divide exists in the perception of such *social expectations*. It was mentioned in Church et al.'s work [7] that some users perceived messengers as a realtime-chat and others as a system similar to e-mails. Therefore, different perceptions of how fast one should answer a message existed.

3.3.1.11 Previous Research on Location

Like *time*, *location* too has been assessed with several other features which is noticeable in A.3. In previous works the current location of the user was often a feature to consider in regards to mobile notifications. As an example, if the user is currently at work, it is likely that they do not wish to be interrupted by unimportant non-work-related messages. However, if they are at home, the same notification could be perceived as a lot less disrupting, maybe even more important because the notification could have to do with hobbies, which the user engages in at home, e.g. book recommendations for someone who enjoys reading.
There are different variations in the granularity of the classification of the location. Often, previous researches were distinguishing between where the user lives, where the user works and a generic "other places" [78]. However, Exler et al. [20] propose the usage of certain place types like *Library* and *Shopping Mall*. Because of social expectations a noisy notification is unacceptable in a library and personally many people go to library to work. Therefore, the perceived importance of a notification might decreases as the user's wish to receive notifications decreases. On the other side, people usually go to a shopping mall for leisure and therefore the demand to only receive important notifications drops. Overall, Exler et al. [20] found 20 places which people often visit. In order to assess these places, the users were asked to specify their work place and home place on a map. The GPS data was then saved. For the more fine-grained rendition of "other places" the *Google Places API*[1] can be used.

3.3.1.12 Previous Research on User Emotion

The *user emotion* has only been examined slightly so far. Schulze et al. [98] have focused on interruptibility during conversations in their work. They noticed when a user is in an emotionally involving talk, whether it be a positive or negative one, the interruptibility is lower than when no conversation is taking place.

3.3.1.13 Previous Research on User Mood

Yuan et al. [110] have investigated the usage of *mood* as a feature to predict interruptibility of a user. They let people rate their mood on a scale from *pleasant* to *unpleasant* according to the brief mood introspection scale (BMIS) measurement [67] and noticed that people are more interruptible when they are in a more *pleasant* mood.

[1] https://developers.google.com/places

3.3.1.14 Previous Research on Proximity

The *proximity* has sometimes been recorded using the proximity sensor. Mehrotra et al. [70] ranked proximity quite low, meaning this feature does not provide a lot of information in their data.

3.3.1.15 Previous Research on Future Activity

Future activities can be a useful feature but possible assessment methods are very limited. So far this feature has been derived from events noted in the calendar application of the user. Rosenthal et al. [91] used *calendar information* to determine future meetings. Their work is limited to the scenario whether someone is at a meeting and how they want to be notified.

3.3.1.16 Previous Research on Luminosity

Luminosity can quite easily be assessed using the light sensors of a smartphone. However, this feature was not researched a lot. The reason is likely that no apparent relation to the importance of a notification was evident.

3.3.2 Previous Research on Intrinsic Features

Sahami Shirazi et al. [93] conducted a large-scale assessment of notifications and therefore collected a great amount of notification data. Hereby, they focused on intrinsic factors, like the *application category* and the blacklisted applications from which the user receives no notifications. Being blacklisted is an indicator that the respective application provides too many unneeded notifications. Also, they gathered qualitative feedback which gives information about the *frequency of notifications* by an application or even the sending of the exact same notification. In their work it is apparent that smartphone users think of notifications of the *application category Communication* as important, whereas communication applications include messengers, email and the like.
Most *intrinsic features* have been examined in combination with several other *intrinsic features* and also *extrinsic features* which can be seen in the tables A.1, A.2 and A.3. Mehrotra et al.'s[70] work for example, appears in several cells in the column *time*, meaning they have considered a great amount of *intrinsic features*.

3.3.2.1 Previous Research on Application Name and Application Category

Application name and *application category* ranked highest in Mehrotra et al.'s [70] work as features which increased the information gain to determine the acceptance of a notification by users. Notifications which were about communication with other people were evidently more often accepted compared to notifications from other application categories.

3.3.2.2 Previous Research on Notification Content, Relevance and Urgency

The *notification content* is often needed to derive the *urgency of a notification* and its *relevance*. Sometimes the latter two have been inquired using ESM studies [47,

71]. So far the relevance of a notification was usually provided as predefined notifications with a certain degree of relevance in a controlled study [13, 47, 63]. Czerwinski et al. [13] conducted a controlled study in which they sent relevant and irrelevant notifications to a user during the execution of a given task. They noticed that relevant notifications were perceived as less disruptive.

3.3.2.3 Previous Research on Notification Frequency and Reminder Frequency

Study participants have often mentioned the *frequency of notifications* in qualitative parts of studies [4, 93] as an issue in regards to notifications. Some works have considered how often a specific notification was triggered. For instance, Rosenthal et al. [91] assessed how often certain callers have contacted a user. If the notification frequency or the *notification reminder frequency* are exceptionally high, the information gain lessens and applications can start to annoy the user so they will block notifications from certain applications [93] or even delete the application [23].

3.3.2.4 Previous Research on Other Party

For the specific type of notifications which are sent by communication applications, the person who sends the message is an important feature as well. Rather, the relationship between the user and the sender should be considered [70]. As an example, it is sensible that during work mostly work-related notifications are important. However, due to the close relationship within families, the messages from family members can be very important, even if they are not work-related at all. Such a message could for example be amongst the line of: "I can't fetch up the kids from kindergarten. Are you able to leave earlier from work today??". Mehrotra et al. [70] let the user assign categories to their contacts. Those categories were *Work*, *Social*, *Family* and *Other*. Multiple categories were possible for the same person and the request for this assignment was made as soon as a notification by a previously uncategorised person was triggered.

3.3.2.5 Previous Research on Past User Reaction

The *past user reaction* has also been considered as a feature to derive the future reaction of the user. This feature was linked to other features [69, 70]. For instance, the system PrefMiner by Mehrotra et al. [69] derived association rules based on the past user reaction at certain *times* and *locations* which were used to filter unwanted notifications. Users of their system rated the filtering system as useful and thought the system properly filtered unwanted notifications most of the time.

3.3.2.6 Previous Research on Phone Attendance

Mashadi et al. [66] examined whether it had an influence on the user's interruptibility if he was using the phone at the time the notification arrived. More notifications were attended immediately compared to when the user did not actively use the phone.

3.3.2.7 Previous Research on Other Intrinsic Features

Features which have not been paid a lot of attention to so far, are *notification sentiment*, *pleasureability*, *concurrent applications*, *battery level*, *internet connectivity*, *concurrent notifications*, *contrast level*, *application usage frequency* and *notification settings*.
For contrast level a noticeable link to the perception of notifications is missing. In regards to *concurrent applications* it has been examined whether applications were active but not which specific applications. Mashadi et al. [66] noticed that people reacted sooner to notifications when they were actively engaged with the phone which means the phone was unlocked and an app was running in foreground. Pleasureability has been examined by Aranda et al. [4]. Aranda et al. [4] collected qualitative data of how user's felt about notifications. Based on the qualitative data, they noticed that the *frequency* and the pleasureability influence the *enjoyability* of a notification. As far as to our knowledge the *notification sentiment* has not been examined so far. In regards to notification settings Yoon et al. [109] took into account whether the user actively changed the settings of notifications from certain applications. In their work they derived four types of subjects. A *sensitive* group which actively tried to change the settings but still felt stress, a *disoriented* group which did not know how to change the settings and therefore felt stress because of the notifications, an *indifferent* group which did not change the settings and also did not feel stressed and lastly an *informed* group which used the possibility to change notification settings and did not feel stressed.

4. Our Contribution

As a basis, we want to use previously researched features which have a strong influence on the user's interruptibility, acceptance or perceived importance of the notification. Therefore, we chose the five features which had the most influence on the information gain in regards to notification acceptance in table 3 of Mehrotra et al.'s [70] work: *application name*, *application category*, *phone attendance*, *location* and *time*. Also, we include some other features which were shown to have a strong impact. In our work we want to examine the following well-known features:

Time *Time* is an easily accessible feature and has provided a lot of information in previous works. When tending to new or infrequently used features, we want to also consider the relationship to this established feature.

Activity *Activity* has been researched in many works to not only determine the interruptibility but also to derive opportune moments to send the notification.

Social Situation Schulze et al. [98] had a strong focus on the *social situation* in their work which showed that the kind of conversation or non-conversation can influence the perception of a notification.

Location *Location* too has been considered a lot in previous literature. However, we want to use a more fine-grained approach for the often used category *other*. The usage of smartphones in places other than *work* and *home* can vary greatly as stated by Exler et al. [20].

Application Name Certain applications which tend to flood the user often get blacklisted [93] while the notifications of certain other applications receive priority by the user.

Application Category We want to assess the *application category* because previous works have noticed that certain *application categories* are perceived as more important than others. It might be interesting to see how this feature relates to the idiosyncratic features *user emotion*, *user personality* and *user interest*.

Notification Content The notification content likely relates to the user interest. However, assessing notification content may lead to privacy concerns.

Other Party of the Notification The relationships between people usually have an emotional connotation. For instance *family* often encompasses people who offer support and bring joy. Depending on the *user emotion* a message from certain people might sometimes be more appreciated. Parkinson et al. [76] argue that emotions are interpersonal and not just a personal cue. They also state that one person's emotion has an influence on another person's emotion. Therefore, notifications triggered by people might lead to emotional responses by the receiver.

Phone Attendance When the user has been tending to their phone, it is likely that they are more willing to accept a notification [66].

Battery Level We also want to assess the *battery level*, even if the results in previous research were not promising. This piece of information is easily accessible.

Internet Connectivity Same as for *battery level*, *internet connectivity* has been assessed in previous works as noticeable in A.1, A.2 and A.3. However, no connection was found as to the best of our knowledge. Since this feature is easily accessible, we want to assess it, too.

Also, we want to assess the following features which have not been thoroughly examined as far as we know:

Formality of an Activity The *formality* of a conversation can influence the interruptibility of a phone user [98]. We suspect that not only during conversations but also during other formal activities, like meetings, formal dinners, etc. the receptivity for notifications drops.

Meaningfulness/Emotionality of an Activity Similar to *formality* we suspect that not only during conversation [98] but also during other potentially *meaningful* or *emotional* activities the interruptibility by notifications decreases.

Notification Sentiment The *notification sentiment* can be an interesting feature in relation to the *user emotion*. We hypothesize that depending on the user's current emotion they might want to receive positive notifications when in a certain emotional state and are more tolerant of negative notifications in other emotional states. For instance, a sad user might not wish to receive negative news. However, sometimes negative notifications from a family member might be very important so despite being sad, the user might wish to see it. Therefore, *notification sentiment*, *user emotion* and *other party of the notification* might interrelate in this example.

Application Usage Frequency In Aranda et al.'s work [4] some qualitative data leads to the assumption that applications which are used frequently, do not need a lot of notifications to lead the user's attention towards the application. Thus, it might be interesting to assess this assumption quantitatively.

Concurrent Notifications If the user receives several notifications at the same time in the notification drawer, it could lead to annoyance. Aranda et al. [4] noticed that frequent notifications reduced the enjoyability of a notification.

Concurrent Applications So far it has been considered whether the user is currently actively using the phone or not [79]. However, it has not been considered which kind of application is currently used. We suspect that depending on the certain application the user might not want to be interrupted. As an example, the user might play a reaction game and due to a *pop-up notification* the game starts to lag and the user automatically looses the game. This could be quite frustrating.

Additionally, we want to include the following features because we hypothesize a relation between these and some of the novel features above such as notification sentiment:

User Interest A problem about notifications is that people either receive too many notifications or fear that they miss important ones. Due to this problem, users tend to blacklist applications which trigger many notifications, often about pieces of information which do not necessarily interest the user [93]. Fischer et al. [25] deducted in their work that people are receptive of notifications which suit their interests regardless of time. We want to examine *user interest* together with other features, e.g. *user emotion*.

User Personality We plan to examine several features which are strongly related to the user themself. It is likely that these features interrelate. For instance a person with high *neuroticism* value might be more sensitive towards notifications with a *negative sentiment*.

User Emotion When the user is in a certain emotional state certain notifications might be more important than others. Depending on the *emotion of the user* we hypothesize that a user will have a different receptivity towards notifications. For instance if the user is in a sad mental state, a notification by a friend about some funny event might be more important than when the user is in a positive mental state. Therefore the *user emotion* is likely to relate to *notification sentiment* but might also relate to *user personality* and *user interest*.

In the following we want to describe how we will asses these features. In regards to features which to our knowledge have never been used before, we also want to explain in more detail why we want to assess those.

4.1 How we Assess Time

In table 4.1 we offer an overview over the features we assess in regards to time. We assess the day of week including a weekend indicator [78] and date including a holiday indicator using Android's Notification Listener Service[1] [71]. Also, we assess *arrival time*, *removal time* and the time difference between receiving the notification and removing the notification, called *handling time*.

[1] https://developer.android.com/reference/android/service/notification/NotificationListenerService.html

Feature	Description
Day of the Week	Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday
Weekend Indicator	Boolean which is true when *Day of Week* is Saturday or Sunday
Date	the exact date in YYYY\MM\DD-format
Holiday Indicator	Boolean which is true when *Date* is a public holiday
Arrival Time	The time when a notification arrives in the format HH:MM:SS+Timezone
Removal Time	The time when a notification is removed either by acceptance or deletion by the user or by an update of the notification in the format HH:MM:SS+Timezone
Handling Time	The time difference till a notification is handled starting from the *arrival time* till *removal time*

Table 4.1: The exact features we assess in regards to time

4.2 How we Assess Activity

We want to inquire the activity during the *arrival time* of a notification. The user can choose between the categories in table 4.2. These categories are a mixture of Mehrotra et al.'s [71] and Yuan et al.'s [110] work, which we found suitable to describe most activities.

Activity	Description
Work & Education	Activities which are related to work or education, e.g. studying for exams, attending lectures, working on a project, etc.
Communication	Talking or writing to people
Transport	Being on the way to some place
Self Care & Personal	Self-care measures like going to a doctor, tending to family or tending to one's believes, e.g. going to church
Exercise & Sport	Doing sports, e.g. going to the gym, swimming, etc.
Food & Drink	Having a meal or snack or drinking a beverage
Games	Playing a game
Media Consumption	Consuming media, e.g. watching TV, reading a book, listening to a podcast, etc.
Rest	Resting in order to gain some energy, e.g. sleeping or taking a nap
Idle	Being engaged in no specific activity
Other	Activities which do not fit above categories

Table 4.2: The activity types which we use.

4.3 How we Assess Social Situation

In regards to the social situation we want to assess, whether the user is in *company* or *alone*.

4.4 How we Assess Location

Since Exler et al. [20] noticed in their work that previous place categories might be insufficient, we want to use the more fine-grained place types which we assess upon arrival and removal of a notification, see table 4.3. Exler et al. [20] reduced the over 120 place types which the Google Places API[2] offers to 20 place types which are often frequented. However, we do want to note that their study was conducted in Europe while a part of our work will be conducted in East Asia. So frequently visited places may vary, e.g. the *place type Bakery* might be visited less often. That is why we will use all *place types* which the Google Places API offers. In addition we want to use the types *Work* and *Home* which the user should specify during the setup of the system. Also, we add the *place type Transit*. The user might be in motion and the *location* changes frequently within a short time.

Place Types	Assessment
Study-/Workplace	User defines their work or study place during setup of the system
Home	User defines their home place during setup of the system
Transit	If the user is in motion no specific place type should be applied but *Transit*
Google Place Type	If none of the above apply we use the Google Place API to determine the *place type*
Other	if none of the above *place types* fit, we choose *other*

Table 4.3: The place types we consider for locations

4.5 How we Assess Application Name and Category

We want to assess the name of the application as the *application name*. In order to assess the *application category* we want to use a mixture of Mehrotra et al.'s [70] and Sahami et al.'s [93] categorization. Instead of the generic *application category* defined by the Google Play Store *Communication*, we will use *Text Messenger*, *Voice & Text Messenger* and *Email* as proposed by Sahami et al. [93]. Furthermore, we add the categories *Forum* and *Browser*, which are grouped under *Communication* as well.
The Google Play Store category *Productivity* contains applications of the category *Calendar* and *Clock* as well, which we will separate. The categories, which we consider, are in table 4.4. In order to categorize the *application category* of a notification, we first derive the *application name*. Then we derive the respective *application category* on the Google Play Store and using this information we categorize it into one of the categories in table 4.4.

[2]https://developers.google.com/places/

Application Category	Description
Text Messenger	Text messengers are applications which can be used to send messages where the reply is expected to be quite fast, e.g. SMS
Voice & Text Messenger	This category describes those applications which are not only text messengers but also offer the option to do voice chats, e.g. Skype
Email	Emails are applications which allow the user to use their email-accounts and send emails, e.g. Google Mail
Social	This includes social media applications but excludes their respective messengers, e.g. Facebook but not Facebook Messenger
Browser	Browser applications allow the user to open websites and surf the internet
Forum	Forum applications describe applications which offer a discussion board for groups of people. These kinds of applications are generally used to talk with several people and not with only one other person
Calendar	Calendar applications offer a calendar to note events and will often send reminders
Weather	Weather applications give information about the weather
Clock	Applications of the clock category are used to disruptively notify the user at a certain pre-set time
Music & Audio	Music applications are used to listen to music and organize audio data
Game	Game applications allow the user to play games on the phone. Google Play Store offers several game categories which we all group under one category
Google Play Store Category	If none of the above categories suits the application, we use the assigned category in the Google Playstore if available
System	Notifications by the system itself fall under this category
Other	If an application which does not fit the above categories triggers a notification, we categorize it as *other*

Table 4.4: The application categories which we consider

4.6 How we Assess Notification Content

We will send notifications to the user via Firebase[3]. Similar to Fischer et al. [25] who sent their participants daily SMS during their study, we want to generate notifications as well in order to gain a better understanding of how users perceive certain content in certain situations.

[3]https://firebase.google.com/

4.7 How we Assess Other Party of the Notification

The user can choose between the categories as shown in table 4.5, which are close to Mehrotra et al's [71] categories. The user can choose a category in the context of a notification.

Other Party	Description
Stranger	A person whom the user does not know
Partner	Romantic or Queer-romantic partner of the user
Immediate Family	This includes only children, parents and siblings
Extended Family	This includes only family which does not belong to the immediate family, e.g. aunts, cousins, grandparents, etc.
Close Friend	This refers to friends which one share a deep bond with
Average Friend	This refers to friends which are not extremely close but enjoy to talk to and spend time with
Acquaintance	A person one knows but is not befriended with
Superior	People at work or education who are of higher rank, e.g. supervisors, professors, tutors, upperclassmen, etc.
Subordinate	People at work or education who are of lower rank, e.g. underclassmen, someone one gives tutoring, someone who works under one's supervision as an intern, etc.
Peer	People at work or education who are of the same rank, e.g. if one is a student fellow students of the same year/-class, supervised by the same professor, etc.
System	The phone system issued the notification
Application	The application issued the notification to bring attention to itself, e.g. a game application which reminds the user to play the game again
Other	If none of the above suits the other party, *Other* will be applied

Table 4.5: The other party types which we consider

4.8 How We Assess Phone Attendance

For the phone attendance we will assess whether the user has been using the phone at *arrival time* as a boolean.

4.9 How we Assess Battery Level

For the battery level we assess the percentage of electricity which is left on the phone.

4.10 How we Assess Internet Connectivity

We assess the internet connectivity as a boolean which indicates whether the user is currently connected to the internet or not.

4.11 How we Assess Formality of an Activity

We assess the formality of an activity on a scale from 1 to 7 with 1 being *not formal* and 7 being *very formal*. The user will rate the *formality* of their ongoing *activity*.

4.12 How we Assess Meaningfulness or Emotionality of an Activity

We assess the meaningfulness or emotionality of an activity on a scale from 1 to 7 with 1 being *not meaningful/emotional* and 7 being *very emotional/meaningful*. The user will rate the *meaningfulness/emotionality* of their ongoing *activity*.

4.13 Why and How we Assess Notification Sentiment

We want to assess the notification sentiment as it is possible that it offers information about the order in which notifications should be relayed to the user if there are *concurrent notifications* at the *arrival time* of a notification. The reason being that most people tend to prefer receiving bad news before good news [59, 65]. So assessing the *notification sentiment* to determine whether the notification is *positive*, *negative* or *neutral* might help to relay notifications in a user-preferable order. Also, the sentiment of information can influence a person's affective state [104] and thus, their interpersonal behaviour [106]. Upon receiving bad news people tend to harbour negative emotions compared to when receiving good news. Therefore, the *user personality* might also play a role. A neurotic person might handle *negative* notifications worse than other people. In our work we want to differentiate between *positive*, *negative* and *neutral* sentiment.

4.14 Why and How we Assess Application Usage Frequency

In [4] they collected qualitative data in which several participants expressed the unnecessity of notifications for applications which they use frequently because they will check the application either way. Thus, notifications were rather annoying due to the unnecessity. Therefore, we want to collect quantitative data by assessing how much an application is used within a month.

4.15 Why and How we Assess Concurrent Notifications

Since the human information processing capacity is limited [57, 64] a huge influx of information at the same time might be exhausting for the user. Also, as mentioned in 4.13 the order of the concurrent notifications might be able to improve the perception of the notification by delivering bad news first [59, 65]. In order to assess concurrent notifications we reuse the *time* features and check for notifications where the *arrival time* or *removal time* are overlapping. We count the number of notifications at *arrival time* and the number of notifications at *removal time*.

4.16 Why and How we Assess Concurrent Applications

While the user usually reacts quickly to notifications during the usage of their phone [66], it is possible that they actually do not wish to be interrupted. It is possible that they are doing work-related activities on the phone or are engaging in leisure activities where they do not wish to be disturbed. Therefore, we assess the applications which are running in foreground at *arrival time*.

4.17 How we Assess User Interest

We want to assess the individual interests of a user as a list. The items of the list include a topic and the intensity of the interest on a scale from 1 to 7 with 1 being *slightly interested* and 7 being *strongly interested*. Also, we want to assess the user's disinterests and triggers. Disinterests are topics which are of no interest to the user and triggers are topics which elicit negative emotional reactions by the user and make them uncomfortable. A list might look like table 4.6. We want to assess these pieces of information during the setup.
We assess the situational interest of the user towards notifications, too, on a scale from 1 *not interesting* to 7 *very interesting*.

Interest	Intensity
Figure Skating	7
Jin Boyang (Figure Skater)	7
Shoma Uno (Figure Skater)	5
International News	6
North Korea Conflict	4
Food	6
Culture	5
Social Justice	7
Dogs	2
Saboteur (Card Game)	4
Disinterests	
Fashion	
Celebrity Culture	
Triggers	
Violence	

Table 4.6: Example of a user interest list

4.18 How we Assess User Personality

We will use the Eysenck Personality Inventory (EPI) to assess the personality of a user [21]. Mehrotra et al. [71] found that extroverted users tend to feel more disrupted by notifications. They also notice that *extraversion*, *conscientiousness* and *neuroticism* influence the time till a notification is seen and that both *extraversion*

and *neuroticism* influence the time till the user makes a decision significantly. Since both *extraversion* and *neuroticism* had influence on more factors, we want to delve deeper into this area and use EPI because it specializes in the two personality traits *extraversion* and *neuroticism*.

4.19 How we Assess User Emotion

In order to assess emotions we want to inquire how the user felt before and after a notification. We want to assess the *emotions* according to the *Geneva Emotion Wheel version 3.0* [95] as shown in figure 4.1. However, we exchanged the center of the wheel with *apathy* after the pilot of our study because participants asked for a neutral choice. We also provide definitions by the Oxford Dictionary[4] to the *emotions*. If the definition contained difficult English words we exchanged them with their respective definition by the Oxford Dictionary and so on. The *emotions* with their respective definitions were used as listed in table 4.7. Also, we assess the intensity of the felt *emotion* on a scale from 1 to 7, with 1 being *not intense* and 7 being *very intense*.

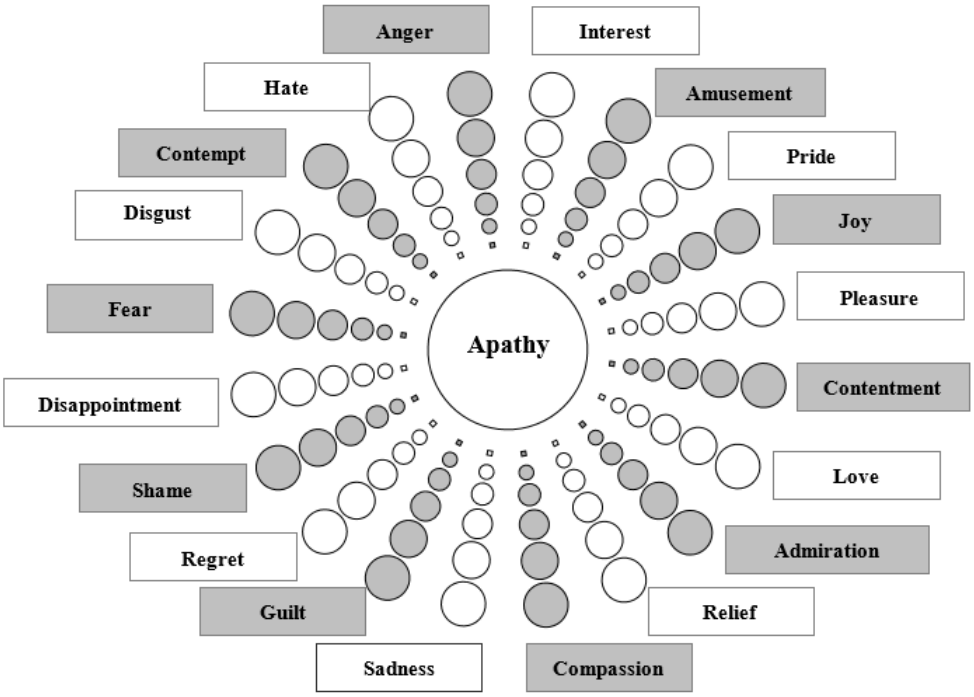


Figure 4.1: Geneva Emotion Wheel version 3.0 [95]

[4]https://en.oxforddictionaries.com/

Emotion	Definition
Apathy	Lack of interest, enthusiasm, or concern
Interest	The feeling of wanting to know or learn about something or someone
Amusement	The state or experience of finding something funny
Pride	A feeling of deep pleasure or satisfaction derived from one's own achievements, the achievements of one's close people, or from qualities or possessions that are widely admired
Joy	A feeling of great pleasure and happiness
Pleasure	A feeling of happy satisfaction and enjoyment
Contentment	A state of happiness and satisfaction
Love	An intense feeling of deep affection
Admiration	Respect and warm approval
Relief	A feeling of reassurance and decrease of tension following release from anxiety or distress
Compassion	Sympathetic pity and concern for the sufferings or misfortunes of others
Sadness	The condition or quality of being sad
Guilt	The fact of having committed a specified or implied offence or crime
Regret	Feel sad, remorseful, or disappointed over something that one has done or failed to do
Shame	A painful feeling of humiliation or distress caused by the consciousness of wrong or foolish behaviour
Disappointment	Sadness or displeasure caused by the non-fulfillment of one's hopes or expectations
Fear	An unpleasant emotion caused by the threat of danger, pain, or harm
Disgust	A feeling of strong dislike or strong disapproval aroused by something unpleasant or offensive
Contempt	The feeling that a person or a thing is worthless or beneath consideration
Hate	Feel intense dislike for
Anger	A strong feeling of annoyance, displeasure, or hostility

Table 4.7: The definitions of the emotions in GEW

5. Our Study

This chapter depicts how our study is designed and how we planned to conduct it. In chapter 4 we have chosen the features which we want to assess and explained how we want to assess them. We designed our study, conducted a one week pilot study with five participants, revised the design and then conducted the study with several participants from August 2017 till November 2017.

5.1 Study Design of the Pilot Study

A study participant was supposed to use an application implemented by us which collects data in the background. Since not all features which we want to asses were automatically collectible, the application also generates ten questionnaires per day between 6 AM and 12 midnight roughly every two hours if notifications were collected since the last questionnaire. The questionnaire for the pilot study contained the questions as listed in list 5.1.

We conducted a pilot study with five participants for one week. Due to the pilot. we were able to find some technical issues which we were able to rule out before the actual study. Also, the participants provided us with feedback on the user interface, the questionnaire and the workload which helped us to derive our final concept.

5.2 Study Design of the User Study

For our final study design we developed an application which would collect data on notifications and generate questionnaires between 6 AM and 12 midnight roughly every two hours. Additionally, the participant will receive roughly two dedicated notifications about their *interests/disinterests* per day which, too, will cause questionnaires once removed. Technical details about the implementation of the application will follow in chapter 6. In the following we want to go into detail how our study was constructed.

1. At what kind of place were you when the notification arrived?
   Answer: A place type as specified in chapter 4 in table 4.3.
2. At what kind of place were you when the notification was removed? (if coordinates differ from coordinates assessed at *arrival time*)
   Answer: A place type as specified in chapter 4 in table 4.3.
3. How did you primarily feel shortly before the notification arrived?
   Answer: One of the 20 emotions of the GEW v. 3.0.
4. How intense did you feel [chosen emotion]?
   Answer: Value from 1 *not intense* to 7 *very intense*.
5. How did you primarily feel after reading the notification?
   Answer: One of the 20 emotions of the GEW v. 3.0.
6. How intense did you feel [chosen emotion]?
   Answer: Value from 1 *not intense* to 7 *very intense*.
7. What kind of activity were you engaged in when the notification arrived?
   Answer: An activity type as specified in chapter 4 in table 4.2.
8. Were you doing this activity alone?
   Answer: Choose either *not alone* or *alone*.
9. How meaningul/emotional was the activity?
   Answer: Value from 1 *not meaningful/emotional* to 7 *very meaningful/emotional*.
10. How formal was the activity?
    Answer: Value from 1 *not formal* to 7 *very formal*.
11. Did you notice the notification?
    Answer: Choose either *yes* or *no*.
12. Who sent the notification?
    Answer: An other party as specified in chapter 4 in table 4.5.
13. How interesting is the content?
    Answer: Value from 1 *not interesting* to 7 *very interesting*.
14. How urgent is the notification?
    Answer: Value from 1 *not urgent* to 7 *very urgent*.
15. How important is the content?
    Answer: Value from 1 *not important* to 7 *very important*.

List 5.1: Daily Questionnaires before the pilot study

5.2.1 Subject Sampling

We decided to mainly recruit study participants in Hong Kong and Germany. However, we were also open for participants abroad. Our requirements for participation were the possession and daily usage of a smartphone with Android 5.0 (API level 21) or upwards, access to Google features, intermediate English skills and minimum age of 18.
The application is implemented for Android 5.0 and upwards. We use several APIs

provided by Google. Therefore, the application could not run in places where Google services could not be accessed. Thus, we had to exclude potential participants located in Mainland China.
In order to reach participants we used social networks and academic mailing lists as our main channels. From August 2017 to September 2017 we had our focus on recruiting participants in Hong Kong. Afterwards we recruited participants in Germany from October 2017 to November 2017.

5.2.2 Course of Study

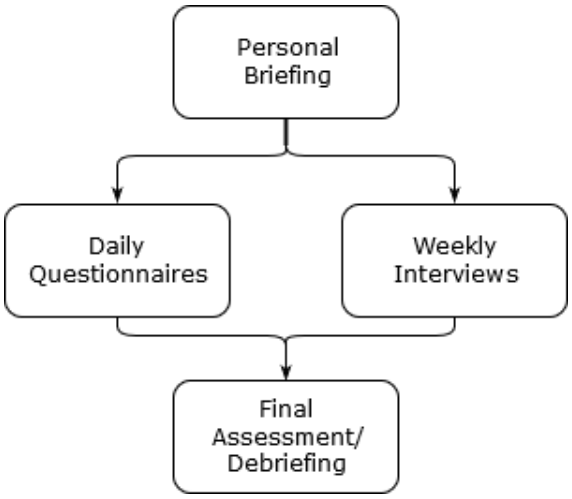


Figure 5.1: Course of the study

Figure 5.1 depicts the general course of our study. Every participant is supposed to receive a personal briefing which is depicted in more detail in figure 5.2.
During the briefing session we will explain the purpose of our study. We explain the current state of notifications which tend to be flooding or misleading in regards to their importance. Next, we will outline the study to the participant. The participants will know that for the participation the installation of an application which will collect data in regards to their notifications is required. Also, the necessary actions on their side which include the answering of the daily questionnaires and the participation in the weekly meetings will be clarified. Room for further questions is given and they will have to sign the *data privacy statement*. After signing, the application will be installed. The application is distributed via Google Play Store where the participants can download the application. Once the application is installed we setup a participant ID and the needed permissions for the application. We also insert the location of the participant's home and workplace. Afterwards, we will give a short briefing about the questionnaire which they will have to fill in. Thereafter, we ask the participant to write down their *interests*, *disinterests* and *triggers*. For the *interests* we request them to rank their interest towards specified topics on a scale from 1 *slightly interesting* to 7 *strongly interested* as described in section 4.17.
As depicted in figure 5.1, the participants will answer the daily questionnaires in the following weeks. Additionally, they will have to attend weekly personal interviews. These actions will span four weeks.
After the time span of four weeks the study will be concluded with a debriefing session as shown in figure 5.3. For the final assessment the participant will take the

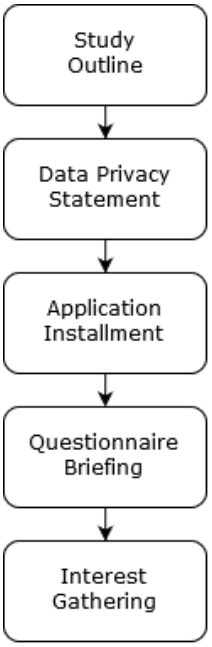


Figure 5.2: Course of the personal briefing session

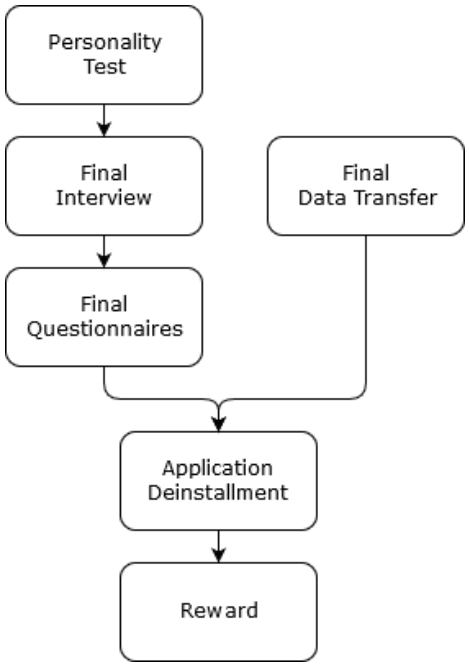


Figure 5.3: Course of the personal debriefing session

Eysenck Personality Inventory. Following the personality test, we will conduct a final interview with the participant. Once the interview is concluded, we refer the user to final questionnaires about features and about demographic data assessment. Parallel to the previous steps, we will transfer the remaining data of the application installed on their phone. Once all these steps are finished, the participant may delete the application and receives a reward for their participation.
The course of the study was fixated as outlined above to the greatest possible extent. However, we allowed some flexibility in case of scheduling and location issues, e.g. due to illness or the participant is living in another city/country.

5.2.3 Interest Gathering

As outlined above, we requested the participants to specify their *interests*, *disinterests* and *triggers* and rate their *interests* adequately, resulting in lists similar to the example depicted in table 4.6 in chapter 4. We assessed *interests* and *disinterests* to decide on dedicated notifications for the study participants. The *triggers* helped us to make sure, we would not send psychologically harmful or upsetting content to the respective participants.
This part of the study was designed as a *Wizard of Oz* study. The dedicated notifications were chosen by manually crawling the internet for adequate websites. Mostly, one researcher would look for websites which align with the participant's *interests* or *disinterests*. We tried to choose reputable sources. For their *interests* we often chose articles from reliable news sites, blogs, YouTube[1] and Medium[2]. Additionally, we tried to look for recent and unpopular articles (meaning, articles which are harder to find because they are not top results of common search engines), as an attempt to avoid sending articles which the participant has already

[1]https://www.youtube.com/
[2]https://medium.com/

seen. However, this is to be deemed difficult. For example, it is difficult in case of certain *interests* which are about very specific issues from several years ago. For instance, a game which was brought to the market several years ago and does not provide any new extensions or updates. In the following we refer to these interest- and disinterest-based notifications as *dedicated notifications* by our application. The dedicated notifications were delivered to the participant at random times, usually between 6 AM and 12 midnight in order to not disturb the user too much.

5.2.4 Daily Questionnaires

The daily questionnaires which the participant had to fill in were basically an ESM study. After the pilot study we were able to make some adjustments to the questionnaires (see list A.1 in the appendix). We removed question 14 *How urgent is the notification?* and added *Apathy* as another emotion and *Stranger* as another other party type upon suggestion of pilot study participants. Furthermore, we added definitions of the emotions because despite intermediate English skills, some words were still hard to understand.
The questionnaires were triggered about 10 times a day between 6 AM and 12 midnight in roughly two hour intervals. The participant was notified of a new questionnaire with a notification. We allowed some flexibility for the participants to answer questionnaires later on to mitigate the disturbance due to our study. However, we advised them to answer as soon as possible.
For the questionnaire we selected notifications of applications which frequently triggered notifications during the past time interval.
The participants of our pilot study needed roughly 30 seconds to 2 minutes to answer one questionnaire. The more time has passed in regards to the study, the shorter the needed time for questionnaires was due to memorization of the questions. Therefore, we estimated an average of 1 minute per questionnaire will be needed.

5.2.5 Weekly Interviews

During the weekly interviews we want to assess a participant's behaviour, habit and opinion on different aspects of notifications. The participant will be invited to a casual meeting place and be offered snacks and beverages. During the study period with focus on Hong Kong, we invite participants to meet on the campus of the Hong Kong University of Science and Technology (HKUST), the university of Hong Kong (HKU) or the City University of Hong Kong (CUHK). For the study period with focus on Germany, we invite participants to meet on the campus of Karlsruhe Institute of Technology (KIT) or in the city of Karlsruhe. If participants are not able to come to these places, we offer the interview via Skype or WhatsApp call.
For each interview we ask for permission to record the interview. If no such permission is given, we take notes during the interview. The participant will have to specify their ID so we can assign the interview to the data by our application. If problems have occurred during the past week they will be noted or clarified. We decided to construct *semi-structured* interviews in order to be able to flexibly adjust to a participant's answers. It allows us to change the order of questions when the participant addressed a topic which we would inquire anyway or to ask further questions when the participant raised opinions which were unexpected. The questions alter each week through the course of the study and were developed by

one researcher and checked by another one. Additionally, we note adjustments to respective interest lists if participants wished to make changes.
The prepared questions are depicted in lists 5.2, 5.3, 5.4 and 5.5. The interview of the fourth week was integrated into the debriefing session. Also, the last interview repeated some previously asked questions to see whether some participants changed their opinions or had additions to their previous answers.
Run-throughs of the interviews were strongly dependent on the participant. We can roughly estimate two short interviews (list 5.2 and list 5.4) with 10 minutes each and two long interviews (list 5.3 and list 5.5) with 30 minutes each.

5.2.6 Final Questionnaires

The final questionnaires were implemented using Google Forms[3]. One questionnaire allowed the participant to rank features depending on their personal opinion of how much they influence the respective participant's perception of the importance of notifications and their acceptance of a notification. One exception is the *user personality* because this feature does not vary for one participant. Therefore, the user ranked this feature according to their assumption of how it influences the perceived importance of people in general.
The second final questionnaire is for demographic data assessment. The participant is asked to specify their age, gender, highest level of education, their current work/study field and the used phone model. We refrained from assessing the participant's ethnicity because we anticipated low representation for different ethnicities. Therefore, it might be traceable for certain participants which ID was theirs.

- Do you sometimes not tend to notifications immediately?
- What are reasons for you to not tend to them immediately?
- Do you have applications which you have blacklisted from sending you any notifications?
- Why did you blacklist these applications?
- What does it mean for you if you delete a notification?

List 5.2: Interview after first week

- What are your thoughts about the notifications from our application which do not request you to fill in questionnaires? (referring to dedicated notifications)
- Going through features and ask about their opinion on the influence of each feature on the perceived importance and acceptance of notifications
- What makes a notification important for you?

List 5.3: Interview after second week

[3]https://www.google.com/forms/about/

- How often do you feel annoyed by notifications?
- In which situation do you feel annoyed by notifications?
- Under which circumstances do you like to receive interesting notifications?
- Would you like to receive notifications about all of your interests or just certain ones?

List 5.4: Interview after third week

- What are reasons for you to not tend to notifications immediately?
- What does it mean for you if you delete a notification?
- What would be your opinion if a smart notification system existed? + description of such
- Do you think that notifications which change your emotion tend to be important?
- Do you think there is a difference in sender type (human, application, system) in their potential to change your emotion?
- Would you prefer notifications which already contain all needed information or short summaries?
- Going through features and ask about their opinion on the influence of each feature on the perceived importance and acceptance on notifications
- What makes a notification important for you?

List 5.5: Interview after fourth week

5.2.7 Reward

Overall, a participant's workload will result in roughly 7 hours during the course of four weeks. We decided to reward participants who took part in the study in Hong Kong with 40 HKD (about 5 US Dollar) each. Also, we raffle 250 HKD (about 32 US Dollar) to the participants. Upon finishing the study, participants in Germany are rewarded with a small present as a token of appreciation. Additionally, we raffle two 20€ (about 23 US Dollar)-Amazon-vouchers for the study participants in Germany. During the meetings we offer snacks and beverages as mentioned above. Study participants who could not attend the meetings physically, received a mail with a small gift as an appreciation of their efforts instead.

6. Implementation

As described in chapter 5 we needed an application which can be distributed to our study participants. The application had to collect data and generate questionnaires in order to conduct our study. Our application is based on Piatkowski's work [81].

6.1 Tools

We mostly used the same tools as Piatkowski [81] for our implementation. Thus, we used Android Studio [39] including the Android Software Development Kit (SDK) as our integrated development environment (IDE). Android Studio is the official IDE by Google for Android app development. The IDE is based on IntelliJ IDEA [51] by JetBrains and offers several features which we made use off. These features include a gradle-based build system, an instant run feature to accelerate testing on devices and GitHub integration. Additionally, we used Postman [84].

6.1.1 Postman

Postman [84] by Postdot Technologies is a REST client which allows the quick sending of Hypertext Transfer Protocol (HTTP) requests. HTTP requests allow communication between a client and a server. We made use of this feature to send POST requests. POST requests allow sending data to a server. Postman itself allows further features like mocking servers to help decoupling front-end development from back-end development.

6.1.2 Compile Time and Test Time Dependencies

The dependencies at compile time and test time were the same as the ones used in Piatkowski's work [81]. Therefore, we used *Lombok* [87], a tool which helped to reduce so called *boilerplate code*. *Boilerplate code* refers to code which is repeated several times with few changes. One such example would be Getter- and Setter-methods which might need to be implemented for all attributes of a class. With the help of *Lombok* it is possible to reduce the repetitive code by using annotations which will indicate the automatic generation of certain methods, e.g.

Getter-methods via the annotation *@Getter*. Moreover, like Piatkowski [81], we used JUnit [50], Mockito [105] and Roboelectric [89] for testing. JUnit is the standard framework for testing of Java code. Mockito allows the creation of mock objects for the tested object to interact with. Thus, it allows an easier and more efficient implementation of tests, as objects which are not the focus of the test, can be replaced by a mock object. Roboelectric allows the running of tests without an emulator or device. It provides implementations for the Android SDK stub classes for which the actual implementation usually takes place on the emulator or on a device. Thus, it allows the testing on Java Virtual Machine (JVM) which on the other side allows faster testing.

6.1.3 Run Time Dependencies

Run time dependencies are needed during the whole run time of the application. We have used several dependencies which were used by Piatkowski [81] as well. The overlapping dependencies are as follows:

AppCompat v7 A support library which adds the Action Bar and support to material design user interfaces.

Preference v7 Another support library which provides APIs for adding preference object, e.g. CheckBoxPreference and ListPreference.

Design The design support library provides further material design support for items like navigation drawers and tabs.

Couchbase Lite The embedded JSON database Couchbase Lite [9] offers a lightweight database with CRUD (create, read, update, delete) functions.

Joda Time Joda Time [52] is an alternative to Java date and time classes before Java 8, which offers several useful and easy methods to work with time such as a user-friendly representation of the date. While Android supports Java 8 now, it does not include the new time and date APIs yet.

Additionally, we have used the following dependencies:

Firebase Cloud Messaging Firebase Cloud Messaging (FCM) [42] offers cross-plattform messaging services. It allows two message types, these being *notification messages* and *data messages*. *Notification messages* allow the delivery of notifications on a client application. For *data messages* the client app first has to process the delivered data and can then generate a notification on its own. Additionally, FCM allows the sending of data from the client application to a developer server. We only used the *data messages* feature.

JSch JSch [49] by JCraft is a pure Java implementation of Secure Shell 2 (SSH2). SSH2 provides an encrypted channel to log into a remote computer, to execute commands on this computer and to transfer files. Transferred data will automatically be encrypted, authenticated and compressed.

Google Maps Android API The Google Maps Android API [43] allows the usage of maps and handling of coordinates in an Android application.

Google Places API The Google Places API [44] provides a convenient UI-widget called PlacePicker. It allows a user to set a certain location of a map or look up a place on Google if internet connectivity is given. Also, it provides additional information about certain places such as their place type. As mentioned in section 4.4, we use these place types in our study.

google-places-api-java The Java client google-places-api-java [11] is distributed under the MIT license (see A.2.1) and allows a convenient use of the Google Places API.

emoji-java The library emoji-java [17] which is distributed under the MIT license (see A.2.2) as well, offers a transcription of emojis.

6.2 Components

We kept Piatkowski's components [81]: *Notification*, *Logging*, *Applist*, *Data Access Object* (*DAO*), *Util* and *Settings*. The use has been altered to suit our objectives. Additionally, we implemented the following components: *ContextInformation*, *TextProcessor*, *Firebase* and *Questionnaire*. The dependencies between the components can be seen in figures 6.1, 6.2, 6.3 and 6.4.

6.2.1 Util

Util provides data and resources to the other components. The class *PreferenceProvider* in *Util* enables access to the *PreferenceManager* API which allows the convenient saving of key-value pairs. We save the user ID, the number of questionnaires which were already sent on a day and location of the home- and study-/workplace. The *ResourcesProvider* provides graphical resources for the implementation of the GUI.

6.2.2 DAO

The purpose of the DAO is to maintain persistence amongst the data. Therefore, the abstract *PersistenceManager* class enables the access to entries of our database. For our usage of the *DAO* component we made some adjustments to Piatkowski's version [81] to suit our needs to save more features in regards to notifications. Thus, we altered the views of our database in the *CouchbasePersistenceAdapter* so they provide a view on all needed features about notifications and the adjusted information about applications as later described in subsection 6.2.6. Additionally, we added a view for our FCM related data as later mentioned in subsection 6.2.9.

6.2.3 ContextInformation

Due to our need of collecting a variety of data, we included a *ContextInformation* component which is supposed to retrieve the needed data. The purpose of the classes in this component are to allow automatic collection of the features, we have specified in chapter 4. It contains the following classes:

BatteryStatusRetriever The *BatteryStatusRetriever* class provides the current battery level.

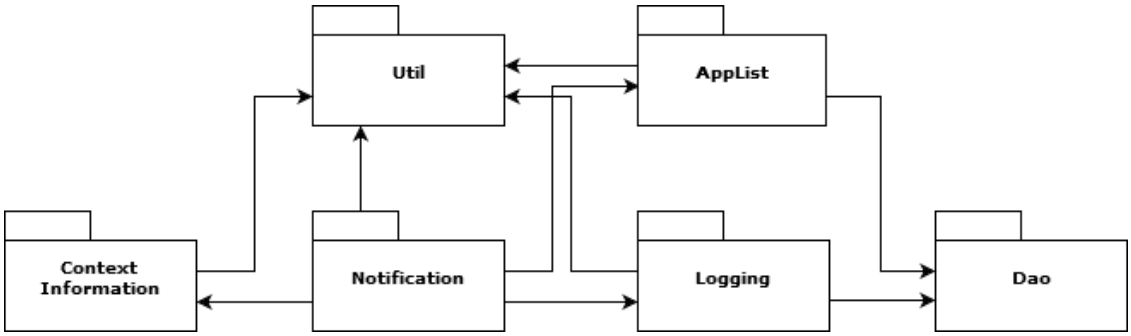


Figure 6.1: Dependencies of the Notification component

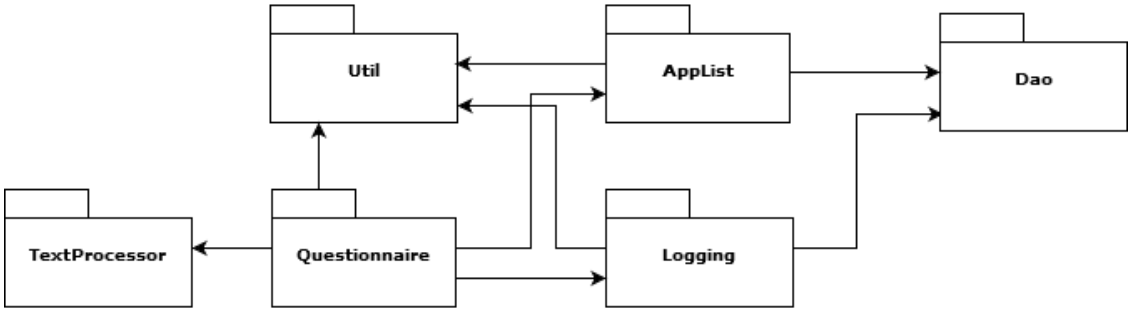


Figure 6.2: Dependencies of the Questionnaire component

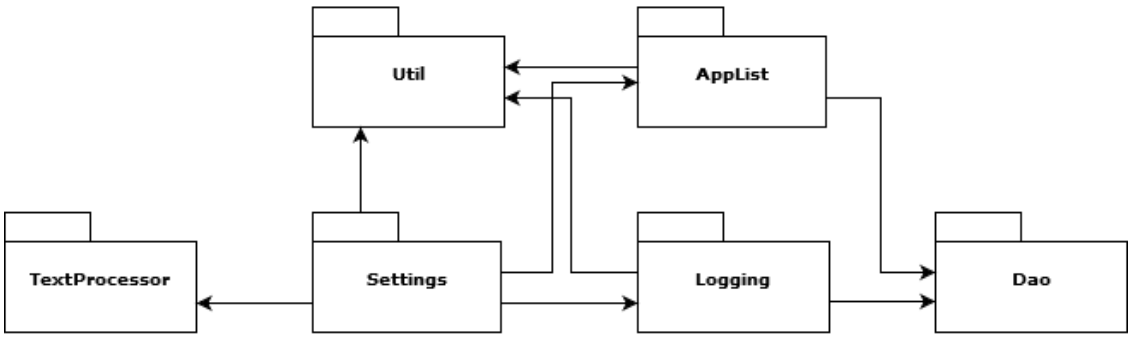


Figure 6.3: Dependencies of the Settings component

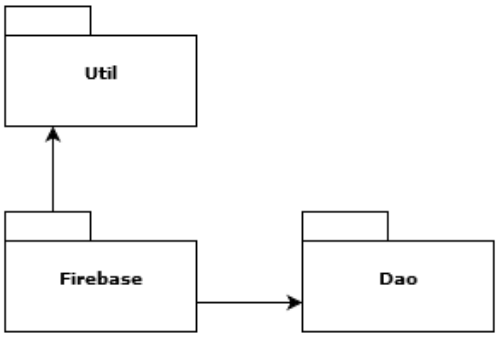


Figure 6.4: Dependencies of the Firebase component

ConcurrentApplicationsRetriever It retrieves the currently running processes. Starting from Android 5.0 the access to this information tends to be more restrictive. We used the *UsageStatsManager* API to retrieve this information. This API requires the `PACKAGE_USAGE_STATS` permission which is added to our manifest file.

EventTypeRetriever The *EventTypeRetriever* class will assess whether a notification was *accepted* or *deleted*. It uses the *UsageStatsManager* as well in order to check if the respective application of a notification is running in foreground. If the application is running in foreground, we assume the notification was *accepted*. If the respective application is not running in foreground, the notification was *deleted*. So far there is no more precise way of differentiating between the two events.

InternetConnectivityRetriever This class provides whether currently internet is accessible or not.

LocationRetriever The *LocationRetriever* class retrieves the current location of the phone. It implements the *LocationListener* API and needs the `ACCESS_FINE_LOCATION` permission. Depending on the current state of the phone, it will use GPS to retrieve the location if GPS access is available. If GPS is not available, it will try retrieving the location via the network provider if internet is available. If neither GPS nor internet are available, the location cannot be retrieved. The location will be provided as longitude and latitude coordinates.

PhoneAttendanceRetriever In order to assess whether the phone was attended at a certain time, we check whether the phone was locked or not. If the phone was unlocked, we categorize attendance as attended, otherwise not.

RetrievePlacesTask Since we do not wish to collect longitude and latitude coordinates themselves, the *RetrievePlacesTask* translates given coordinates into place types using the *google-places-api-java* Java client and the *Google Places API*. It also compares the given coordinates to the coordinates of the home- and study-/workplace of the user. The algorithm allows a tolerance of 50 meter derivation from home- and study-/workplace and retrieves place types in a vicinity of 30 meters. We allow this tolerance due to inaccuracy of smartphone sensors. If the current longitude and latitude coordinates are similar to the coordinates of a previously received notification in our database, we will reuse the place types if that entry already has this information available, instead of requesting the information anew. This is to reduce battery and data consumption.

6.2.4 TextProcessor

The *TextProcessor* component uses a façade pattern to offer an interface to its classes. Another component may access the *TextProcessor* class to acquire the language and sentiment of a given String. The *TextProcessor* will delegate the String to the respective classes.

LanguageDetector The *LanguageDetector* can differentiate between three languages. Since our participants are majorly from Hong Kong and Germany, the *LanguageDetector* differentiates between Chinese, German and English.
Chinese includes both simplified and traditional Chinese and languages which majorly use Chinese characters will be classified as Chinese as well. The Chinese language detection is based on checking the number of Chinese characters in a String. Chinese characters occupy a certain Unicode range. Due to the applied CJKV (Chinese, Japanese, Korean, Vietnamese) writing system [85], certain characters which have a minuscule difference, e.g. a slightly different angle of one stroke in a character, are represented by the same character in Unicode. This helps to reduce the vast number of Chinese characters. Thus, our system also counts Chinese characters which might also indicate another language like Japanese. The Chinese characters in Japanese and Chinese are frequently interchangeable or semantically similar [22]. Thus, it does not disturb our purpose if we classify a notification written in Japanese as Chinese. While Chinese characters exist in other languages as well, their usage is minuscule. The Korean language is majorly using Hangul instead of Hanja and the Vietnamese language has adopted a latinized writing system. Chinese characters are only rarely used in the latter two languages nowadays and Chinese and Japanese remain the two major languages which use a significant number of Chinese characters [22].
For the detection of English and German language we first check if the used characters are majorly characters of the Latin alphabet. If this is the case we first check the String for occurrences of umlauts (ä, ö, ü) and the sharp s (ß) which likely indicate German language. If this is not the case we count the occurrence of frequent trigrams in both German and English language or the occurrence of frequent words of each language. If the count of these indicators is above a certain threshold, we assume the String to be of the indicated language. We used the frequent trigrams of Grefenstette's work [30]. For the frequent English words we used the free *5000 word corpora* [19] by researchers of the Brigham Young University (BYU), USA. The corpus is based on the *Corpus of Contemporary American English* (COCA) which contains 520 million words. COCA is a genre-balanced corpus. For frequent German words, we used the *10k words corpus* of the *Leipzig Corpora Collection* [28]. They counted word occurrences in German news and provide a descending list of words with their respective occurrences. We have used the top 5000 words of the list.
We tested the *LanguageDetector* by using a dataset based on the Chinese microblogging site Weibo[1] [61], the *1M sentences corpus* of the *Leipzig Corpora Collection* [28] and the *Twitter Sentiment Analysis Training Corpus* by Ibrahim Naji [73]. The test resulted in $F_1(German) = 0.99\%$, $F_1(English) = 0.96\%$ and $F_1(Chinese) = 0.99\%$ with our dataset which overall contained 2.8+ million tokens. $F_1()$ describes the F-Score.

SentimentCalculator We determine the sentiment of a notification in our *SentimentCalculator* class using the lexicon-based approach [72], hence, we count the number of occurrences of words which indicate a certain sentiment.
For the Chinese language we use the NTU Sentiment Dictionary [56] which

[1] https://www.weibo.com/

offers lists for negative and positive phrases in traditional and simplified Chinese. For the English language we use the *Opinion Lexicon* which contains lists of positive and negative opinion or sentiment words by Hu and Liu [37]. In order to derive the sentiment for the German language, we use *SentiWS - a Publicly Available German-language Resource for Sentiment Analysis* [88]. For the sentiment, we based our tests on the *Chinese sentiment dataset* by Zhang et al. [111], the *Potsdam Twitter Sentiment Corpus* [8] and again the *Twitter Sentiment Analysis Training Corpus* by Ibrahim Naji [73]. We tested the classification of tokens which were classified as negative or positive. 43% of the data could not be classified. 16% were wrongly classified as their opposite sentiment and 41% were correctly classified as their respective sentiment. Thus, amongst the remaining data 71% was classified correctly. The database contained 1.5+ million tokens. Since we tried to minimize background processing as much as possible to prevent high battery drain, we used the simple lexicon-based method of calculating the sentiment. The tokens which do receive a classification have a high accuracy which should be sufficient for our exploratory purpose.

We tried to preferably choose corpora from microblogging websites for our tests due to their shortness which are similar to notifications.

6.2.5 Notification

The *Notification* component serves as the receiver for notifications on a device. It contains the class *NotificationListener* which implements the *Notification Listener Service* as mentioned in section 2.1.5. Therefore, the `BIND_NOTIFICATION_LISTENER_SERVICE` permission is included in our manifest-file. Via the *onNotificationPosted()*-method we are able to receive notifications. This method delivers notifications which were *posted* or *updated*. In order to receive notifications which were removed, the service provides the method *onNotificationRemoved()*. In both cases the received notification will be delegated to the *NotificationService* class. The *NotificationService* class will process the respective notification. When it was posted, it will check whether it was *posted* or *updated*. When it was removed, we will check whether the notification was *accepted* or *deleted*.
The *NotificationService* uses the *ContextInformation* component, to acquire further information about a notification as described above. Therefore, it will inquire the *battery level*, *concurrent applications*, the *internet connectivity*, the *phone attendance* and the *location*. Once the location is retrieved, the *LocationListener* will be stopped to avoid unnecessary battery drainage. The longitude and latitude of the current location will be provided to the *RetrievePlacesTask* in order to asses the corresponding place types. After acquiring the needed information, the *NotificationService* logs this data along with the *notification title*, *notification ticker*, *notification text*, *application* and the current *time*. Therefore, the *Logging* component is used which will save the data in the database on the respective phone. For the *notification title*, *notification ticker* and *notification text* emojis will be transcribed using *emoji-java*. This simplifies later text processing.
Additionally, the *NotificationService* will update the *AppList* if a notification was removed. It will increase the value of the counter for the respective application which the notification belongs to.

If a removed notification is a dedicated interest- or disinterest-based notification from our application, a notification to answer a questionnaire about the notification will be triggered.

6.2.6 AppList

The purpose of the *AppList* component is to organize information in regards to applications. We count the number of notifications an application has received since the last questionnaire. Secondly, we count the total numbers of questionnaires which have been generated per application during the study so far. This helps to decide from which application we should choose a notification to create questionnaires about.

6.2.7 Questionnaire

The *Questionnaire* component did not exist in Piatkowski's work [81]. We added the *Questionnaire* component in order to control and organize the questionnaires sent to the user. The questions of our questionnaire are depicted in list A.1 in our appendix.
As mentioned in subsection 5.2.4 where we specifically explained our design of the daily questionnaires, we want to trigger ten questionnaires every two hours between 6 AM and 12 midnight. Therefore, we set alarms to start *NotificationPickerTask* for the specific time slots. *NotificationPickerTask* will then choose notifications for the questionnaires based on the frequency of sent notifications of an application. Thus, if an application has sent a lot of notifications in the past time slot, a notification by this application will likely be chosen. However, we consider the ratio between the frequency during the past time slot and the number of questionnaires we have already triggered about an application in order to prevent a too monotonous dataset. We receive the necessary information using the *AppList* component (see subsection 6.2.6). Once a notification is chosen for the questionnaire, a notification is sent to the user to answer the questionnaire. Afterwards, notifications which will not be used for questionnaires anymore, will be finalized by applying the *TextProcessor* to calculate the *notification sentiment*. Then the notification will be removed from the database and written to a log file.
We added the class *QuestionnaireFragment* in order to provide a GUI for the user to answer the questionnaires. The GUI provides the user with the application icon, notification title, notification ticker and notification text which can be seen in figure 6.5. The questions are as described in list A.1. We provide the user with the *arrival time* and possible locations if available, as a memory aid. The question about the *place type* at *removal time* will be omitted if the recorded location is near the location at *arrival time*. If no location was recorded, this part of the memory aid will be omitted. The place type can be entered via an *AutoCompleteTextView* element [40]. An example of the *AutoCompleteTextView* which allows the user to type a word, which can be completed with suggested place types, can be seen in figure 6.6. For the emotion wheel, we implemented a button which will depict the definition of the chosen emotion (see figure 6.5). By clicking on the button, a picture of the emotion wheel will appear where the user can choose an emotion as depicted in figure 6.7. Also, if the questionnaire is about a dedicated notification by our application, the question about the *other party* will be omitted and set to *application* as *other party*. Once a questionnaire is submitted, it will be removed

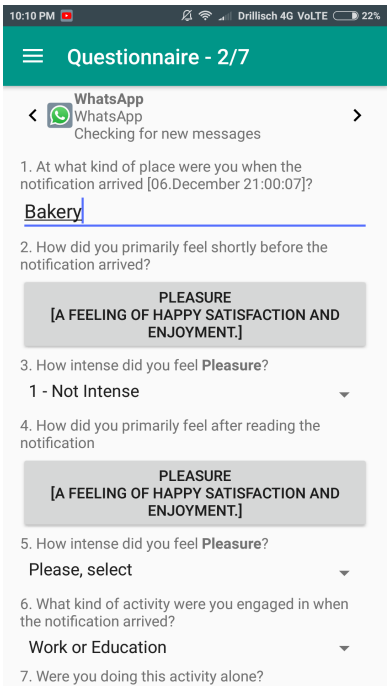


Figure 6.5: Example of the upper part of the questionnaire

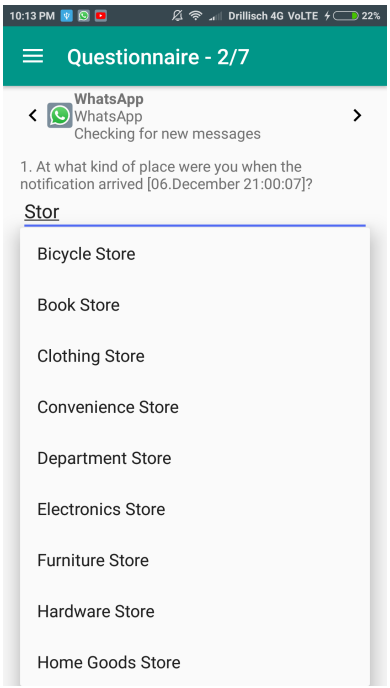


Figure 6.6: Example of the AutoCompleteTextView for answering the Place Type question

Figure 6.7: Example of the Emotion Wheel

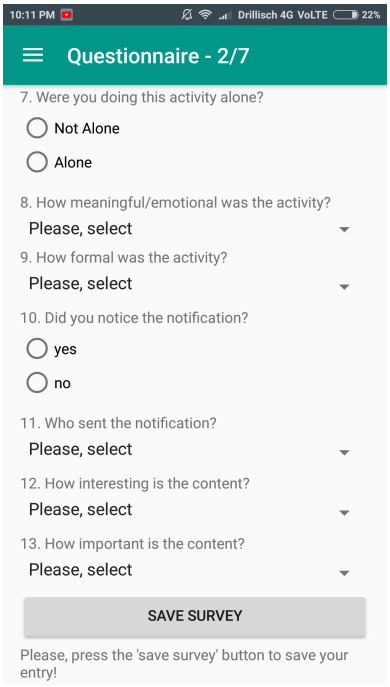


Figure 6.8: Example of the lower part of the questionnaire

from the database and written to a log file. The questionnaire can be submitted by clicking the *Save Survey*-button as displayed in figure 6.8 which depicts the lower half of our questionnaire. If the button is clicked without answering all questions, a popup will appear which requests the user to answer the unanswered questions, specifying the numbers of the missing questions. If the notification is saved, a *Thank You*-message will appear.

6.2.8 Logging

The *Logging* component takes care of the collected notification data and logs them in the database. The structure of this component stays nearly unchanged compared to Piatkowski's work [81]. We adjusted attributes of the class *EventEntryManager* which poses as the extension of the *PersistenceManager* class of the *DAO* component (see subsection 6.2.2), in order to suit our purpose of collecting a wider range of features. The *EventEntryManager* allows to load data in regards to notifications from the database. In our work, we consider the *EventTypes* `NOTF_ACCEPTED`, `NOTF_REMOVED`, `NOTF_UPDATED` and `UNKNOWN`.
We adjusted the Piatkowski's [81] *LogFragment* class so it would show recent notifications, including notification title, ticker and text to the user for their own interest.
The class *CsvWriter* will write the collected data about notifications into a file. The filename includes the participant ID. The *CsvWriter* will write all necessary information about the features we want to collect into the file. Notification title, ticker, text and precise location coordinates are omitted. The only exception are notifications generated by our own application where we save the notification title and text. The class *FileTransfer* uses *JSch* (see subsection 6.1.3) to send the file via a secure channel to our server. Data will be transferred once the *Questionnaire* component has finished selecting a notification and the notifications which will not be needed for future questionnaires are processed. The data will only be transferred if internet access is available. Otherwise, the transfer will be deferred till the start of the next time slot.

6.2.9 Firebase

The *Firebase* component allows us to receive data messages using the *Firebase Cloud Messaging* (FCM) service. It poses as the interface of our Wizard of Oz study. We use Postman (see subsection 6.1.1) to send notification contents to our application.
An exemplary notification content can be seen in figure 6.9. FCM needs JSON-formatted messages. Our data messages contain the participant ID of the participant whom the notification is dedicated to. Then we specify the title of a notification, the notification text and a URL. The URL leads to the respective article. Then we specify two points in time. These are usually 6 AM and 12 midnight of a certain date. The notification will be sent via HTTP. The HTTP request has to be directed to the endpoint `https://fcm.googleapis.com/fcm/send` from where the data message will be distributed to our application. Our application receives the data message via our *Firebase* component and triggers the notification at a random time between the two stated points in time. In order to do so, we extend the *FirebaseMessagingService* API in our class *FirebaseNotificationReceiverService* which will receive an incoming data message.

A rough excerpt of the implementation can be seen in listing 6.1. We overwrite the method *onMessageReceived(RemoteMessage remoteMessage)* which will be called when a data message arrives. Next, we extract the actual content from the JSON-formatted data message and check whether the message is directed to the respective participant by comparing the participant ID. If the ID is correct, we proceed to generate a random point in time between the specified ones. If the ID is incorrect, no further actions will be taken. Then we create a notification to the user for the generated time and save the notification to the database. The data will be needed again in case of a boot start to regenerate the notifications. Once the notification is sent to the user, it will look like in figure 6.10. If the participant chooses to accept the notification, the content will be shown in a *WebView* by our application as seen in figure 6.11. Once the notification is removed, a questionnaire about it will be triggered.

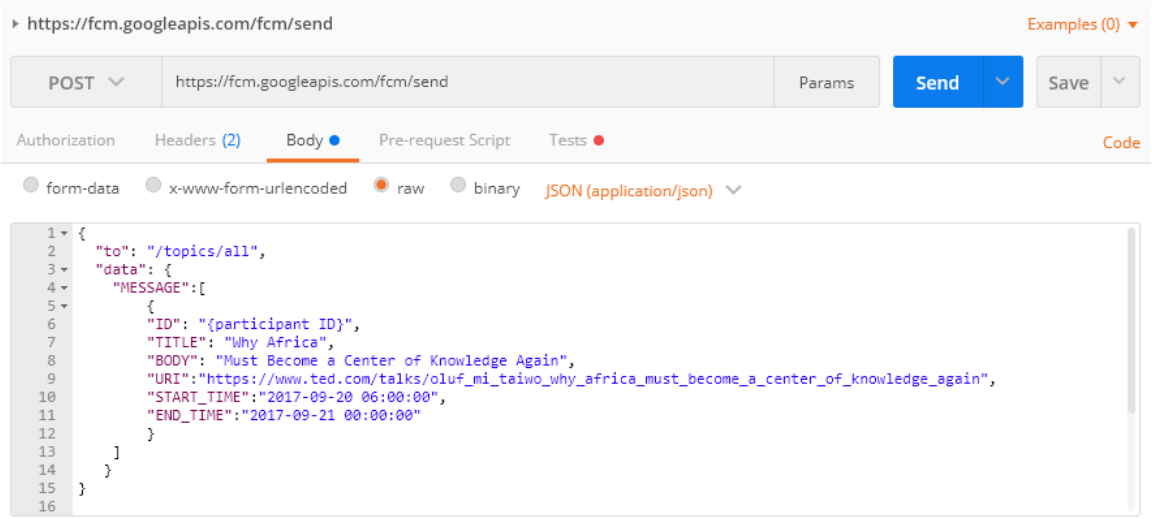


Figure 6.9: Example of notification content which we send to a participant using Postman

```
@Override
public void onMessageReceived(RemoteMessage remoteMessage) {
  if (remoteMessage.getData().size() > 0) {
    Map<String, String> data = remoteMessage.getData();
    String messagesText = data.get("MESSAGE");

    try {
      JSONArray messagesArray = new JSONArray(messagesText);

      for(int i = 0; i < messagesArray.length(); i++){
        JSONObject messageObject = messagesArray.getJSONObject(i);

            if(messageObject.getString("ID").contentEquals(
              new PreferenceProvider().getStringValue(PreferenceProvider.Key.ID))){
                Timestamp rand = calculateRandomTime(messageObject);
                enterFirebaseEntry(rand, messageObject);
                prepareNotification(rand, messageObject);
            }
      }
    } catch (JSONException e){
      e.printStackTrace();
    }
  }
}
```

Listing 6.1: Excerpt of FirebaseNotificationReceiverService class

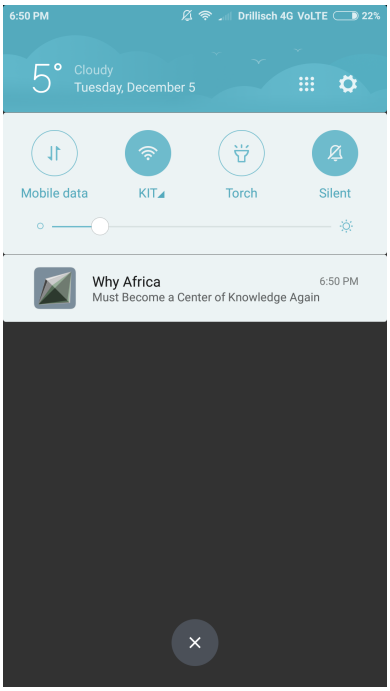


Figure 6.10: Example of a dedicated notification sent via FCM

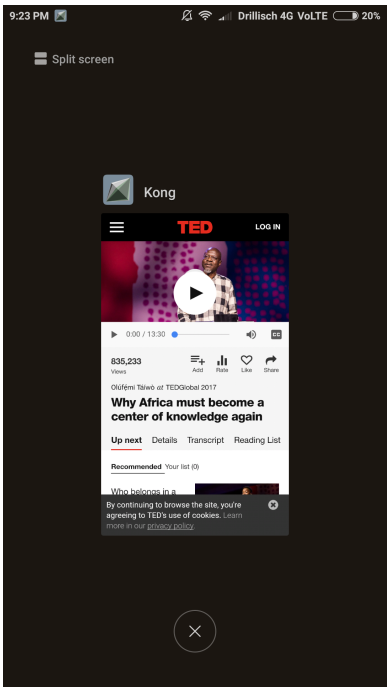


Figure 6.11: Example of an accepted notification opened in the WebView of our application

6.2.10 Settings

In our *Settings* component, we implement our class *SettingsFragment* which allows the participant to set up their participant ID and grant the needed permissions (see figure 6.12). Also, they can specify their home- and study-/workplace. They can pick these place types on a map. For this purpose, we implemented the PlacePicker using the *Google Places API* (see figure 6.13). At the bottom of the page, we implemented a "Finish Study"-Button. Clicking this button will cause the remaining data to be processed and sent to our server. The button will only be needed for the final meeting as mentioned in chapter 5.

6.2.11 Other

Like Piatkowski [81] we needed a *BootStarter* class which extended a *BroadcastReceiver* to receive an intent when a smartphone is restartet. Once the phone restarts, the previous alarms will be deleted and we reset the alarms anew. Also, we reset the dedicated notifications which were saved to our local database of the app as mentioned in subsection 6.2.9.

6.3 Technical Issues

During the pilot study we were able to rule out some issues regarding our application and make adjustments to the GUI. One of the participants lamented the sensitivity of the emotion wheels. Previously the emotion wheels were directly below the questions. Thus, when scrolling, they might accidentally tap on another emotion. We fixed this by integrating buttons to open the emotion wheels. It will be closed again by choosing an emotion.

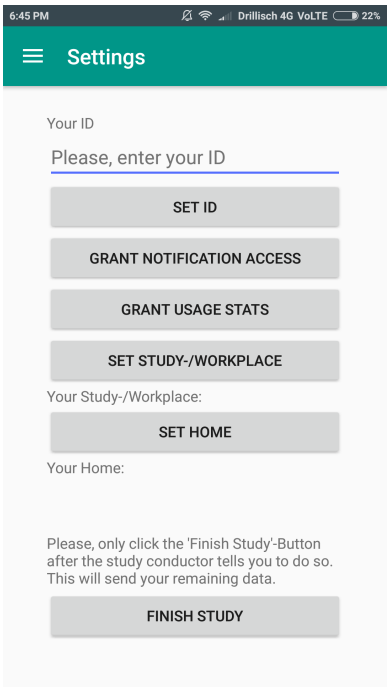


Figure 6.12: Settings of our application

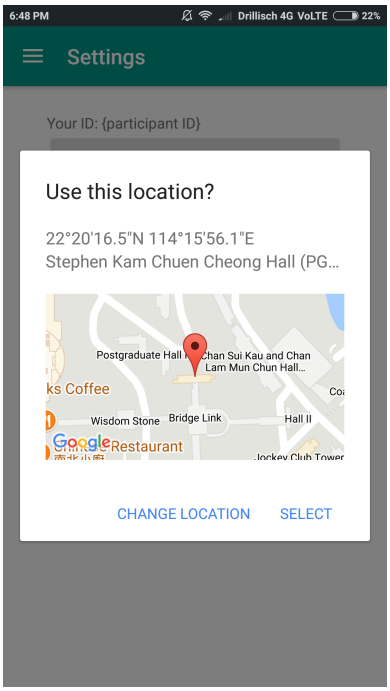


Figure 6.13: The PlacePicker in the settings

However, we also faced issues which we were not able to resolve. The most integral one is the malfunctioning of the *NotificationListenerService* which would often stop working or would be terminated by the system while it is running in the background. Many phones offer battery saving options in their phone settings which terminate applications in the background to save energy. We had to ask our participants to exclude our application from any battery saving options. This posed to be difficult as several participants were not well-versed enough about their phone to know such a detail. We noticed that our application had to be granted the Autostart permission on Xiaomi smartphones which used the MIUI firmware. On Huawei phones with Android 5.0 our application had to be included to *Protected Apps* in the settings, which allows the application to keep running once the screen is locked. Fortunately, most of the study participants were understanding and allowed us to take such measurements. Despite this, the *NotificationListenerService* would sometimes stop working in some cases. This issue was reported to Google via its Issue Tracker [3]. However, a solution was not available during our project. In case of malfunctioning, we had to ask participants to revoke the permission for notification access and grant it again. This solution was often sufficient. In one case, a participant was cleaning their system. The cleaning altered internal settings of our application. We had to ask them to deinstall and reinstall the application.
We faced the issue that a Samsung device threw a *SecurityException*. This happened because certain Samsung devices introduced a cap of 500 alarms. When using repeating alarms, the previous alarms do not get deleted, unless the flag `FLAG_UPDATE_CURRENT` is used for the respective *PendingIntent* of the notification [77]. We were unaware of this limitation because none of our pilot study participants possessed Samsung phones. The issue occurred to two of our participants in Hong Kong. We fixed this issue and it did not occur to our participants in Germany.

Another issue, which occurred on a Xiaomi device, was that the *PlacePicker* malfunctioned. This issue was reported to Google via its Issue Tracker, too [2]. We circumvented this issue by providing another interface for the participant to provide their home- and study-/workplace coordinates.

7. Evaluation

We conducted the study as outlined in chapter 5 with overall 32 participants. We had 13 female and 19 male participants, age ranging from 19 to 30 years old with an average of 23 years and standard deviation of 3 years. 11 participants have graduated from high school, 15 participants have graduated from Bachelor's studies and 6 participants have graduated from Master's studies. They are currently working or studying in different areas ranging from Computer Science, over Medicine to Media Design. The fields can be grouped as follows: Technology (16 participants), Engineering/Research (6 participants), Business Administration (4 participants), Biology (3 participants), Culture/Social (3 participants) and None (1 participant). One participant indicated to study two courses of studies which leads to a total of 33 answers in regards to the field categorizations.

7.1 Qualitative Data

As outlined in subsection 5.2.5, we conducted several interviews leading to 1d 7h 22min 40sec of audio data which we transcribed additionally to our written notes of interviews which we could not record.
When we asked participant P15 *"What makes a notification important for you?"*, they expressed their feelings about notifications as a metaphor which we want to use as an introductory example of the conflicting nature of notifications:

"I think, I'd make the analogy of my professor. Like, my professor sitting at the desk of his office. [...] He's the user [...], the notifications would be staff, students or friends... and they would either talk to him or give him stuff to work on. So sometimes the notification helps to remind me...- not remind -, notify me of things which need to be dealt with quickly. In another way it disturbs [the] current activity I am doing because I can't really ignore it..." (Participant P15)

The metaphor shows that sometimes notifications are appreciated for their usefulness but sometimes unwelcome due to being disruptive. Finding a way to measure which notifications are important and how to reduce the negative effects of notifications is the main goal of this area of research. Thus, we want to analyse the

properties of notifications by evaluating the results of our qualitative data.
In the following we want to go through the questions of the weekly interviews and share our insights. Quotations were translated to English if the interview was not conducted in the English language and grammar mistakes were corrected. Dependent on the question, participants gave several answers to our questions.

7.1.1 Reasons for Long Reaction Time

We asked our participants whether they sometimes receive notifications which they do not tend to immediately. All participants affirmed this question and stated several reasons as to why they do not tend to notifications immediately. The reasons not to tend to notifications are diverse and can be grouped as follows:

Preoccupation 28 participants: The participant is already engaged in an activity and cannot give full attention to the notification. Participants said they were preoccupied with another task, e.g. work, and therefore were too busy to tend to notifications immediately or could not afford such a context switch due to work ethics.

Reminder 14 participants: The notification is supposed to serve as a reminder for a later point in time. This reason relates to *Preoccupation*. However, a special purpose is given to the notification. Participant P8 gave a good example of such a situation:

> *"Yes, the latest example would be for example: When [*Friend*] sent me a list of participants [for an event], I was at university and let the notification stay. So when I come home, I will have a reminder that I still want to tend to it; basically a semi-reminder."* (Participant P8)

Properties of the Notification 7 participants: Tending to the notification has certain properties. For instance, the notification requires WiFi access for system updates, or will cause a conversation partner to know that a message was read but apparently ignored.

Handling of the Notification 6 participants: Handling of the notification will occupy a lot of resources, e.g. time, or the user does not know how to handle the notification.

Affective State 6 participants: The participant is not in the *mood* or *emotion* to deal with the notification. Some participants mentioned that they needed to be in a certain affective state to deal with notifications. However, it was hard for them to describe the specific kind of affective state. Participant P6 gave an interesting reply.

> *"Usually, the reason is to not loose my focus on what I am doing or to postpone the things about the notification to a moment where my mind is in the mood to do this, that is the mood to reply messages... When I know my mind is in the mood to do that... [*Interviewer: How would you describe this mood?*] So it is a compromise of being tired of what I am doing, so needing a break and at the same time a mind that is empty enough to focus on what to read."* (Participant P6)

The answer implies their mood is related to their current activity and feelings towards this activity. Also, a willingness to take in new information has to be present.

Lack of Interest 4 participants: Notifications are seen but forgotten, or the participant simply does not care enough about it to take any actions, e.g. because the phone is not near the user.

Company 3 participants: The participant is currently engaged with other people and might notice the notification but will choose to take care of the people in their vicinity first.

Efficiency 1 participant: One participant deliberately collected several notifications over time in order to deal with all of them at once.

> *"Yes, very often, for example with WhatsApp notifications. When I receive them, I look briefly who sent it and what they sent... I prefer to answer a bunch of notifications at once instead of constantly answering a few and then being interrupted, for example at work; or calendar notifications. I sometimes let them stay for longer... [...]. During freetime, too. I formed the habit to handle them all at once instead of one at a time."* (Participant P12)

It is evident that dependent on the situation the perceived importance of a notification varies. Participants will postpone the handling of notifications to a later time when they are currently preoccupied with certain activities or are engaging with other people. Even the affective state has to be in a certain condition for some people to tend to their notifications and some do not value notifications highly enough to take care of all of them.

7.1.2 Blacklisted Applications

We asked our participants whether they have blacklisted applications to send notifications and if so, for which reason. The participants can be clustered in 4 major groups.

Blackisted 21 participants:

- **Muted Contacts/Groups Only** 4 participants: Some participants have only muted certain contacts or groups because these tended to send unnecessary information.
- **Blacklisted Applications** 17 participants: The majority of participants have blacklisted applications from sending notifications. They stated several reasons: The notifications were uninteresting or unimportant (11 participants); The notifications were annoying (9 participants); The participants would check the application regularly by themselves (3 participants). 6 participants specifically stated they blacklisted game applications because the notifications were annoying and did not serve any other purpose than motivating to play the game. Communication applications were mostly not blacklisted. Only one participant (P3) stated they actually only blacklisted WhatsApp and Facebook Messenger because they were annoying.

Nothing Blacklisted 11 participants:

Flooded/Unfamiliar 5 participants: A few participants have not blacklisted any applications from sending notification. A few of them did not know about this feature and will consider blocking notifications in the future. Some of the participants have deinstalled applications as an alternative countermeasure, like participant P24:

"No, I haven't [blacklisted anything] but it is a good idea. However, I don't have so many apps, so it is manageable. Currently I don't get flooded by notifications. However, this was the reason why I deinstalled Pokemon Go because it had too many notifications. That was unnecessary then." (Participant P24)

Not flooded 6 participants: Some participants have not blacklisted any applications from sending notifications and do not feel flooded by notifications. They tend to have few applications installed, e.g. due to small memory size (P23).

Additionally, 3 participants noted that system notifications were often unnecessary or flooding, as participant P25 described:

"System notifications are annoying but you cannot block them. System notifications show you what you know anyway. For example your battery is low or your data volume exceeded its limit; you know this anyway already." (Participant P25)

Interestingly, despite regularly using their phones some users are not technically well-versed enough to know about all features the Android system offers. This aligns with Yoon et al.'s [109] work which noticed a group of people which can be described as *disoriented*. Participant P13 would be affected by such an disorientation:

"Actually I don't have many apps... [...] WhatsApp, Facebook, then, for example "Battery is fully charged"... Otherwise, I might receive breaking news... I don't even know where it comes from. Such a notification saying: "Breaking News", currently with Catalonia" (Participant P13)

Another participant did not know one could reach the notification settings of an application by long-pressing a notification of the application. This is not necessarily connected to the background of the participants as it includes both, people working or studying in the fields Technology and non-technological fields. It shows a lack of guidance to the abundance of features Android actually offers. Thus, some users cannot utilize all features to adjust notification settings.

7.1.3 Reasons for Deleting Notifications

We were also interested in reasons as to why participants deleted notifications. Various reasons were mentioned:

Uninteresting 19 participants: 19 participants stated a likely reason was that the content of the notification was uninteresting.

Unimportant/Irrelevant 17 participants: Several participants noted that the content of the notification was not important or not useful to their current situation and will likely not gain any importance in the future.

Notification is Sufficient 7 participants: Some notifications already serve their purpose by appearing in the drawer such as calendar notifications or weather notifications. They already contain all needed information so a further handling of the notification in the specific application is unnecessary.

Quantity 5 participants: If the amount of notifications is too much, some participants tend to delete them. As P18 states:

> *"When there are a lot, I may clear all, even though there are some important ones. [...] When [there are] too many, [it is] too bothersome to read all"*
> (Participant P18)

Preoccupation 3 participants: A few mentioned, they would delete notifications when they were busy because of another activity.

Affective State 3 participants: Some also stated, they would delete some notifications because of their current mood or emotion.

Unexpectedness 3 participants: Sometimes notifications which are sent from unexpected applications, e.g. a translation application which sends notifications about news (P18), get deleted. P1 puts it as follows:

> *"I don't delete unless it's strange and I don't know why it comes."*
> (Participant P1)

which adds to the issue of the *disoriented* group of people [109].

Orderliness 3 participants: A few participants wish to have an orderly notification drawer. They delete notifications so their notification drawer will be *clean*.

External Device 2 participants: Two participants noted that they check certain notifications on other devices. The smartphone does not always synchronize properly and displays notifications which they have already handled on other devices again. These will be deleted.

System 2 participants: When the smartphone seems to start getting slower, a few participants will delete all notifications to free the CPU.

Self-Checking 1 participant: One participant mentioned they would check certain applications regularly anyway. So they will delete notifications when they know, they will access the respective application later.

Language 1 participant: Lastly, one participant noted that they prefer to receive notifications in their mother tongue. Especially when they feel stressed or in a hurry, they prefer to receive notifications in their native language rather than others and will delete more of the notifications in their non-native language.

The main reasons to delete notifications are content-related. Participants wish to receive interesting and important notifications. Receiving too many notifications on the other hand will cause several participants to delete all notifications even if useful notifications were amongst them. This shows the need of a smart notification system which either adapts to the user's need or let them handle notifications in a more appropriate way. However, considering previous subsection 7.1.2, it will be necessary to properly guide the user to such measures.

7.1.4 Interesting Notifications

After the second week we asked the participants about their opinion on our dedicated notifications. 17 participants liked the interest-based notifications. Some participants raised interesting thoughts in regards to interest-based notifications:

"I think, when I have free time, then I would inform myself about these topics. That's why I don't need an application which annoys me on the sideline."
(Participant P12)

Some people see the purpose of a smartphone simply in its function as a communication device. Receiving notifications about their interests does not align with their usage of the phone.

"I received notifications about books. Generally I found them interesting but the articles themselves were not so appealing to me. The informative content was quite disappointing. I couldn't do a lot with it then." (Participant P13)

Believing that a link will lead to good content but then reading something unsatisfying could be frustrating. However, it does not necessarily have to be solely a problem of articles. Game notifications which are excessively positive about their own application and where users know that the actual content is not as promising might cause a dislike of this discrepancy, too.

"I think it's good, sometimes it just sends the movies I watched. So it gives me more info about it. [...] The interests keep on changing, so this kind of notification is good, but the content... but the interests change over time so the content needs to change." (Participant P23)

A problem with human interests is its ever-evolving form. People will dismiss former interests and form new interests. A system which sincerely wants to send notifications the user cares about will have to swiftly adapt to a user's new interests. However, P19 has raised a contrary concern:

"I don't think, I want to receive notification from my software because that means the software knows about my interests. I don't like the feeling of being targeted. I don't want to receive notifications from an automatic algorithm. It makes me angry when it is targeted." (Participant P19)

Some users will likely feel uncomfortable to be surveilled by their system in regards to their interests. Considering such a case, it might be profitable to allow the user to choose between a manual and an automatic adaption.

"Most of them were pretty interesting. There were things about politics, those were also things I partly wouldn't have noticed otherwise and I mostly liked to read them. [...] Yes, I think notifications about interests are definitely good but you need to adjust more precisely which interest exactly because some topics... You are so involved in the topic, you will get the information anyway. But interests which are so multifaceted, for example international politics, this is so diverse, this is good, because you don't have time in your free time to research everything by yourself." (Participant P24)

Depending on the topic notifications can help the user to stay up-to-date with topics they actually care about but are too busy to research in their daily life due to a busy schedule or maybe because they wish to use their free time for more relaxing activities. Also, users might not necessarily wish to receive notifications about all of their interests. As stated by participant P24, some topics are topics which they are so engaged in that they might already be an expert of this field. So, additional information will be unnecessary.

"Often I see them during the day, then I read them later and don't have to take care [about pastimes] later." (Participant P27)

Interesting notifications might not necessarily be important but are acceptable because they might come in handy when the user is free. In this case, interesting notifications should be postponed to points in time when the user is actually free and could need some pastime instead of sending an interesting notification during, e.g. work.
During the interview after the third week, we asked under which circumstances participants liked to receive interesting notifications. The most common situation were when the user felt bored and were idle or resting (11 participants) or when they are not working (8 participants). Likely, in relation to idleness, a few participants like to receive interesting notifications when they are on transit (4 participants). 3 participants explicitly stated they never wanted to receive interesting notifications and 2 participants stated they would like to receive interesting notifications any time. Another participant stated they could receive interesting notifications any

time, but the time they tend to it might be a lot later (P13). And P4 would like to receive interesting notifications any time except for when they are in company or resting. Other circumstances included when they were feeling happy (P1), when they were feeling curious (P6), when it is interesting in regards to their current situation (P8) or when they are at work (P9). The appropriateness of interesting notifications is mostly situational. For most people, they are nice to have when they basically are not engaged in anything important. 7 participants like to receive notifications about all of their interests. 17 participants prefer to receive notifications about subsets or specializations of their interests. Especially interests which were connected to activities, e.g. sports, meeting friends, were subjects they liked to engage in and not to be informed about. 2 participants mentioned that they would like to receive situationally interesting notifications, e.g. notifications about soccer on the weekend (P21) or receiving a recipe when they want to cook instead of at random times (P6). It shows that even for interesting notifications, participants wished for an added value in order to receive notifications about their interests. It should either add to their situation or inform them about issues which otherwise would have gone unnoticed.

7.1.5 Annoyance

We wanted to know how often our participants felt annoyed by notifications:

frequently 11 participants: Several participants felt frequently annoyed by notifications. They felt like they receive many unnecessary notifications or noted that they would feel annoyed whenever notifications arrived while they were busy. These participants felt annoyed on a daily basis.

occasionally 8 participants: Some participants occasionally felt annoyed by notifications. One participant stated that it strongly depends on their current situation, whether they currently have lectures or not or what kind of business they are engaged in (P8). It also depends on the frequency and quantity of notifications. Participants would feel more annoyed if they received a lot of notifications at some point.

rarely 13 participants: Several participants stated they rarely felt annoyed by notifications. They either were able to handle notifications well or simply do not care about notifications. Even if they received many, it would not bother them. Interestingly, one participant mentioned that they currently are barely annoyed by notifications. However, it used to be different and it strongly depended on their basic mood. Currently, they were feeling more relaxed and in the past they felt more tense (P10).

Participants have various reasons to be annoyed by notifications. The most common reasons are when they receive a lot of notifications (14 participants), when the notification is irrelevant or uninteresting (8 participants) or when they are busy (6 participants). Other reasons are when the notifications convey negative content (P9), when the participant is already irritable (P15), when their eyes are dry because of looking at a screen for too long due to work (P17), when they are enjoying their current activity but then receive work-related notifications (P16), when it causes some sort of bad conscience, e.g. because they actually have something to do but

let themselves be distracted because they actually sort of enjoy notifications more than their current activity but should not let themselves be distracted (P10), when the battery is low (P25) or when they are in company of close people (P4). P32 mentioned to be annoyed that one application did not send notifications despite not being blacklisted. This application is a messenger application. It leads to confusion as they do not know when people have written them. It shows that the point of notifications is to delegate important information to the user.
Overall, it shows again that smartphone users tend to be flooded by notifications and several receive notifications which do not serve any good purpose to them. Also, the current context of the user plays a factor.

7.1.6 Smart Notification System

Since this field of research tries to figure out how to make notification systems more efficient for the user, it is also important to know how a user would feel about such a system. Therefore, we asked our participants about their opinions on such a smart notification system which would be able to track their context, adjust notifications and filter unnecessary ones. 22 participants were in favour of a smarter notification system. They stated it would come in handy if certain notifications would be filtered and delegated to a more fitting time. 6 participants raised data privacy concerns. They either felt uncomfortable to be monitored or were afraid that untrustworthy parties will be able to access their data. 4 participants also raised trust issues towards the system. If the notification system would accidentally filter important notifications they would rather let themselves be flooded by notifications than use such a system. 4 participants also stated they do not need such a system, as they do not feel bothered currently and 1 participant would wish to be able to manually adapt rules as those should change over time.
This shows that the majority of participants do feel like the notification system as is has potential to be improved. However, the introduction of a smart system will have to acquire the trust of the users.

7.1.7 Emotional Influence

We hypothesized that notifications which elicit an emotional response from the user tend to be important and thus, asked our participants whether they believe that notifications which change their emotions tend to be important. 24 participants believed that notifications which change their emotion tend to be important, 4 participants doubted this. P20 brought the example of receiving a spam email. They first read the notification and felt happy about the notification as it offered free flights. However, they realized it was a scam email next and felt unhappy. Their emotions changed but the notification was not important in the end. It connects to the previously mentioned discrepancy between the information in the notification and the actual information behind the notification which can lead to negative feelings (see subsection 7.1.4). The remaining 4 participants thought that sometimes notifications which changed their emotions tend to be important but not necessarily always.
In regards to whether all other parties have the potential to influence ones emotions, 19 participants believed only real people had the potential to influence one's emotion. 8 people believed that applications, too, could influence one's emotions. Mainly, news were able to have such an emotional impact. One participant noted

that a long anticipated game was able to elicit joy when sending notifications because the game was connected to fond childhood memories (P31). 3 participants also believed that the system could elicit emotions. However, those were rather negative due to annoyance. Participant P4 brought one positive example of a system notification:

"Since [my smartphone] had a few bugs which repeatedly occurred and I hoped to receive an update, [...] So when the update arrived and the bug was corrected- This was really cool and also made me happy." (Participant P4)

However, overall these responses align with the results of previous works which noticed the importance of the other party of a notification.

7.1.8 Notification Design

We also wanted to assess how satisfied our participants were with the current design of notifications. 9 participants like the way it is. 7 participants also like the shortness of the notifications but sometimes feel like the preview is insufficient and wish for a better summary. 5 participants wish for notifications to contain all needed information so it would render clicking the notification to gain access to the whole content unnecessary. 4 participants would prefer if notifications allowed more interaction, e.g. using buttons to answer or switching to the *big view notification* when necessary. Often the *big view notification* is not properly utilized by applications and does not provide more information than the normal view. 2 participants would prefer if the notifications were even shorter than they are now. One of them did not want third parties to see notifications on their phone and gain information about them (P30) and the other believed that people will be misguided to believe that they already accessed all needed information and will not bother to access the actual information (P19). The opinions are multi-faceted and shows that a more user-oriented approach could be preferable. Also application developers should utilize the possibilities they are offered by the Android system like the *big view notification* as several participants do wished for more information in their notifications.

7.1.9 Influence of Several Features

In the following we want to present the opinions of our participants on the influence of several features on their perceived importance and acceptance of notifications. First, we want to present the results of the final questionnaire. We asked our participants to rate the influence of different features on their perceived importance and acceptance of notifications. The results can be seen in table 7.1 and 7.2. We can see that the influence on the perceived importance and the acceptance are similar. Overall, each feature exerts some influence on both, perceived importance and acceptance, according to the opinion of our participants.
There are a few tendencies which are noticeable. We can see that according to our participants, the three *intrinsic features other party*, *application* and *application category* influence the importance the most. While on the other side, the three *extrinsic features activity*, *interest* and *time* influence the acceptance the most. When

we compare table 7.1 and table 7.2, we can notice that for a majority of *extrinsic features* the influence on the acceptance is rated higher than the influence on importance. These *extrinsic features* are: *time*, *location*, *activity*, *social situation*, *formality of an activity*, *user interests*, *user emotion* and *emotion intensity*. The *intrinsic features* which received a higher rate for their influence on acceptance are: *notification sentiment*, *battery level* and *internet connectivity*. *Notification sentiment* however, has the smallest difference between its rating for its influence on the perceived importance and acceptance.

Feature	AVG	SD
Other Party	5.156	1.716
Application	5.125	1.293
Category	5.031	1.425
Activity	4.906	1.487
Interests	4.875	1.293
Formality	4.844	1.66
Time	4.594	1.885
Social Situation	4.593	1.637
Mean./Emot.	4.5	1.561
Internet Connectivity	4.313	1.722
Location	4.188	1.648
Conc. Application	4.031	1.704
Phone Attendance	3.969	1.759
Emotion Intensity	3.906	1.548
Personality	3.875	1.691
Notif. Sentiment	3.813	1.509
Emotion	3.813	1.424
Battery Level	3.719	1.972

Table 7.1: Influence of Features on Perceived Importance

Feature	AVG	SD
Activity	5.125	1.495
Interests	5.125	1.409
Time	5.031	1.741
Formality	4.906	1.627
Social Situation	4.781	1.727
Other Party	4.75	2.077
Category	4.719	1.7
Application	4.656	1.613
Location	4.438	1.749
Internet Connectivity	4.406	1.835
Mean./Emot.	4.313	1.379
Emotion Intensity	4.281	1.718
Emotion	4.156	1.481
Battery Level	4.031	2.172
Notif. Sentiment	3.844	1.481
Phone Attendance	3.688	1.685
Conc. Application	3.656	1.632
Personality	3.563	1.952

Table 7.2: Influence of Features on Acceptance

It is unsurprising that *extrinsic features* are believed to have a stronger influence on the acceptance of a notification. Many *extrinsic features* describe a situation, e.g. where someone is doing something while feeling a certain way. The situation will change after a while. Even for the two other *intrinsic features*, we can notice that they are not of a static nature. The *battery level* and *internet connectivity* will change over time. However, *battery level* has a comparatively high standard deviation in both cases which should be considered.
On the other side, the majority of *intrinsic features* have a higher influence on the perceived importance according to the opinion of our participants. These *intrinsic features* include: *application*, *application category*, *other party*, *phone attendance* and *concurrent application*. The *extrinsic features* which received a higher rating for their influence on importance rather than acceptance are: *meaningfulness/emotionality of an activity* and *user personality*. The first three are comparably static as the *application*, *application category* and *other party* do not change for a notification. For the *extrinsic feature user personality* roughly the same applies. The personality of a person can make gradual changes during a life time but will not

change abruptly from one day to another [99]. The other features are interesting as they are not of a static nature. The *meaningfulness/emotionality of an activity* might could have a higher influence on the importance as the activity itself is of importance to the participant. So it could lower the perceived importance of a notification.
In the following we want to give an insight into the thoughts of our participants in regards to these features.

7.1.9.1 Influence of Time

Often time relates to a certain routine of a person (27 participants). Several participants stated that they prefer notifications arriving outside of their working or studying hours which are usually in the morning and in the afternoon. Notifications would pile up over the day and the huge amount of notifications they have to tend to in the evening or night tends to be annoying. Generally, the time indirectly influences the perceived importance or acceptance due to the activity it implies. Thus, it is unsurprising that in both, table 7.1 and table 7.2, our participants rated activity higher than time. P17 presented another nice aspect of time:

"[...] For applications, it would be very different dependent on the time. For example, there is an application which counts how much I walk. For example if I receive the notification: I walked half the amount of what I wanted, then I'd be sad in the night, because I cannot achieve the goal but if I receive it in the morning, I'd be happy because I can achieve my goal." (Participant P17)

This shows that the meaning of notifications can change dependent on the time they arrive. The interestingness of notifications can even change over time:

*"Generally, the mood might be different in the morning. For example, I might find a notification interesting in the morning but uninteresting in the evening... Maybe when I stand up in the morning and see [*Interesting News*] and it is the first time I see it, that I hear about it. Then I think of it as interesting. But I don't have time and have to get ready for work and I think to myself, I will read it in the evening. But during the course of the day, my co-workers tell me what has happened because they heard it in the news. This is uninteresting in the evening because I already heard about it."* (Participant P13)

In a way it relates to the other issue of receiving information several times or via several channels. These channels might be other devices where the information update does not get synchronized or friends and colleagues share information with us which then turn irrelevant as notifications. Synchronization with other devices should technically be possible. However, synchronization with all information channels, including people could be a huge intrusion on a user's privacy as it may include the necessity of the device to listen to a user's conversations.

7.1.9.2 Influence of Application

Often applications which belong to the category *Communication* were mentioned as being important. Some participants had specific applications of the category *Communication* which were more important in their opinion because more important people would only contact them via a certain application, e.g. superiors would contact one using emails rather than using an instant messaging service or a certain group of friends used a certain instant messenger (16 participants). However, notifications from certain applications can receive situational importance as in participant P17's example:

"Also, Google Maps can be important when I am outside and it will tell me where I need to go. [It is] only important when I am outside and don't exactly know where to go." (Participant P17)

This shows that in special cases the importance of a notification from the same application can vary.

7.1.9.3 Influence of Application Category

All 32 participants thought of Communication applications as important. The importance stems from the fact that users like to connect to other people, like how participant P24 puts it:

"Evernote and Outlook have a special position, then Communication has priority. [These] maybe aren't that important but these are notifications which I rejoice over." (Participant P24)

Notifications triggered by actual people are seen as more interesting and participants mostly agree on communication being the main purpose of smartphones.

7.1.9.4 Influence of Location

Similarly to time, the location also indirectly implies the activity. When someone is at their work place or in the library, they are likely working or studying. Additionally, certain place types imply certain social situations, as P12 mentioned when they visit a restaurant, they are usually in company and thus would not like to receive notifications. Same as for time, we notice in table 7.1 and table 7.2 that our participants rated the influence of the location lower than both activity and company in regards to the perceived importance and the acceptance of notifications. Our participants mentioned that they prefer to receive notifications when they are on transport (11 participants), at home (11 participants) or at restaurants/canteen (5 participants). For the latter one, they added they preferred it when they were alone. One participant mentioned, they would like to receive notifications when being in the waiting room of their doctor and two mentioned the rest room would be a suiting place. All these place types imply the activity type *Idle*, or at least the mind is in an idle state when one is eating alone. However, the actual activity type at home can be very diverse. The work place, however, was often mentioned as a place where they do not wish to receive notifications and this place type strongly implies the activity type *work*. Also, different places elicit different needs, as in participant P18's example:

"Different places have different needs, for example [on the] bus [I] may want to get some quick response, news, very short story without many words. But in bed [I] want to see some story [or] theory, longer ones, for example a person's history... On bus [I want] quick international... brief news, depending [on] where [I am], different content [is suitable]. On bus [I do] not [have] so much time to read [the] whole story." (Participant P18)

Or the relevance of certain notifications can change depending on the location as in participant P8's example:

*"Yes, when I am at home - that might not only be the place - but when I don't plan to leave the house anymore, then I don't care if it will start raining outside in 5 minutes. That would be different when I was sitting at [*Study Place*] and then receive the notification "In 25 minutes it will start to rain". Then I'd leave 10 minutes earlier."* (Participant P8)

Thus, there are a few cases where the place type directly influences the perceived importance or acceptance of a notification.

7.1.9.5 Influence of Notification Sentiment

The sentiment of a notification can be perceived differently by different people. Participant P20 for instance stated that their personal sense of positivity is to save or grow money. 9 participants believed the sentiment of a notification does not influence their perceived importance or acceptance of a notification. This shows in table 7.1 and table 7.2 where notification sentiment received a comparatively low rating. 9 participants believed that negative and positive notifications tend to be more important than neutral ones and 4 participants believed that negative notifications tend to be more important than others because they believed those notifications convey content which has a negative impact on them or close people. 10 participants noted they prefer to receive positive notifications over negative ones. However, depending on other features like interests even negative notifications can be important, like in participant P31's example:

"Yes, because uhm, one always likes to read something positive. Something negative would be dependent on the mood. For example currently with the federal election. It interests me, how it will continue. When there are problems... These notifications are rather negative, this has to do with my interests... I still look at [these notifications]." (Participant P31)

Also, an interesting consideration is the influx of bad news which people are nowadays exposed to like in participant P17's case.

*"I guess, it depends on my mood. If I'm sad, I prefer to see something happy but when I'm happy, I don't prefer to see something sad. I am not sure how exactly it relates, or how much they influence it. I don't know if positive or negative notifications are equally important. I have been in some channels in telegram [...]. For example in Instagram, I follow some news channel, sometimes they make me stressed because I received lots of negative notifications, for example a lot of bad news, mostly about [*Home Country*], so I blocked it. I prefer not to see it, when it's negative."* (Participant P17)

Negative media exposure can relate to anxiety [68] and acute stress [34]. Therefore, especially applications of the news & magazines category but also social media as mentioned by P17 should be cautious of sending user's too many negative news.

7.1.9.6 Influence of Interest

The interests are mostly supposed to relate to the importance and acceptance of a notification (25 participants). However, when a notification arrives while the user is engaged in an activity, the user will not tend to interesting notifications (5 participants). One participant described the interestingness of a notification as another scale which does not relate to its importance (P25). 3 participants believe that there is no relation because they would rather look for content which suits their interests by themselves. Furthermore, interests are topics one is interested in. So some participants specifically mentioned, they are interested in their relationship with other people. Participant P8 puts it nicely together:

"Yes, of course. Starting with separating my interests in... Close friends, average friends and acquaintances. The interests in my relationships to people... Or a news article [...] about the cucumber harvest in the Scottish highlands 2014... I probably...- So, maybe I would click it, because it sounds so absurd but in general when I read an article then it is an area which interests me." (Participant P8)

7.1.9.7 Influence of Emotion

The opinions about the influence of emotion are quite diverse. P30 believes that different emotions can change the acceptance of notifications. When feeling anger or interest, they believe they would only accept notifications which are centered about the topic that caused their emotions, while when feeling sadness or relief they would tend to notifications about a broader area. 7 participants believe that the emotion does not influence the perceived importance or the acceptance of a notification. Also, 7 participants believe that the intensity of an emotion does not have an influence either. 15 participants believe that when they are feeling a positive emotion, they will be more accepting. Only participant P17 believes to be more accepting when feeling negative:

"Yes, maybe it matters. When I'm in a good mood I usually don't check social media, but when I am not in a good mood, I would use my phone more, I will check more notifications. [...] When I am sad it is very important how intense [I feel the emotion]. When I am stressed,... I'd do some sports. when I am in [a] good mood, it is all the same. When I am sad, I don't do something useful. So I prefer to do "something", not because checking social media or phone is important to me, but it keeps me busy." (Participant P17)

6 participants noted, it might be helpful to receive positive notifications when feeling sad and 5 participants claimed, when they feel angry, they would rather not receive notifications. 2 participants mentioned they would still want to connect to people when they feel negative emotions and 14 participants claimed to be less accepting when feeling negative emotions. The way people handle different emotions

can vary greatly. Some would like to receive positive notifications when feeling negative emotions, but e.g. P19 believes they would feel angry if they received positive notifications in such a situation because it might indicate someone else was having a good time and not them. 4 participants also mentioned, they would not accept notification when they felt interest and when their interest revolved around something not related to their phone. 12 participants did believe that the intensity of an emotion has an influence, as in participant P24's example.

"Yes, absolutely. When you work on a project which does not work well then hardly any notification will make me think: this is totally important. I will first be tense and thus, everything else seems unimportant to me. I think, the difference between positive and negative is not that big. It rather depends on how strongly I feel the emotion." (Participant P24)

7.1.9.8 Influence of Activity

As we can see in table 7.2, the activity influences the acceptance of notifications rather strongly, according to the opinions of our participants. 25 participants do not want to tend to notifications while studying or working. Physical activities were also mentioned as activities when they do not wish to receive notifications like during sports (10 participants) or cooking (2 participants). 6 participants mentioned that they do not wish to receive notifications while engaging in communication. During idleness 15 participants thought, it is a good situation to receive notifications and 6 participants liked to receive notifications while resting. 4 participants liked to receive notifications while eating, 4 others do not. For some people eating is often an activity they engage in when they are in company. 4 participants thought positively of receiving notifications during media consumption, while 2 participants were against receiving notifications during media consumption. One participant mentioned, they do not wish to tend to notifications while engaging in tourism. Another participant does not wish to receive notifications during personal activities, like going to church. It also depends on how immersed one is into the activity (3 participants) and how interested one is in the activity (4 participants).
We can see that smartphone users have certain activity types when they are more willing to tend to notifications and certain other activity types when notifications tend to be unimportant compared to those activities. The activity types in which they prefer to receive notifications tend to be more passive such as rest and idle. Lastly, P1 mentioned that the relevance of the notification towards the ongoing activity matters in regards to how important the notification is.

7.1.9.9 Influence of Social Situation

Many participants would not want to tend to notifications when they are in company (30 participants). 5 participants, however, stated if there was no conversation going on, they would check their phones and one participant stated that if their company checked their phone, they would do it as well. Another participant stated they would not tend to notifications while in the presence of a new person, they are not familiar with yet. On the other hand, if the other person was an old friend, they would allow themselves to occasionally tend to notifications (P28). Then one participant thought, they might check their notifications more in company because

it meant, they were not working in that moment. Only one person believed there was no difference in whether they were in company or not. Most of the participants did not want to tend to notifications in the presence of other people due to respect and politeness for the other person. The thought raised by participant P28 is an interesting one. A more fine-grained specification of what kind of company one is in might lead to different perceptions. P20, as well, mentioned they will care less about their company if they do not like them.

7.1.9.10 Influence of Formality

The formality of an activity is linked to the company in a certain way. 30 participants said, in more formal situations they would ignore their phones and would not want to receive notifications. Several stated that in the company of friends which is more casual, they would rather check their phones than in a formal situation such as a meeting or business dinner. They explained when in company of friends the situation is "more permissive" (P7). Therefore, like in the previous section, it would be interesting to look more precisely at the company a user is in. This shows in table 7.1 and table 7.2 where formality ranked higher than company in both. 2 participants out of the 30 participants stated they would still be open for very urgent notifications, e.g. a call from their parents. One participant stated that the *notification mode* mattered. They do not want their phone to ring during a formal situation. If the *notification mode* was *silent*, it would be acceptable. One participant stated it had no influence. Interestingly, participant P24 mentioned that their state of mind changed dependent on the formality and activity of a situation.

"I also feel differently when I am in a meeting or when I am hiking. For example, when I am in a meeting and have a short break, then I would not be in the mood to read about extreme sports." (Participant P24)

7.1.9.11 Influence of Meaningfulness/Emotionality

When it comes to meaningfulness or emotionality of an activity a certain ambivalence existed as described by participant P23:

"It depends actually if I'd say how meaningful it is... It is our normal routine that we go studying. We say it is meaningful in the long-run... Although it is important, we don't view it like that; but things like meetings, those kind of things are important. So if something is important but a routine... I tend to say it is not important..." (Participant P23)

Certain activities which might be meaningful are so ingrained in our daily lives that we do not assess them as very meaningful anymore. 2 participants also explicitly mentioned they did not face any such situations and several other participants had similar uncertainties as P23. Overall 28 participants believed, they would not tend to notifications in very meaningful or emotional situations. One participant would be open for urgent notifications, another one believed it was more dependent on the activity itself and 2 participants were unsure. Overly meaningful or emotional activities might be rare and thus harder to assess.

7.1.9.12 Influence of Other Party

As depicted in table 7.1, the other party of a notification is believed to be the most influential factor on the perceived importance. However, the way the other party influences the perceived importance depends on the smartphone user. 19 participants believed notifications from closer people were more important. Generally, they ranked them above work-related contacts. 4 participants believed the family to be the most important and one participant would rank superiors, immediate family and close friends equally high. 3 participants assessed their superiors as more important than close people. One of them being participant P23 who reasoned as follows:

"[...] For my family, if I am busy, I don't have to respond. Because they will understand. It depends on the person. For some people if you delay, they will feel offended; closer people will be more understanding if [there is] no response."
(Participant P23)

6 participants believed that the actual content is more important than the other party of the notification at times. Often notifications from close people do not contain any significant content but only a personal value due to our closeness to these people. Participant P12 describes this objectively as follows.

"From the System most [are] completely uninteresting. From applications, too. [...] Average friends are also not so important because mostly it's just small talk. And very close friends... To be honest, everything in regards to chatting is unimportant, except you want to make an appointment, because otherwise it's just small talk."
(Participant P12)

Additionally, 2 participants noted that in general notifications from actual people are more important and 4 participants thought of notifications triggered by individuals as more important than by groups. Generally, the other party is a very important feature to our participants but the expression of its importance varies highly dependent on the participant.

7.1.9.13 Influence of Phone Attendance

When the phone is not in use, the user has to go through the hassle of taking out their phone and unlock the screen to tend to a notification. Thus, several participants believe, they will tend more to their notifications when they are already using their phones (24 participants). 2 participants also stated they do not register the *notification light* anymore which was their only *notification mode*. 1 participant even stated they ignore *vibration*. 3 participants mentioned the issue of notifications accumulating while they do not use their phones, which will cause them to delete more notifications. Lastly, 5 participants believe phone attendance has no influence on their perception of notifications. Overall, the influence is speculated to be rather low and only serves as a tendency. In some cases notifications are only useful when the user is using their phone, e.g. participant P6 mentioned, they only care about the existence of internet availability when they are using their phone.

7.1.9.14 Influence of Concurrent Applications

When the user is actively using their phone, they will usually continue using it till they reach a breakpoint which allows them to switch the context before tending to an incoming notification. Applications on the phone which could cause such an immersion would be games (15 participants), text messengers (11 participants), video players (7 participants), readers (4 participants), video messengers (1 participant), finance applications (1 participant), maps (1 participant) and Google (1 participant). Participants would like to first finish using the application before tending to an incoming notification. In certain cases, e.g. during games, it would cause annoyance when a notification arrives. 7 participants believed the concurrent application had no influence. However, if a very important notification arrived while being immersed in an application smartphone users would still disrupt their current engagement as how participant P1 puts it:

"Not necessarily. No matter if I am chatting on WhatsApp or am on YouTube. If my supervisor writes me, I will tend to it immediately." (Participant P1)

7.1.9.15 Influence of Battery Level

The battery level only exerts an influence when it comes to a critical low (22 participants). When the battery level is very low, participants will tend to less notifications, delete or ignore more and accept less. However, the threshold varied for our participants between 5% and 20% according to their opinion. 10 participants believed the battery level had no influence. They were either practically always able to charge their battery or their battery simply worked very efficiently so they did not have to charge it often.

7.1.9.16 Influence of Internet Connectivity

When it comes to the internet connectivity, participants believe that they received less important or interesting notifications when there was no internet access (13 participants). For instance, notifications from communication applications would mostly not arrive. Only 2 participants believed that the notifications they receive without internet connection were important, as they would still receive calls, SMS and calendar notifications which are in general important. 14 participants believed their acceptance would be lower as certain notifications might require internet. Especially if they had to use mobile data, they would be reluctant to accept a notification. 7 participants believed there was no difference because they usually always had internet access. Participant P29 mentioned an interesting aspect in regards to countries.

*"A few years ago, when I was still in [*East Asian Country*], I had unlimited internet. There I received notifications all the time, no matter if I was shopping, in the metro, on the way... There I always looked at everything immediately. Here in Germany, my habits have changed."* (Participant P29)

Participant P29 described, they deal with mobile data a lot more economical now. The costs for mobile flats are quite expensive in Germany compared to certain other countries. Also, certain countries offer more free internet at public spaces. So, while the concerns in regards to mobile data usage exists in different countries as well, the frequency one faces this problem might be different depending on the country.

7.1.9.17 Influence of Personality

The answers to the question about whether the personality could influence a person's perception of notifications were rather speculative and hypothetical. As people have their own personalities, it is difficult to completely empathize with another personality. Overall, 25 participants believed neuroticism/emotional stability influences the perceived importance and acceptance and 20 participants believed extraversion has an influence. Some participants theorized that extroverted people were more active and thus tended less to their phones, others believed extroverted people might value quantity over quality while introverted care more about the actual content of the notification. On the other side, since they believed that introverted people do not engage as much with people physically face-to-face, they will put more emphasis on notifications. The opinions were greatly diverse. As an example, participant P2 spoke from their own experience:

"I am rather introverted and sometimes I just let notifications be when I think, now I can't answer them as properly as I could. I think, it depends on whether one is extroverted or introverted because I have to think a lot about it,... to sort my thoughts in order to give a good answer. Extroverted people might answer faster."

(Participant P2)

7.1.10 What Makes a Notification Important?

For many participants the last question requesting them to describe what makes a notification important for them posed to be a difficult one. The answers are varied and several participants listed several features. The most frequently mentioned attribute was the personal relevance of the notification (15 participants). However, this personal relevance could include many different notifications, starting from notifications triggered by close people due to the personal connection to work-related notifications over to news about politics which might affect them. The second most frequently mentioned attribute was the other party (13 participants). This also shows in table 7.1 where other party received the highest rating for its influence on the importance of a notification. 4 participants specifically mentioned notifications by close people and 4 participants mentioned the importance of notifications from their immediate family. Participant P17 talks about the personal significance of notifications from their family:

"But I guess, the most important factor is the sender, even more than the content, because my family will worry if I don't answer them, so I prefer to answer them very quickly, I frequently answer my mom quickly even if it's just... "Hello, whats up?"."

(Participant P17)

The family situation can vary greatly between people. As previously mentioned in subsection 7.1.9.12 P23's parents are tolerant of delayed replies. Then, 8 participants stated that the content itself determines the importance of a notification. 6 participants believed the notifications had to relate to their interests to be important and 5 participants thought of urgent notifications as important. 4 participants classified work or study related notifications as important and 3 participants believed

notifications about future activities were important. So far the mentioned attributes were mostly intrinsic. It shows that the properties of the notification itself mostly determine its importance for the participants. However, extrinsic features, too, can play a role:

"I think the value of notifications should be compared to what you are doing. So getting [your] daily routine is important, because [your] daily routine indicates what [you] are doing and the importance of what [you] are doing." (Participant P18)

According to participant P18, the importance of a notification should be compared to the current ongoing activity. If the activity itself is important, the importance of a notification can be reduced. 4 participants thought of the current external situation as an important factor. On the other side 4 participants believed the external situation to be of secondary importance or not relevant at all.
Since the purpose of the phone is to communicate, 3 participants believed communication related notifications to be the most important. Then, 3 participants attached importance to notifications they were expecting, e.g. an answer to a request. On the other side, 2 participants thought of notifications which relayed requests to them as important. 4 participants thought of notifications which were of emotional significance as important. This shows that emotions are a feature which should be considered for the derivation of importance. 1 participant thought of system notifications as important as their phone had to function in order to be able to handle other important notifications. Another participant believed that notifications had to relay new information which the user did not know about beforehand and another one thought of interest-based notifications as unimportant but nice-to-have. Lastly, 1 participant (P8) mentioned the public relevance:

*"This is complicated. So, [there are] different things which can make a notification important. Once, when it is something that needs my immediate attention. That would make it important. Generally, consequences for people who are not me. For example, when a notification arrives: "[*President from a Certain Country*] has done some horrible things again",... like, for me this would be irrelevant because I am here in Germany and [*self-description*]. I won't have have any negative consequences but it is a relevant topic for so many people, even if it does not affect me. When it is something what I otherwise would have missed, for example from my calendar- Though, this would relate to the first category. When it is a notification from a person whom I like to converse with, even if the notification is trivial but it has emotional significance [...]. There are people with whom I could converse about the weather and it would be more important than with... someone else... [...]. But it depends on where I am, the emotional situation... It depends on so many factors! It is difficult to put this in clearly quantifiable factors."* (Participant P8)

Participant P8's description of *What makes a notification important?* describes well how fickle this question is. Several features intertwine to make a notification important. We can notice three kinds of importances: *subjective/personal importance*, *objective importance* and *public importance*.
Overall, the qualitative data allows us to draw several hypotheses in regards to

notifications which we list in our appendix A.3. We believe that all mentioned features can influence the perceived importance of notifications. Furthermore, we add a few more fine-grained hypotheses. For example, that the change of emotion, the valence of an emotion, etc. influence the perceived importance of a notification. In the following, we want to analyse whether our collected data allows us to confirm some of these hypotheses.

7.2 Quantitative Data

7.2.1 Descriptive Analysis

Overall, 3772 questionnaires were answered. 813 of these questionnaires were about dedicated notifications by our application and 2959 were about notifications the user would have received during their everyday life. The number of answered questionnaires varies dependent on the participant (see table 7.1). Amongst the 2959 notifications 53.3% were rated as not important. Also, 51.1% of these 2959 notifications were rated as not interesting. This shows that a large portion of notifications is not useful to the users.
Amongst all collected notifications 42 845 notifications were accepted and 80 469 notifications were deleted. Our participants handled roughly 127 notifications per day. It has to be considered that not every participant had a study period of exactly 28 days due to scheduling of the final meeting. Thus, the average of notifications per day is not exactly the number of all handled notifications divided by 28 days and 32 participants.

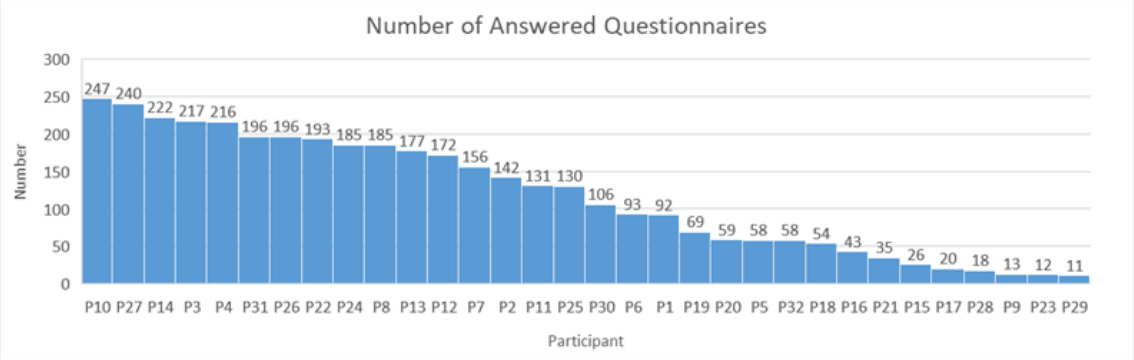


Figure 7.1: Number of answered questionnaires per participant

7.2.2 Statistical Tests

We have used different tests depending on the data. If possible, we used the Pearson's χ^2 Test of Independence [24] for categorical features which allows to draw conclusions about the association between features and the perceived importance. However, our data did not always meet the requirement of less than 20% of the expected cases being higher than 5 counts or all expected cases being higher than 1 count [36]. Therefore, we cannot use Pearson's χ^2 Test of Independence in these cases. This is due to high levels in our groups and scarcity of data, e.g. for certain applications certain importance rankings never occur in our data set. In this case we use the Kruskal-Wallis Test [55] instead. Kruskall-Wallis is a rather robust non-parametric test which is usually used when the assumptions of normal distribution

and homogeneity are violated. When these assumptions are violated, analysis of variance (ANOVA) [24] cannot be used, especially when sample sizes vary [24]. We tested our data using Shapiro-Wilk Test [100] and Levene's Test [60] for normality and homogeneity respectively. Our data violates these assumptions in some cases, so we will limit us to using Pearson's χ^2 Test of Independence and Kruskal-Wallis Test for categorical features. When using Pearson's χ^2 Test of Independence, we also check Cramer's V [10] to measure the effect size. When using the Kruskal-Wallis Test, we follow up the results with a pairwise comparison using Dunn's post-hoc test [16]. We use the following formula proposed by Rosenthal [90] to measure the effect size of groups pairwise; with z being the z-score and N being the sample size:

$$r = \frac{z}{\sqrt{N}} \tag{7.1}$$

$$z = \frac{X - \bar{X}}{s} \tag{7.2}$$

X represents the smaller mean of the two groups which are compared. We subtract the mean of all scores $\bar{X}$ and divide by s. s represents the standard deviation. It has to be considered that the sample size varies depending on the group. For instance, if we use the Kruskal-Wallis Test to look into the difference of two groups of the feature *application category*, then the sample size of the category *Social* (137) and *Productivity* (174) are not the same. In the case of Kruskal-Wallis, the sample size N refers to the sum of the sample sizes of the two groups for which the effect size is to be calculated. For the following pairwise comparison, we check the adjusted p-Values which were adjusted using the Bonferroni correction [15] for multiple tests. Checking the exact p-Value would lead to having a higher than 5% probability of the occurrence of Type I errors. Type I error means the null hypothesis is actually correct but is rejected. We report the combinations which were statistically significant or display at least a small effect size.
For numerical values, we use Spearman's correlation coefficient [24], also called Spearman's ρ. Spearman's ρ is rather robust against violations of assumptions as well and the correlation coefficient can function as an effect size itself. We also use bootstrapping for additional robustness. Bias corrected and accelerated bootstrap 95% confidence intervals will be reported in square brackets. For all mentioned effect sizes the classification works as follows:

$$|z| >= 0.100 \quad \& \quad |z| < 0.300 : \text{small effect size (*)} \tag{7.3}$$

$$|z| >= 0.300 \quad \& \quad |z| < 0.500 : \text{medium effect size (**)} \tag{7.4}$$

$$|z| >= 0.500 : \text{large effect size (***)} \tag{7.5}$$

The p-Values are classified as follows:

$$p < 0.05 \quad \& \quad p >= 0.0.1 : \text{statistically significant (*)} \tag{7.6}$$

$$p < 0.01 \quad \& \quad p >= 0.001 : \text{statistically very significant (**)} \tag{7.7}$$

$$p < 0.001 : \text{statistically highly significant (***)} \tag{7.8}$$

We will mark the effect size and significance using the asterisk (*) as depicted above. Our tests resulted in the three tables: table 7.3 with the results of Pearson's χ^2 Tests of Independence, table 7.4 with the results of the Kruskal-Wallis Tests and table 7.5 presenting the results of Spearman's ρ Tests. In the following we will evaluate the different features.

Feature	Pearson's χ^2	p-Value	Cramer's V	df
Social Situation	9.033	0.172	0.049	6
Phone Attendance	32.555	0.000***	0.093	6
Internet Connectivity	33.831	0.000***	0.095	6
Sentiment	21.507	0.001**	0.160*	6
Emotion Control	173.193	0.000***	0.152*	12
Emotion Valence	184.046	0.000***	0.156*	12
Reaction Emotion Control	353.441	0.000***	0.216*	12
Reaction Emotion Valence	325.370	0.000***	0.208*	12
Change of Emotion	173.298	0.000***	0.214*	6

Table 7.3: Relation between several features and importance using Pearson's χ^2 Test of Independence

Feature	Kruskal-Wallis Test Statistics H	p-Value	df
Arrival Time	23.557	0.015*	11
Removal Time	24.340	0.011*	11
Category	227.379	0.000***	31
Activity	88.373	0.000***	11
Arrival Place Type	115.720	0.000***	42
Removal Place Type	103.921	0.000***	42
Other Party	247.494	0.000***	12
Emotion	228.492	0.000***	20
Reaction Emotion	477.091	0.000***	20
Change of Emotion Control	154.425	0.000***	6
Change of Emotion Valence	85.306	0.000***	6
Conc. Category (Arrival)	61.382	0.000***	21
Conc. Category (Removal)	106.029	0.000***	25

Table 7.4: Association between several features and importance using Kruskal-Wallis Test

Feature	Spearman's ρ	p-Value	Confidence Interval
Interest	0.587***	0.000***	[0.560,0.611]
Formality	0.251*	0.000***	[0.220,0.283]
Mean./Emot.	0.336**	0.000***	[0.302, 0.368]
Emotion Intensity	0.273*	0.000***	[0.241,0.304]
Reaction Emotion Intensity	0.326**	0.000***	[0.295,0.357]
Battery Level (Arrival)	-0.013	0.430	[-0.047,0.023]
Battery Level (Removal)	-0.031	0.066	[-0.066,0.005]
Conc. Notif. (Arrival)	0.072	0.000***	[0.041,0.101]
Conc. Notif. (Removal)	0.072	0.000***	[0.040,0.100]
Application Usage Frequency	0.045	0.008**	[0.011,0.082]
Extraversion	0.000	0.987	[-0.036,0.035]
Neuroticism	-0.069	0.000***	[-0.100,-0.033]
Lie	-0.058	0.001**	[-0.091,-0.026]

Table 7.5: Correlation between several features and importance using Spearman's ρ

7.2.2.1 Evaluation on Time

As listed in our appendix A.3, we hypothesize that time influences the perceived importance of a notification (H1). Table 7.6 shows the distribution of notifications over two hour time slots during the day for all handled notifications in data. We can see that during 2 AM and 6 AM users did not tend much to notifications. This is unsurprising as these are typical sleeping hours. On the other side, people are generally awake from 8 AM till midnight which we can infer from percentages greater than 10% during these time slots. We can see that around lunch time from noon till 2 PM a slightly higher percentage of notifications are handled compared to the time slot before and after. During late afternoon till evening we can also recognize a slightly lifted percentage of handled notifications which might indicate the time after work. The time slots midnight till 2 AM and 6 AM till 10 AM are not as high as those previously mentioned but not as low as those during very probable sleeping hours. It is likely that due to different sleeping schedules of the participants these time slots fall in between the other percentages. Thus, it seems, we have rather few participants who stand up early in the morning between 6 AM and 8 AM and more participants who probably stay awake till past midnight and wake up between 8 AM and 10 AM.
According to table 7.4 we can see that the importance of a notification is significantly affected by the time of its arrival. A selection of the calculated pairwise comparisons can be seen in table 7.7. We can see significant differences between certain time slots. The same applies to the time a notification is removed (see table 7.4 and table 7.8). However, not many combinations had a significant effect overall and the effect sizes are small. Thus, time only had a small effect on importance according to our data.
According to hypothesis H8.1, the time itself might be a rather indirect influence of the importance of a notification. As 27 participants (see subsection 7.1.9.1) mentioned, time relates to a routine. Time can indicate where a person is at a certain time and what kind of activity, they are engaged in. It might often be a rather indirect factor in regards to whether a notification will be perceived as

Time Slot	Number of Notifications	Percentage
0 midnight - 2 AM	8912	7.2%
2 AM - 4 AM	2258	1.8%
4 AM - 6 AM	1666	1.4%
6 AM - 8 AM	4112	3.3%
8 AM - 10 AM	11060	9.0%
10 AM - 12 noon	12863	10.4%
12 noon - 2 PM	13912	11.3%
2 PM - 4 PM	12974	10.5%
4 PM - 6 PM	14606	11.8%
6 PM - 8 PM	14604	11.8%
8 PM - 10 PM	13371	10.8%
10 PM - 0 midnight	12976	10.5%

Table 7.6: The number of handled notifications per time slot

important or not. Cases where notifications are important due to time alone do exist, according to the example of participant P17 (see subsection 7.1.9.1) where a notification can be more useful in the morning than in the evening. However, these cases might be rare. Further research on which types of notifications have a direct relation between their importance and time would be interesting. This could help to filter cases like P17's example. Another feature which we omitted was the urgency of notifications. Urgency is an issue of time as well. However, the handling of their respective notifications should be different. Urgent notifications should not be deferred to a later time. If we were able to determine which notifications are most likely more important or useful during certain times, we could defer those notifications to these respective time slots.

First Time Slot	Second Time Slot	Adjusted p-Value	Effect Size r
6 PM - 8 PM	6 AM - 8 AM	0.003**	-0.148*
8 PM - 10 PM	6 AM - 8 AM	0.003**	-0.149*
8 AM - 10 AM	6 AM - 8 AM	0.011*	0.158*
10 AM - 12 noon	6 AM - 8 AM	0.032*	0.144*

Table 7.7: Pairwise comparison of arrival time slots

First Time Slot	Second Time Slot	Adjusted p-Value	Effect Size r
6PM - 8PM	6AM - 8AM	0.005**	-0.148*
8PM - 10PM	6AM - 8AM	0.017*	-0.133*
10AM - 12 noon	6AM - 8AM	0.002**	0.176*

Table 7.8: Pairwise comparison of removal time slots

7.2.2.2 Evaluation on Application & Category

Our second and third hypotheses H2 and H3 (see A.3) state that the application and its respective category influence the perceived importance of a notification. Figure

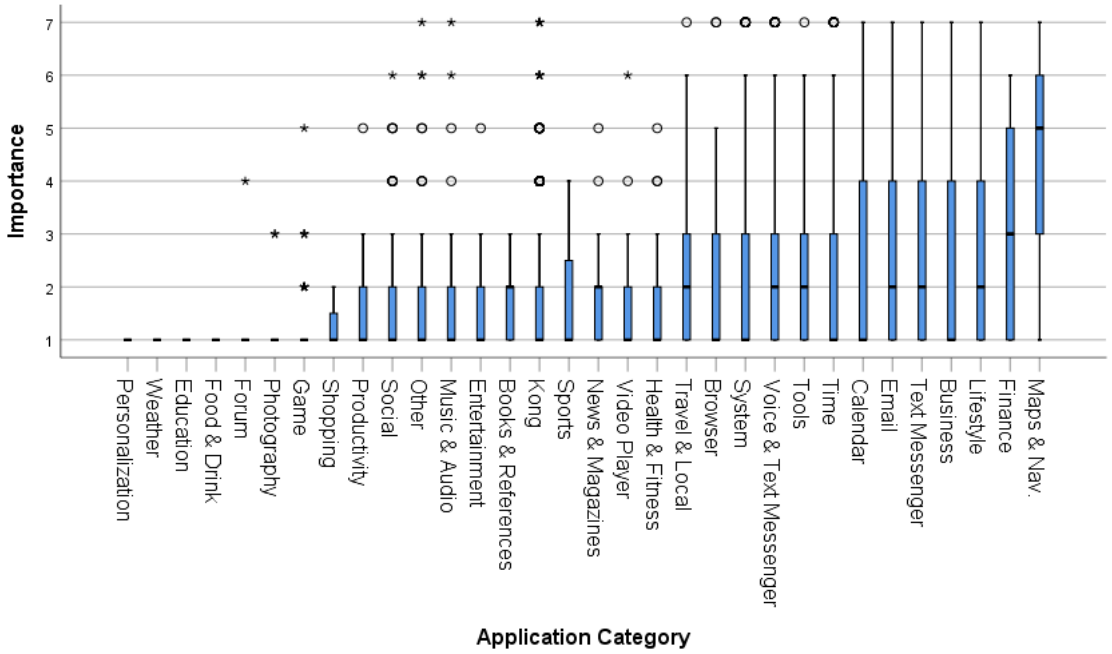


Figure 7.2: Importance of notifications from different application categories sorted by their means

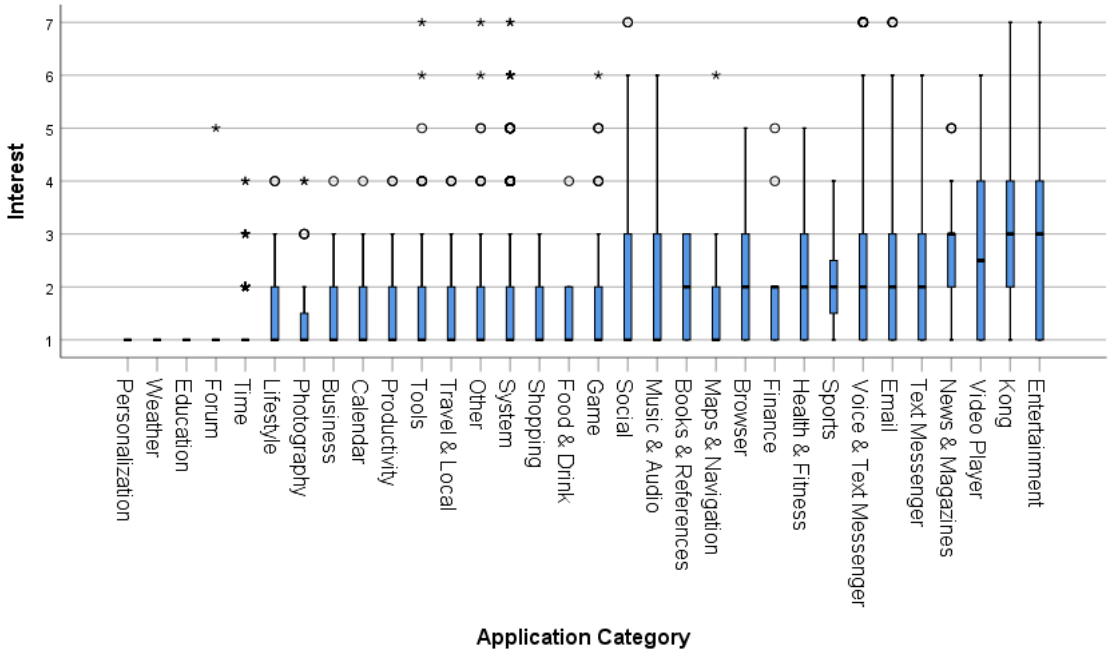


Figure 7.3: Interestingness of notifications from different application categories sorted by their means

7.2 can give us an idea that certain categories tend to send more important notifications than others. Surprisingly, applications which belong to the broader category Communication did not outrank the other categories, despite several participants mentioning Communication as very important. This could be due to a discrepancy in objective and subjective importance. Objectively, a lot of notifications by friends and family are of rather trivial nature, as stated by Participant P12 (see subsection 7.1.9.12). Further studies with a focus on these two types of importances could give a better insight into this issue. This shows in *Voice & Text Messengers* ranking in the upper middle field (see figure 7.2), as this category includes several messenger applications which are used for chatting with other people. *Emails* and *Text Messengers*, like SMS, tend to be more important. They might represent more formal channels while *Voice & Text Messengers* might be more casual channels.
Our own application is categorized under its name under which it was distributed on the Google Play Store, Kong. Interestingly, it ranked higher than the category *Social* - as a reminder: Social contains social media applications, like Facebook [1], Snapchat [2], etc. These applications might tend to send trivial articles and information about other users. Many Facebook users accept friends requests from people they have heard of or even random strangers [14]. It is questionable whether notifications about these people, e.g. their birthday, would be interesting. Figure 7.3 shows how our participants ranked the notifications of different categories in regards to how interesting the notifications were. The purpose of applications of the *Entertainment* category is to entertain the user. So them being most interesting is understandable. However, we can see that the median which is depicted by the thicker black line in the boxplot is at the rating 3. The mean of the interest ratings for *Entertainment* lies at 3.08 with a standard deviation of 1.801. Our scale ranged from 1 *not interesting* to 7 *very interesting*. Thus, notifications still have potential to be truly interesting to the user. Our application, Kong, ranked second when sorted by the mean. As mentioned in subsection 5.2.3, we deliberately sent both, interesting and uninteresting notifications. This might indicate that many application categories send a lot of uninteresting notifications to the user.
According to the results of our Kruskal-Wallis Tests (see table 7.4), the application category significantly influences the importance of a notification. Selected results of the pairwise comparisons in table A.4 and table A.5 in our appendix show that several combinations had significant differences in their importance ratings. The effect sizes were also often large and tend to be higher than the effect sizes of the significantly different combinations for time (see table 7.7 and table 7.8). This aligns with the estimation of our participants that the application category has a bigger influence on their perceived importance of a notification (see table 7.1).
Since the category of the application sending the notification significantly influences the importance of a notification, some of the respective applications of these categories themselves influence the importance as well. We conducted the Kruskal-Wallis Test on notifications triggered by applications of the category Communication. We chose Communication due to the emphasis on this category by our participants during the interviews. This sample set includes *Text Messenger*, *Voice & Text Messenger*, *Forum* and *Email* and resulted in a sample size of 1212 samples. We excluded the category *Browser* which is classified under Communication in the

[1] https://play.google.com/store/apps/details?id=com.facebook.katana
[2] https://play.google.com/store/apps/details?id=com.snapchat.android

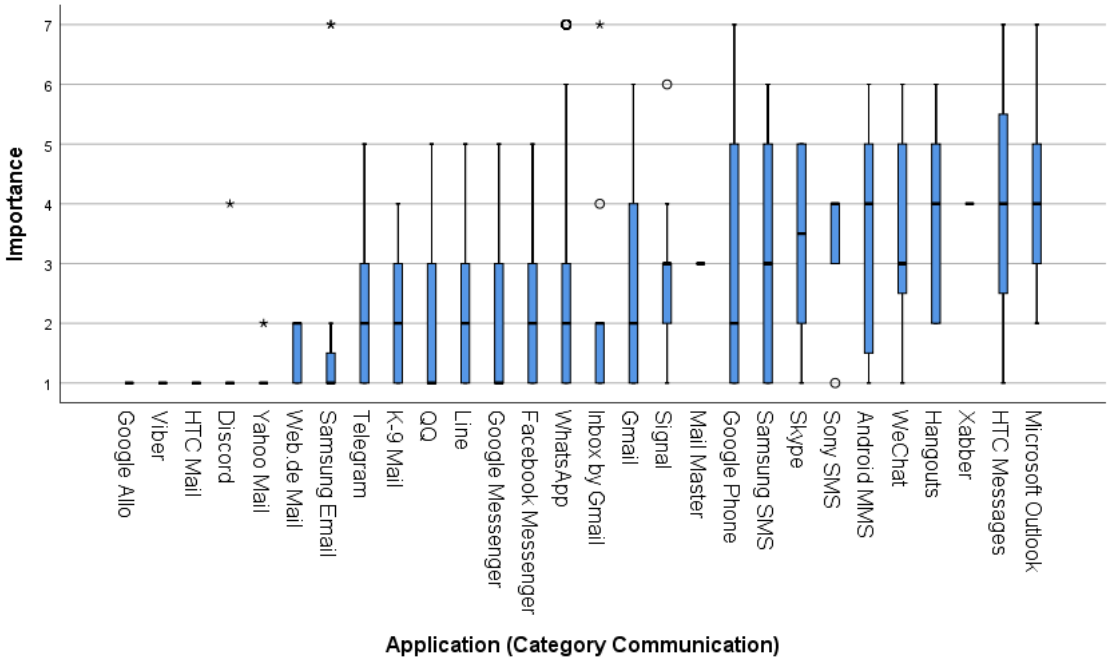


Figure 7.4: Importance of notifications by applications of the category Communication sorted by their means

Google Play Store as well. The specific application significantly influenced the importance of the notification, $H(27) = 161.082$, $p = 0.000$***. Pairwise comparisons showed that 24 combinations had a significant difference (see table A.6). We can see that even applications of the same category had significant differences, e.g. Gmail and Microsoft Outlook which had a medium effect size. The effect sizes are often large. It shows that applications do have a huge influence on the importance of the notification as assumed by our participants (see table 7.1). In figure 7.4 we can see the different applications of the category Communication, excluding browsers. It should be mentioned, that our participants from Hong Kong were mostly recruited at HKUST. HKUST uses Microsoft Office for their mail administration. Thus, Microsoft Office tends to be a very formal channel, where students and staff receive mails in regards to academics which might result in the importance of notifications by Microsoft Outlook (mean = 4.14, SD = 1.432) in our data.
Considering that we chose notifications from applications which frequently sent notifications during the previous time slot for a questionnaire as described in subsection 6.2.7 and that a significant relation between the sender application and the importance of a notification exists, this might allude to a higher than 53.3% (see subsection 7.2.1) amount of unimportant notifications.

7.2.2.3 Evaluation on Location

The location where a user receives a notification should affect the importance of a notification as well, as we hypothesize in A.3, H4. We can see in table 7.4 that the location at which the notification arrives and the location at which the notification is removed significantly influences the importance of a notification. Pairwise comparisons show only a few combinations were significantly different (see table 7.9 and 7.10). According to our data, participants tended to receive more important notifi-

cations when being at the university or in the library. Participant P25 delivered a possible explanation when they were asked about the influence of applications:

"Absolutely, notifications from messengers are personally more important to me. Especially when someone sends me something. They know that I am working. Then they write me when it is something important." (Participant P25)

As previously mentioned in subsection 7.2.2.1, many people have a routine during the day which allows us to infer rough outlines of at what time a person is doing what kind of activity. It also allows guesses about where a person is. During working hours it is likely that someone is at their work or study place. During the evening and night people tend to be at their homes. Thus, some people might tend to receive certain notifications only during work or studies when they actually do not want to be interrupted. However, these notifications might be important as friends are often informed whether someone is working at certain times, hence, they only send important notifications in order to not disturb their friend out of consideration. Furthermore, work-related messages usually also arrive during work hours. Similarly to time, the location can infer what kind of activity the user is engaged in. So, it might not always be a direct influence which might explain the rather small effect sizes. In certain cases, the location should however be a direct influence which should be connected to the knowledge about the place as in P17's example in subsection 7.1.9.2 of the situational importance of Google Maps, when they are lost.

First Location	Second Location	Adjusted p-Value	Effect Size r
Other	University	0.000***	-0.373**
Other	Library	0.001**	0.521***
Home	University	0.000***	-0.108*
Home	Library	0.022*	-0.094
Transit	University	0.024*	-0.207*
Transit	Library	0.032*	0.245*
Study-/Workplace	University	0.019*	0.134*
Study/Workplace	Library	0.049*	0.136*

Table 7.9: Pairwise comparison of arrival place types

First Location	Second Location	Adjusted p-Value	Effect Size r
Other	University	0.000***	-0.358**
Other	Library	0.001**	0.521***
Other	Clothing Store	0.007**	0.492**
Home	University	0.015*	-0.092
Home	Library	0.045*	-0.089

Table 7.10: Pairwise comparison of removal place types

7.2.2.4 Evaluation on User Interest

According to our hypothesis H6.1 (A.3), we believe the situational interest of a user relates to their perceived importance of a notification. Due to data privacy, we were unable to collect the notification content of all notifications, hence, the relation between the individual interest and perceived importance was not assessable for us. Instead, we let our participants rate their interest towards the notification. The situational interest is influenced by the individual interests [32, 96]. In this subsection we mainly refer to the situational interest if not stated otherwise.
In figure 7.5 we see that a higher interest towards a notification likely relates to a higher importance of the same notification. In our boxplot we see that the mean of the importance ratings is accompanied by a higher interest rating. However, we also notice outliers which occur with lower interest ratings. It is probable that people receive notifications which might not be interesting but still important, e.g. a reminder for a meeting one actually does not really want to attend but has to. The other way round is also possible. A notification could be very interesting for a user but not necessarily important. This might lead back to the discrepancy in subjective/personal importance and objective importance.
Figure 7.6 shows the distribution of accepted and deleted notifications across the different ratings. More than 50% of the deletions occurred when the notification was uninteresting. Percentage-wise a higher amount amongst the accepted notifications occurred for ratings above 1 compared to deleted notifications. Participants would rather accept a notification if it aroused their interest more.
Looking at our results in table 7.5, we notice that interest is highly significantly related to importance. Additionally, it is the only feature amongst the numerical features which reaches a large effect size. Thus, we can conclude that the situational interest relates to the perceived importance. It also has the largest effect amongst the numerical features. Due to the interrelation between situational and individual interest [32, 92, 96] this suits the assessment of our participants of individual interests as a high influential feature.
As mentioned in subsection 7.2.2.2, we notice in figure 7.3 that our application ranked second highest in regards to its interestingness according to the mean of all ratings. In table 7.11 we see that amongst the user-owned notifications 51.1% of the notifications were not interesting. We should keep in mind that our application triggered questionnaires for notifications by applications which frequently occurred during the past time slot. This can lead to the hypothesis H2.1 (A.3) that the amount of uninteresting notifications might be even higher than 51.1% if we believe the interestingness of a notification correlates to the sending application.
A Kruskal-Wallis Test indeed reveals an association between the interest and the category, $H(31) = 673.063$, $p = 0.000^{***}$. We followed the test up with pairwise comparisons which resulted in several significant combinations which also show several medium and large effect sizes (see tables A.7 and A.8). Thus, the underlying applications of each category should partially influence the interestingness as well.
Our application was able to achieve a slightly more balanced distribution of interesting and uninteresting notifications compared to categories of user-installed applications. However, they still tended to be only slightly interesting. Despite individually choosing notifications for the specific users via our *Wizard of Oz* study, only few notifications achieved to be very interesting. This shows that deciding on notifications which grasp the user's individual interests tends to be difficult. Thus,

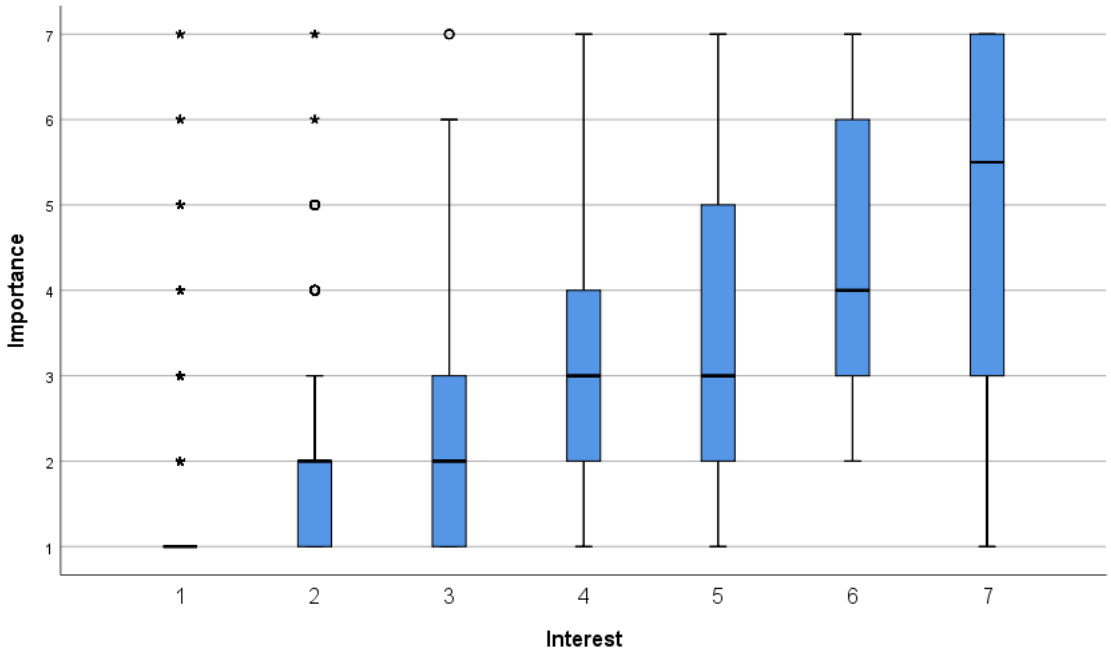


Figure 7.5: Importance of notifications dependent on how interesting they are, sorted by their means

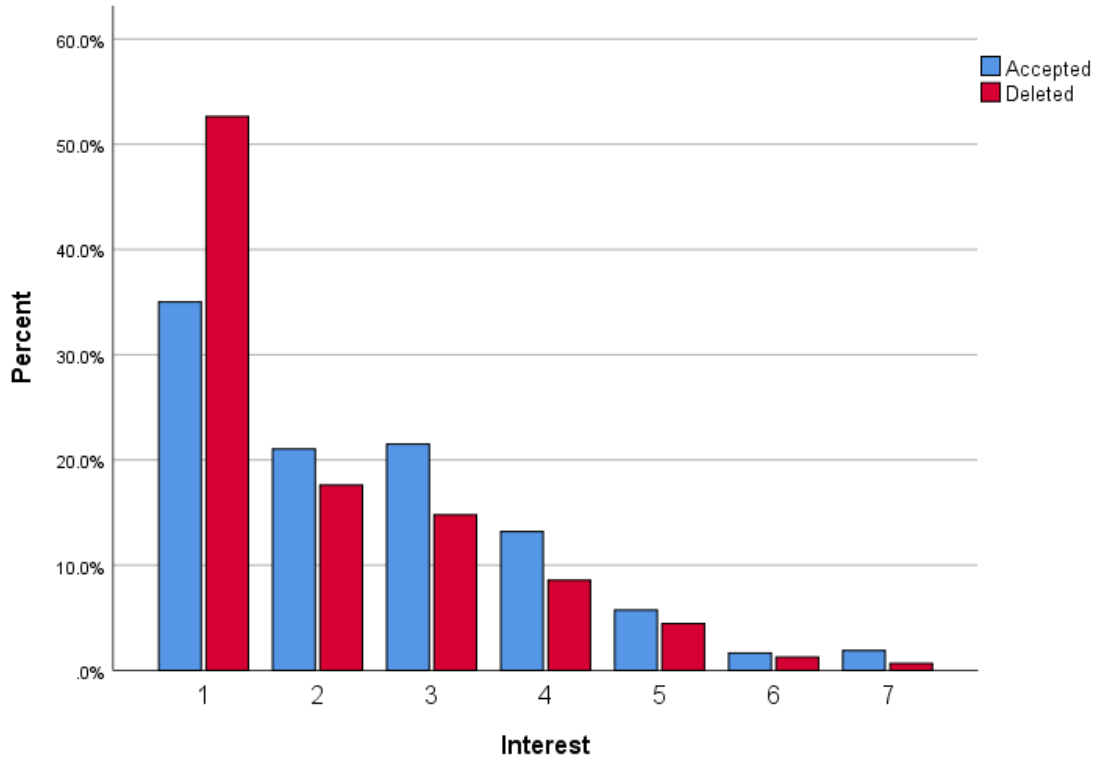


Figure 7.6: Distribution of accepted and deleted notifications dependent on how interesting notifications are

it might be even more difficult for applications to automatically assess the user's individual interests and trigger notifications which truly suit them.

Interest Rating	Applications except Kong	Percentage	Kong	Percentage
1	1511	51.1%	188	23.1%
2	572	19.3%	168	20.7%
3	482	16.3%	195	24%
4	227	7.7%	146	17.9%
5	110	3.7%	69	8.5%
6	36	1.2%	22	2.7%
7	21	0.7%	25	3.1%
	2959	100%	813	100%

Table 7.11: Distribution of notifications in regards to their interestingness

7.2.2.5 Evaluation on Notification Sentiment and User Emotion

In table 7.12 we can see the absolute distribution of emotions at arrival time. We can notice that the emotion *Apathy* occurs fairly frequently (43.1%). One possible explanation is the limited amount of emotions from which the participants can choose. 5 participants mentioned, they fell back on *Apathy* as default if they could not pinpoint their exact emotion using the other emotion types. When discussing this issue of choosing the right emotion, several participants mentioned tiredness and exhaustion as an emotion. While these are not emotions per se, this leads us to an additional hypothesis H18 that the *energy level* of a user influences their perceived importance of a notification as described by participant P8:

"When I come back home tired and feeble after a long working day, I will be less inclined to read an article." (Participant P8)

Apathy aside, our participants reported emotions of a positive valence and high control level most frequently (27.9%). Low control and positive emotions were the second most frequent (21%), followed by low control and negative emotions (4.9%). Lastly, the high control and negative emotions occurred the least (3%). When we look at table 7.13 which shows the occurrences of reaction emotions, we notice the distribution changes compared to emotions at arrival time. The frequency of *Apathy* decreases to 33.6%. High control and positive emotions rise to 34.7%. We notice a major increase in the number of occurrences of the emotion *Interest*. The low control and positive emotions decrease to 18.2%. We can notice a major decrease in *Contentment*. Low control and negative emotions rose to 7.1% and high control and positive emotions rose to 6.4%. It shows that notifications influence the emotions of the user. Overall, we had 1479 (39.2%) changes of emotion. The most frequent change was from *Apathy* to *Interest* which occurred 231 times. Since notifications are usually just small pieces of information, they mostly should not affect our emotions as much. In our data, the majority of notifications did not cause a change of emotion. Thus, it seems likely that if a notification does have an emotional impact it is because of the notification being important.

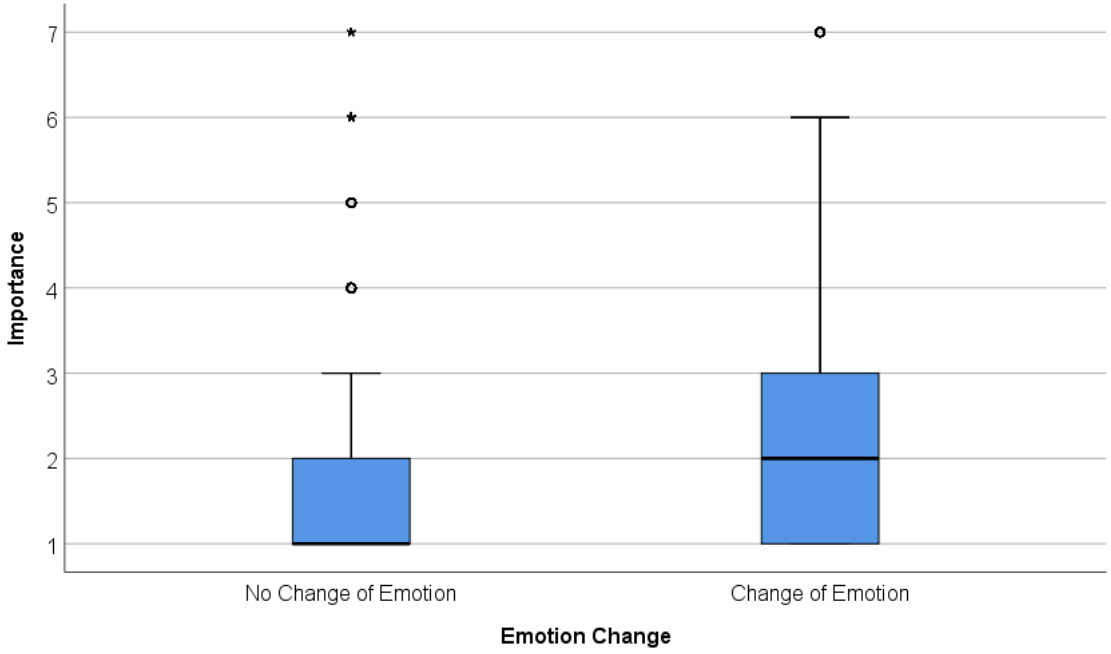


Figure 7.7: Importance of notifications dependent on whether they triggered a change of emotion

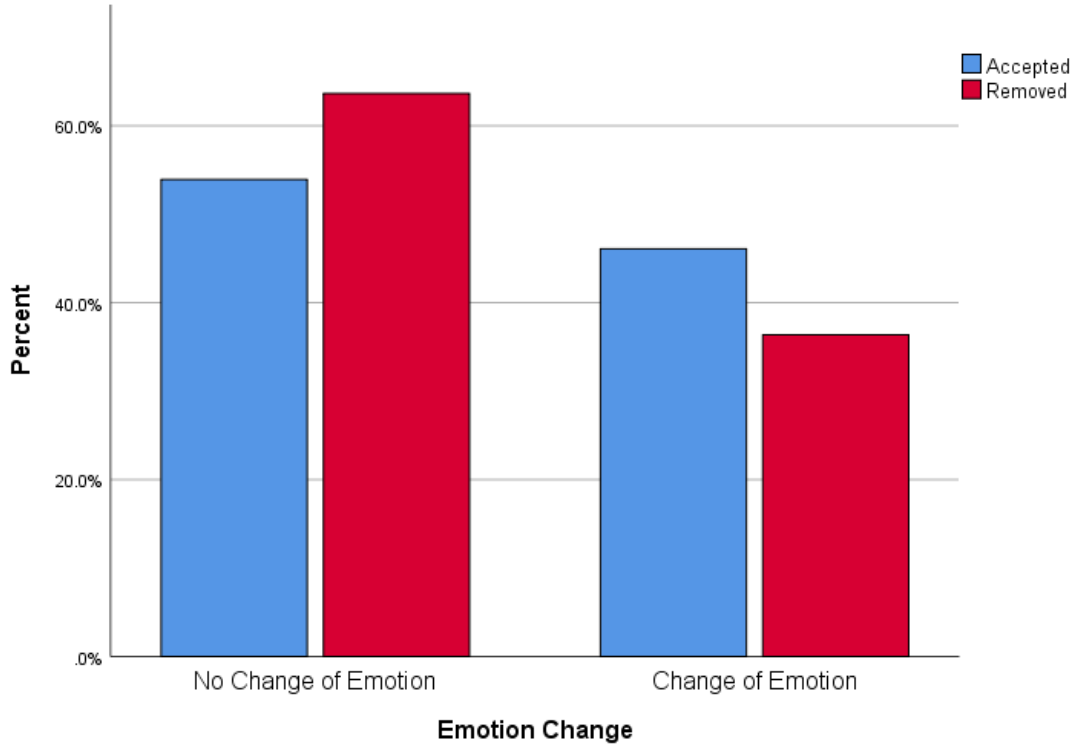


Figure 7.8: Distribution of accepted and deleted notifications dependent on whether the emotion had changed

Emotion	Frequency
Apathy	1626
Contentment	621
Joy	322
Interest	312
Amusement	209
Pleasure	184
Relief	97
Disappointment	75
Sadness	58
Anger	43
Fear	34
Pride	27
Compassion	27
Love	26
Regret	25
Admiration	21
Disgust	16
Shame	15
Contempt	15
Guilt	12
Hate	7

Table 7.12: Number of occurrences of emotions

Reaction Emotion	Frequency
Apathy	1267
Interest	662
Contentment	466
Joy	276
Amusement	226
Pleasure	123
Anger	122
Relief	111
Disappointment	109
Sadness	90
Love	52
Disgust	38
Admiration	33
Fear	32
Hate	30
Regret	28
Compassion	26
Pride	23
Guilt	22
Shame	18
Contempt	18

Table 7.13: Number of occurrences of reaction emotions

We hypothesize that a change of emotion can indicate whether a notification is important (H7.3, A.3). Figure 7.7 shows that notifications which caused a change of emotion tended to be rated more important than notifications which did not change the emotion. According to our results from our χ^2 Tests of Independence, a highly significant association between the change of emotion and the importance of a notification exists. However, the effect size is small in our data. Figure 7.8 shows that percentage-wise slightly more notifications were accepted when notifications caused a change of emotion compared to deleted notifications. We also analysed a more precise specification of the change of emotion. In table 7.4 we see that both the change of emotion control and change of emotion valence are highly significantly related to the importance of a notification in our data. The Kruskal-Wallis Tests were followed up by pairwise comparisons which can be seen in the appendix, table A.12 for change in control and table A.13 for changes in valence. The nomenclature of the changes are X2Y with X indicating the previous condition and Y indicating the reactive condition. For example if a participant stated to feel *Sadness* shortly before the notification arrived and then felt *Joy*, the respective categorization would be a Low2High type of change of control and a Neg2Pos type of change of valence. Pairwise comparisons with changes to a low control emotion tended to have a slightly higher effect size than other changes. However, the effect sizes were rather small overall. Similarly, the effect sizes for comparisons between valence changes tended to be small as well. For more detailed results the change in emotion intensity should be taken into account as well. Maybe a change from, e.g.

Regret to *Interest* cannot indicate an important notifications effectively enough. If the intensity of the reaction emotion changes significantly from the emotion intensity at arrival time, it might indicate an even stronger impact of the notification (H7.4, A.3). However, our dataset is too small to offer enough insights into this combined aspect of change of emotion and change of intensity. When we regard the change of intensity alone, we were able to find a significant relation between the change of intensity and importance using Spearman's ρ. However, we could not notice any effect in our data, $\rho = 0.086$, $p = 0.000^{***}$, [0.048,0.121]. We also looked at the relation between change of intensity and interest towards a notification. The results show a significant relation as well and a small effect size, $\rho = 0.152^{*}$, $p = 0.000^{***}$, [0.118,0.188]. Furthermore, we also analysed the relationship of change of emotions and situational interest. A general change of emotion shows a highly significant association and a medium effect size, $\chi^2(6) = 398.655$, $p = 0.000^{***}$, $V = 0.325^{**}$. This leads us back to the previous assumption that interesting notifications are not necessarily important. However, they, too, relate to a change of emotion. Additionally this guides us to the discrepancy of subjective/personal and objective importance again. Very interesting notifications could be personally important but might not be important objectively, e.g. results of a sports match.
In general we were able to see highly significant relations between emotion intensity and importance which resulted in a small effect size (see table 7.5). Furthermore, the highly significant relation between the intensity of the reaction emotion resulted in a medium effect size. This might indicate that our hypothesis H7.4 - that the change of emotion and emotion intensity could be indicative of the importance of a notification - is possible.
Figure 7.9 depicts importance ratings dependent on the emotion at arrival of the notification. Figure 7.10 depicts the same for the reaction emotions. Interestingly, low control emotions had a comparably high mean. When we look at our results of the χ^2 Test of Independence, we do see that both the emotion control and the reaction emotion control are highly significantly associated to the importance. Both showed a small effect size in our data. High control emotions tend to be emotions which give a person the feeling of being able to make changes to the situation if they wish so [95]. This might indicate that the user is in a state where they feel more active to engage in an activity while in a low control state they might be rather passive and thus can give more attention to notifications and therefore they seem more important.

Our data indeed showed a highly significant association between the activity and the emotion control, $\chi^2(22) = 298.034$, $p = 0.000^{***}$, $V = 0.199^{*}$. For instance, when participants were playing games, they were feeling high control emotions in 56% of the cases while low control emotions occurred only 15.4% of the cases. Another instance would be while exercising: in 70% of the cases, the participants were feeling a high control emotion. In 20% of the cases, they felt a low control emotion. These activity categories indicate that the user is preoccupied with an ongoing activity. In the respective situation the activity might tend to be more important and in reverse causes a notification to seem less important. The other way round, when the participants were resting, they felt low control emotions in 30.9% of the cases while high control emotions occurred in 19.7% of the cases. Here, we might also note that sleep falls under the category resting, where people often likely chose *Apathy* as emotion. During the activities *Transport* and *Idle* the occurrences of low control emotions were higher than high control emotions as well. These activity

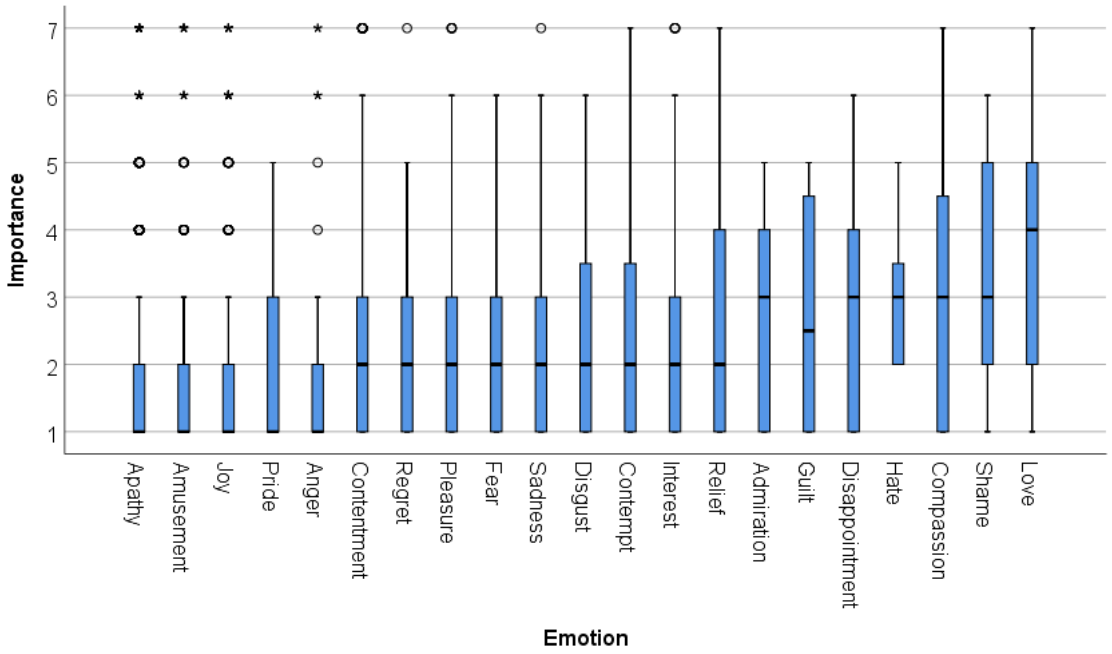


Figure 7.9: Importance of notifications dependent on the emotion, sorted by their means

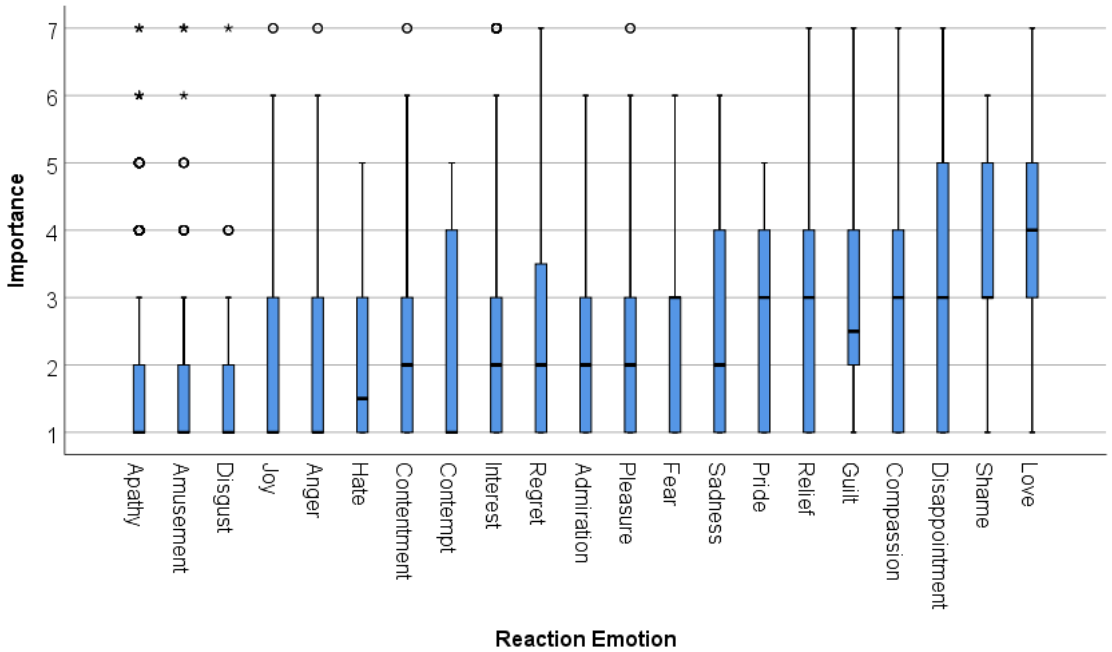


Figure 7.10: Importance of notifications dependent on the reaction emotion

types indicate a rather easy-going activity where the user might not be actively doing anything.
We believe that the emotion and reaction emotion stand in relation to the importance of a notification (H7 and H7.1, A.3). Our Kruskal-Wallis Tests (see table 7.4) confirm this hypothesis as both show that the emotion and the reaction emotion, respectively, influence the perceived importance of a notification. Furthermore, we can see in table A.9 that several pairwise combinations have significant differences. However, the effect sizes tend to be small. When we compare this result to our pairwise comparisons of reaction emotions in table A.10 and table A.11, we notice that a lot more combinations show a significant difference and that more combinations show medium and large effect on the importance. This aligns with our hypothesis H7.1 that a relation between the reaction emotion and the importance of a notification exists.

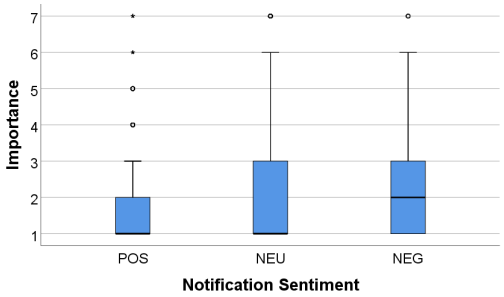


Figure 7.11: Importance of notifications dependent on their sentiment sorted by means

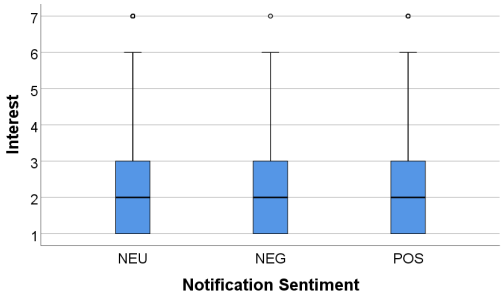


Figure 7.12: Interestingness of notifications dependent on their sentiment sorted by means

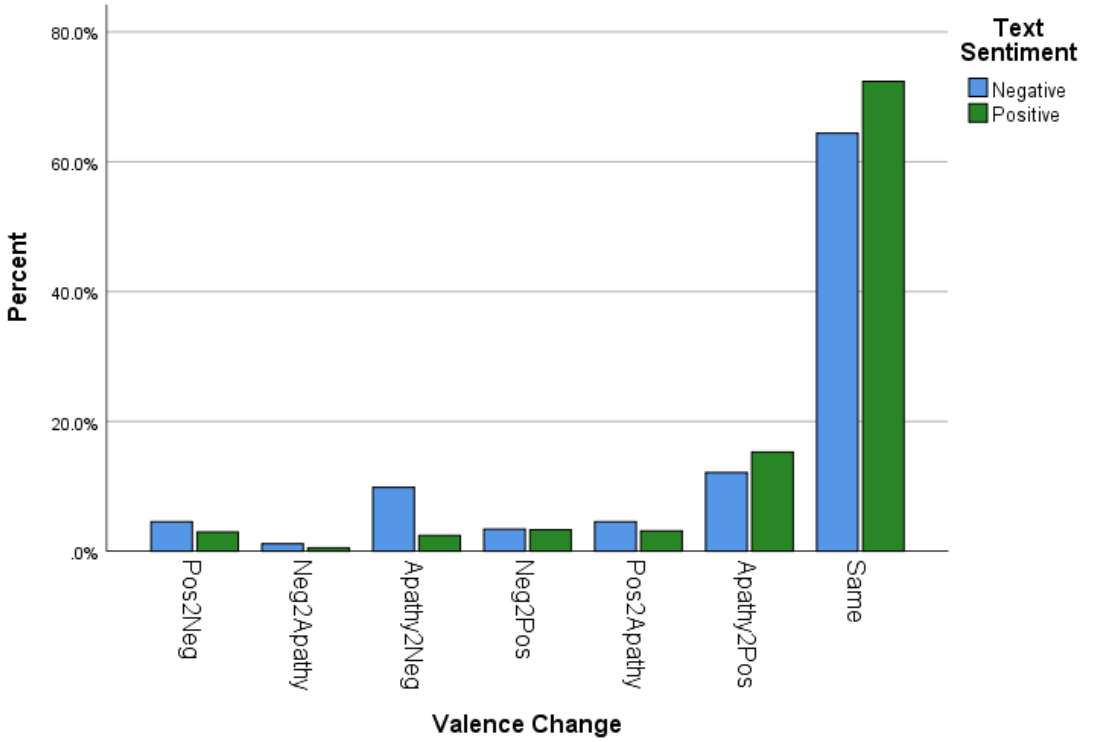


Figure 7.13: Distribution notification sentiments dependent on the cause change of valence

We believe that a relationship between the emotion and the sentiment of a notification exists (H5.1, A.3). Figure 7.13 shows that negative notifications occurred slightly more often in combination with a change towards a negative emotion than positive notifications. On the other side, positive notifications occurred slightly more often when the emotion changed from *Apathy* towards a positive emotion. The differences are rather small, but allow us to see a tendency. A χ^2 Test of Independence limited to the data where the notification sentiment was classified as either positive and negative resulted in a highly significant association between the change of valence and the sentiment with a small effect, $\chi^2(6) = 27.162$, $p = 0.000$*** and V = 0.180*. Furthermore, we hypothesize that the sentiment of a notification relates to the importance of a notification (H5, A.3). Figure 7.11 shows the importance rating dependent on the sentiment of the notification. We want to remind that our *SentimentCalculator* as described in subsection 6.2.4 cannot determine the sentiment of a fairly big amount of notifications which appear in the diagram as *neutral*. Thus, the respective plot for these notifications is not representative as it potentially contains several *positive* and *negative* notifications. The classification of *positive* and *negative* notifications were fairly accurate however. We can notice that negative notifications tended to be rated slightly more important. A possible explanation could be that humans give more attention to negative information which is rooted in evolutionary theories that we focus on negative information due to their potential indication of danger [5]. When positive and negative events occur with the same intensity, we tend to give more importance to the negative event. The next step would be to assess the intensity of positivity and negativity of a notification to draw further conclusions. Overall, this should not lead to the impression that positive notifications should be omitted. Even if they might appear slightly less important, we can see in figure 7.12 that they might still be interesting to the user and serve some personal satisfaction. A significant relationship between the sentiment of notifications and the user's interest towards a notification can be found using a χ^2 Test of Independence, $\chi^2(6) = 14.996$, $p = 0.020$* and V = 0.134*. The effect size is smaller compared to the analysis on the relationship between the importance of a notification and the notification sentiment. Thus, positive notifications which are not perceived as important might still be interesting to the user.

7.2.2.6 Evaluation on Activity, Social Situation, Formality and Meaningfulness/Emotionality

As we previously mentioned in our evaluation on time and location, the activity the user is engaged in should influence their perceived importance of a notification more than the previously mentioned features (H8.1, A.3). While the Kruskal-Wallis Tests (see 7.4) do show that the importance is significantly affected by the activity, the follow up with pairwise comparisons in table 7.14 does not show high effect sizes. One explanation for this dilemma is our leniency in regards to the ESM study. As mentioned in subsection 5.2.4, we allowed the participants to answer questionnaires later on. Thus, the results might not reflect how the participant felt about the notification during the particular moment while they were engaged in a certain activity.

The same issue can be transferred to the feature *social situation* as our participants likely did not answer our questionnaires while they were still in company. Thus, no significance and no effect can be measured in our data in regards to the relationship between the *social situation* and the perceived importance of notifications. Additionally, we had a look at the acceptance of notifications dependent on the activity

First Activity	Second Activity	Adjusted p-Value	Effect Size r
Media Consumption	Rest	0.000***	-0.183*
Media Consumption	Transport	0.001**	-0.162*
Media Consumption	Communication	0.017*	0.133*
Other	Rest	0.036*	-0.122*

Table 7.14: Pairwise comparison of activity types

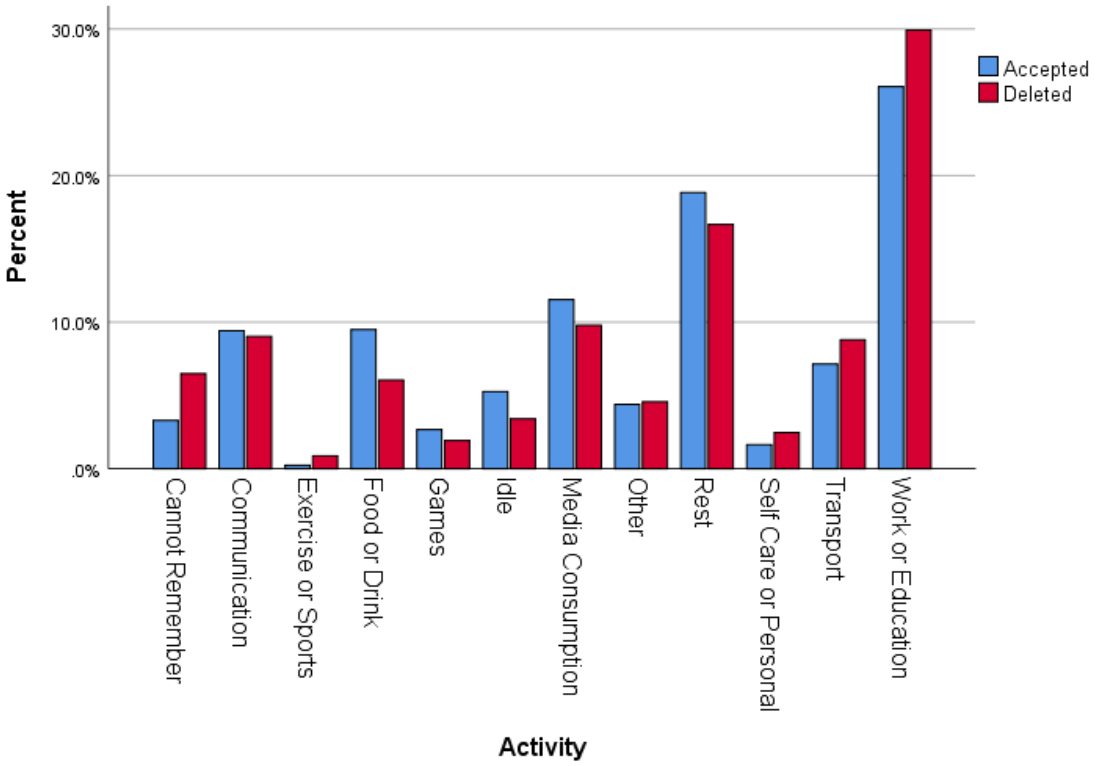


Figure 7.14: Distribution of accepted and deleted notifications dependent on the activity sorted by their means

which is depicted in figure 7.14. Generally most notifications occurred during work. If we look at the distribution, we notice that amongst the accepted notifications a smaller percentage of the accepted notifications were accepted during work compared to deleted notifications. The same applies to exercise. On the other hand, during more passive activities like media consumption, rest and idle, the percentage of accepted notifications was higher compared to the percentage of deleted notifications. Surprisingly, the percentage of accepted notifications during communication was higher as well. A possible explanation could be due to communication including channels which are not face-to-face, e.g. chats, where it is socially acceptable to tend to notifications while waiting for the response as mentioned by participant P8 in one of the weekly interviews. We conducted a Pearson's χ^2 Test of Independence which resulted in a significant relationship between acceptance and activity and a small effect size, $\chi^2(11) = 36.459$, $p = 0.000^{***}$ and $V = 0.155^{*}$. A more detailed specification of the category *work & education* might help to give a better insight since most notifications occurred during work. Participant P23, an engineer, mentioned that their work encompasses physical work in the laboratory for their

experiments and evaluation of the results in the office at their computer. During laboratory experiments they were less receptive towards notifications because the experiment afforded high concentration and precision. The experiment was considerably more important than notifications. On the other hand during office work, they admitted to be more acceptant of notifications.
Both, the formality and meaningfulness/emotionality of an activity were highly significantly related to the importance of a notification (see table 7.5) which confirms our hypotheses H10 and H11 (see A.3). Formality showed to have a small effect size while meaningfulness and emotionality showed to have a medium effect size in our data. This also shows that further description of the activity is helpful as meaningfulness and emotionality of an activity showed a bigger effect than the activity itself. This could potentially be explained following P24's thoughts that the formality of a situation changes their state of mind (see subsection 7.1.9.10). Respectively, if a participant exits a meaningful or emotional situation, the situation might have a lasting impact on them. For instance, if someone attends a very joyful party, they might still feel lingering joy after leaving as the positive emotions will not immediately vanish as they leave. With respect to previous studies on activity with more precise focus on aspects of the activity, e.g. engagement [71, 79], breakpoints [33] and physical activity [71, 78], we should look more precisely at the underlying distinctive features of an activity to help determine the importance of a notification.

7.2.2.7 Evaluation on Other Party

The other party of a notification is assumed to be the biggest influential feature by our participants (see table 7.1). While our tests show a highly significant influence (see table 7.4), the following pairwise comparisons (table A.14) are not as strongly indicative of the importance as the results of the inspection of the application category and applications (table A.4, A.5 and A.6). It does show a significant relation towards importance, however, and should be regarded as an indicative feature of importance. In figure 7.15 we can see that notifications which were sent by a superior as the other party tended to be the most important ones. In our qualitative evaluation (see subsection 7.1.9.12), we noticed that a majority of participants put emphasis on close people like friends and family. This might indicate the difference in subjective/personal importance and objective importance. Participant P12 mentioned that the actual importance amounts to the content only, and 5 more participants agreed with them (subsection 7.1.9.12). Casual talks, however, are important in their own respect as they serve to fulfill interpersonal needs and help construct an individuals personal social reality [18]. They are woven into our everyday lives similarly to participant P23's description of how studies lose their meaningfulness due to daily routines (see subsection 7.1.9.11). These notifications from close people about trivial matters might become so natural that they blend into our regular lives so we do not notice their importance. An interesting follow up study would be to request study participants to blacklist communication applications for a week and then whitelist those again. Then one could compare their assessment of importance of notifications dependent on the other party. The assessment could be compared to a second group which did not blacklist communication applications.

When we look at figure 7.16, we notice that percentage-wise a higher percentage of accepted notifications happen to occur when notifications were sent from people. On the other hand, when the other party was the *System* the notification

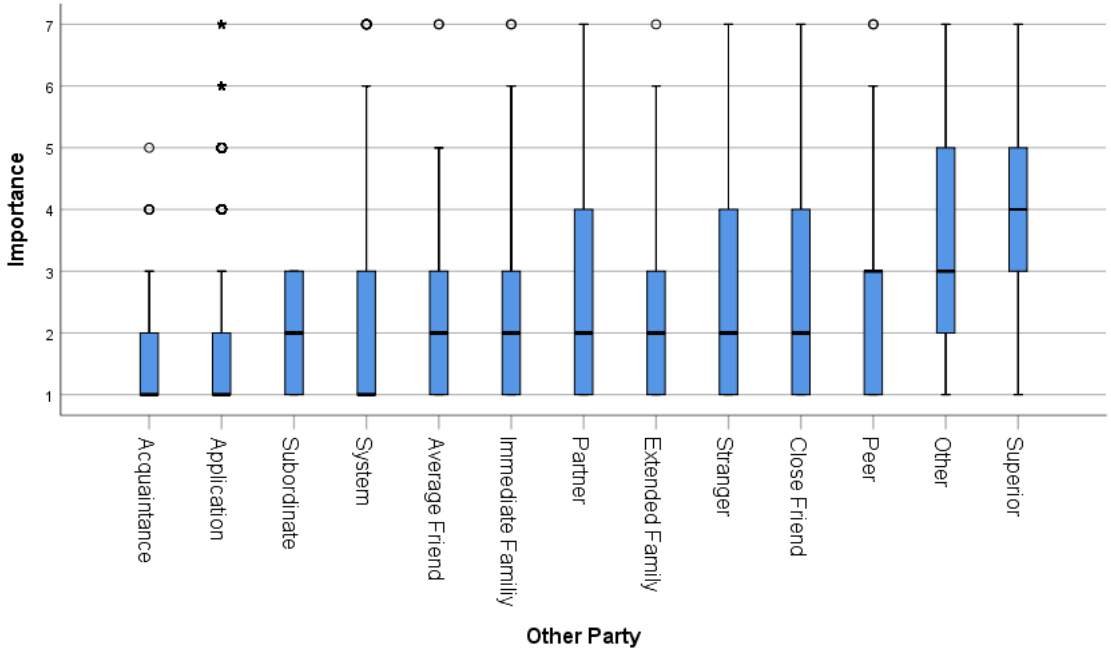


Figure 7.15: Importance of notifications dependent on the other party

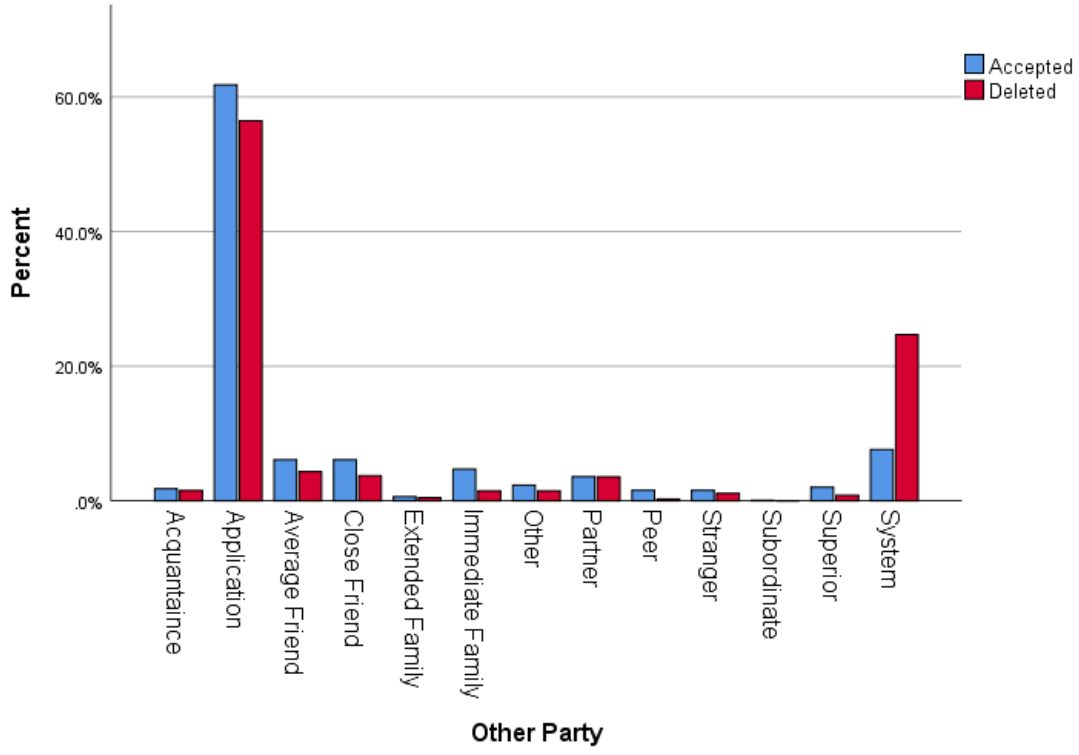


Figure 7.16: Distribution of accepted and deleted notifications dependent on the other party

was percentage-wise often deleted. It aligns with statements of our participants that notifications from people are in general more important (subsection 7.1.9.12) and shows their disdain towards notifications by the system (subsection 7.1.2). For the notifications by applications we cannot be sure whether they have been about people which could be an interesting feature as well.

7.2.2.8 Evaluation on Phone Attendance, Concurrent Notifications, Concurrent Application, Battery Level & Internet Connectivity

As assumed by our participants the features *phone attendance*, *battery level* and *internet connectivity* had no effect in regards to importance in our data (see table 7.3 and table 7.5). We also looked at the number of concurrent notifications at arrival and removal time to see whether it had a relation to the perceived importance but were not able to find one in our data. Similar to the activity the reason why we could not detect a relation in our data might be that we could not assess the situational importance. For instance, when a user was low on battery they likely did not answer our questionnaires and later on when their phone is charged the perception of a notification could be very different. This issue of assessing the importance during the situation is actually difficult to counteract in a study. It might require an additional device for a study participant so they would not have to drain the battery of their own device when their battery is already low on energy. Such micro effects, like low battery, internet connectivity, concurrent notifications, etc. are difficult to assess but would be interesting to look into as they could provide further insight on importance. After all, several participants mentioned that they tend to delete notification when they received too many at once (see 7.1.3). Thus, these effects of those features which have a minor influence or no influence according to our data, are worth to look into.

First Category	Second Category	Adjusted p-Value	Effect Size r
Browser	System	0.000***	0.221*
Browser	Tools	0.000***	0.322**

Table 7.15: Pairwise comparison of concurrent application categories at arrival time

First Category	Second Category	Adjusted p-Value	Effect Size r
Browser	Other	0.000***	-0.276*
Browser	Tools	0.000***	-0.414**
Browser	System	0.000***	-0.222*
Browser	Weather	0.015*	-0.281*

Table 7.16: Pairwise comparison of concurrent application categories at removal time

In regards to the concurrent applications we grouped the concurrent applications into their respective categories. As we can see in table 7.4, we found a significant effect in our data. The follow-up of the Kruskal-Wallis Test resulted in very few pairwise combinations which showed significant effects (see table 7.15 and 7.16).

When we look at the comparisons, it is interesting that notifications seemed to be significantly less important when the user was using their browser. This relates to our hypothesis that the concurrent application relates to the perceived importance. When the user engages in using their phone they might not wish to be disturbed by incoming notifications and thus, they seem less important compared to the ongoing activity.

7.2.2.9 Evaluation on User Personality

Different from Mehrotra et al.'s work [71] the personality traits *Neuroticism* and *Extraversion* did not show an effect in regards to the perceived importance (see table 7.5). Mehrotra et al. noticed that these personality traits influenced the seen time, which is the time till a notification is noticed, and decision time, the time from seen time till removal of the notification. Therefore, we assumed that these personality traits might have an influence on the perceived importance as well. Mehrotra et al. did mention that their sample size might have been small, but so is ours. Thus, it is possible that further studies will be able to reveal relations between personality traits and the perceived importance of a notification. In retrospect, it might be suitable to take a step back and examine all personality traits in regards to importance. Additionally, we could speculate a relationship between the personality traits *Openness* and *Agreeableness* and *user interest* as we have noticed that some notifications are interesting but not important and might serve some personal openness to different matters. For instance P8 mentioned the public relevance of certain issues they would like to be informed about even if it does not affect them. This is opposed to other participants who would like to receive notifications which are relevant to them personally. This could hypothetically be influenced by how open and how compassionate a user is towards issues of other people. Also, Mehrotra et al. [71] noticed that *Conscientiousness* significantly affected the perceived disturbance by notifications. Since we noticed that our participants used different methods to take care of notifications and show different frequency of annoyance by notifications, it could be interesting to see whether *Conscientiousness* might affect the perceived importance of notifications as well.

7.2.3 Limitations

Aside from the previously mentioned technical issues, our work faces a few limitations in regards to the study itself. The most severe limitation might be our leniency in regards to the ESM study which allows the user to answer questionnaires at a later point in time. Thus, when answering the questions when they are in a different context and do not assess the importance of a notification relative to the situation they were in when the notification arrived.
Another issue is the homogeneity of our sample. We only cover a certain age range and a majority of our participants work or study in scientific or technological fields. Thus, our findings might not be representative of older people and despite having participants with work or study backgrounds in business and arts, our data might be more representative of people working or studying in the fields of science and technology.
Due to the technical issues but also due to the lengthy study itself some participants tended to answer only a few questionnaires. Additionally, two participants accidentally deleted the application before they were told to do so. These issues

result in data scarcity. However, we were still able to draw several conclusions from our data.
Our study generated additional notifications as well which might have led to additional annoyance by notifications. This might have affected the reaction towards notifications. However, considering that our participants receive over a hundred notifications per day on average, and that our dedicated notifications were perceived as more interesting than the notifications by user-installed applications, the negative impact should be little.

8. Discussion

Overall, we notice several aspects of importance. So far, we can derive three types of importances which the general importance of a notification is composed of. Our study participants noted an objective importance, a subjective/personal importance and a public importance. The objective importance describes whether the notification has an actual effect or consequence on the user. These notifications could be for example work-related and a third party would also deem them as important. The subjective importance might be of trivial nature but carries an emotional or social meaning for the user. A third party might not deem it as important. The public importance refers to notifications about issues of public interest which might have no consequence on the user but have an effect on a wide array of people. Different people will put different emphasis on these different types of importances. As we see in our qualitative evaluation, only one participant mentioned the public importance. In a way, public importance might be linked to individual interests, as some participants did list *human rights*, *social justice*, *LGBT+ issues*, etc. as their interests. In this regard it could be interesting to assess a person's justice sensitivity [97] and relate it to their interest in notifications of public importance and assess their perceived importance of such notifications as well. Amongst our dedicated notifications, these notifications are a few excerpts of those which are of public concern and achieved an importance rating of 5 or higher (the notification title appears bold):

The Council of Europe makes history with its first resolution on the rights of intersex people[1]

A Land Without Guns How Japan Has Virtually Eliminated Shooting Deaths[2]

Calls for Hong Kong to better protect LGBT rights as city wins bid to host 2022 Gay Games[3]

[1]https://www.ilga-europe.org/resources/news/latest-news/council-europe-first-resolution-intersex

[2]https://www.theatlantic.com/international/archive/2012/07/a-land-without-guns-how-japan-has-virtually-eliminated-shooting-deaths/260189/

[3]http://www.scmp.com/news/hong-kong/community/article/2117697/hong-kong-wins-bid-host-2022-gay-olympics

The UAE's position on gay rights is actually surprisingly progressive[4]

Trump meets Putin in Vietnam How world could be on danger path as North Korea talks loom[5]

EU Spain Juncker does not want Catalonian independence[6]

Egypt mass trial sees hundreds imprisoned over 2013 protests[7]

Mexico: Mental Health Bill Undermines Disability Rights[8]

These pieces of information often do not affect the recipient of the notification as we had no participants in America or the MENA (Middle East, Northern Africa) region. Nevertheless, some of our participants indeed put emphasis on such notifications and therefore, it would be sensible to make further personality studies in order to analyse which kind of people would be interested in receiving such notifications. However, this also rises the question if information of public concern should be presented to everyone even if they are not interested as it effects a broad array of people. Additionally, we should also consider that often public news tend to be negative and thus cause negative effects on reader's well-being [34, 68]. A good balance of keeping the user informed and protecting their mental health needs to be achieved. The order of the notifications should also be considered as people prefer to receive bad news before good news [59, 65]. This might mitigate negative effects of the amount of negative news.
As mentioned before in subsection 7.2.2.9, it might be insightful to delve deeper into the issue of subjective and personal importance using an A/B testing. Some of our participants did mention that the actual importance of a notification is only determined by the content because notifications by friends and family are often quite trivial. It might lead to interesting results to see how people would feel if they were deprived of notifications by close people.
Furthermore, each feature we have looked into should be put into focus in a respective study. Our study was an assessment of several features at once and, thus, did not go into fine-grained details of each single feature. A more rigorous ESM study can help to gain more indications about situational importance of notifications. As we mentioned in our limitations 7.2.3, we often could not assess the importance of a notification right at the situation of its arrival. A dedicated study towards each feature has the potential to be more successful in gaining insights towards these situational importances. We indeed were able to find relations between several features and the importance (see marked hypotheses in listing A.3) but for instance a dedicated study about the activity can allow us to gather more detailed information. As mentioned in subsection 7.2.2.6, work and education for an instance can be split into more fine-grained activities. While we did assess the meaningfulness of the activity, it could be interesting to learn about which exact activities are meaningful to what kind of user. Participant P22 mentioned that each activity type we listed

[4]http://www.independent.co.uk/voices/uae-middle-east-dubai-gay-trans-queer-lgbtq-rights-east-west-divide-language-a7856746.html

[5]https://www.express.co.uk/news/world/877062/Putin-news-North-Korea-latest-Donald-Trump-meet-Russia-Vladimir-putin-world-war-3

[6]http://www.bbc.com/news/world-europe-41610863

[7]http://www.bbc.com/news/world-middle-east-41311210

[8]https://www.hrw.org/news/2017/10/17/mexico-mental-health-bill-undermines-disability-rights

can contain meaningful and important activities to them. In order to be able to assess the situational importance of notifications it will be meaningful to assess the exact situation of the user.
Additionally, we want to mention that several details about a person's circumstances influence their perceived importance of a notification. It is possible to put great detail into the current situation. For example, P17, who stated to work in the IT field, has to look at the screen the whole day, so they prefer not to look at the screen in the evening after work and therefore feel annoyed by notifications in the evening due to their work. However, they stated to be more accepting of voice messages in the evening. So, in certain cases even the field of work or study can be a factor in how to relay notifications. Maybe relaying notifications as voice messages using a Text-to-Speech unit could help in such a situation.
Generally, more detail should be put into each feature to learn about their exact influence of the perceived importance of notifications. Additionally, the distinction between the several types of importances should be considered.

9. Conclusion and Future Work

We started our work with an extensive literature research in order to decide on features which we wanted to investigate in regards to their influence on importance. We chose several features and drafted our study which we tested in a 1-week pilot study. After some adjustments we conducted our 4-week study using an application implemented by us to collect quantitative and qualitative data. The evaluation of the qualitative data allowed us to compile several hypotheses which we tried to proof by evaluating our quantitative data.

In our work we were able to show that several features relate to the perceived importance. However, for some minor features we were not able to find such relations, e.g. the battery level. If we have a look at the qualitative data, our participants did mention situations where the battery level matters. Thus, a higher focus on each single feature can lead to more detailed results. Our future work will have to include such dedicated research to each feature. Furthermore, a focus on one feature per study will shorten the questionnaire immensely and mitigate the participant's workload.

Generally, the results of our work show that several features, both intrinsic and extrinsic, influence the perceived importance of a notification. Thus, it is necessary to consider the user's context and circumstances to construct a smarter notification system which will delegate important notifications to the user during the right situation. Since most features did show a relation to importance, such a system needs to be sensitive towards several features. Researching the detailed influence of each feature will be a vital step in future work in order to mitigate the fear of a few users that important notifications will be filtered. Additionally, we extracted several kinds of importance from our qualitative data. These different kinds of importance will need to be considered in future work as well in order to find relations between several features and their impact on each kind of importance and the value each user puts on these importance.

In the end it might boil down to the reverse question: *What does* not *make a notification important?* Dependent on the particular situation, our participants described situations when each of the features were able to influence their perceived importance of a notification. Thus, our list of hypotheses which is derived from the qualitative data, can function as a basis for future work. When we compare our

qualitative results to our quantitative results, the assessment of our participants in table 7.1 was fairly accurate in which features tend to be more influential and which features tend to be less influential. Thus, more interviews and direct engagement with the user base might help to gain more knowledge about what influences the perceived importance of a notification. As an example, a feature which did not occur to us during our research leading up to the study, but was mentioned by our participants is the energy level of the user. Exhaustion and tiredness could have an impact on the perceived importance as well. Also, the language of a notification (P29) and the discrepancy between the given information in the notification and the actual content behind it (P13) were mentioned which were able to make notifications seem less important. More intensive work with people who are exposed to notifications in order to learn about what they really want seems to be a vital step in further exploration of the fundamental question of this work: *What Makes a Notification Important?*

A. Appendix

A.1 Previous Research on Intrinsic and Extrinsic Features

	General	Time	Activity	Activity Engagement	Formality of an Activity	Emotionality/Meaningfullness of an Activity
General		[78]	[33]	[78]		
		[38]	[54]	[79]		
		[1]	[78]			
		[26]	[38]			
		[110]	[1]			
			[74]			
			[110]			
App Name		[70]	[70]	[71]		
		[71]	[71]			
		[83]				
App Category	[93]	[70]	[70]			
		[82]				
Notif. Content		[69]	[69]	[71]		
		[71]	[71]			
		[25]				
Notif. Freq.	[93]	[82]	[98]			
		[98]				
Notif. Rem. Freq.	[93]	[91]	[91]			
Notif. Sentiment						
Other Party		[70]	[70]	[71]		
		[91]	[91]			
		[71]	[71]			
		[102]	[98]			
		[98]				
Urgency of Notif.		[71]	[71]	[71]		
Notif. Relevance		[71]	[71]	[71]		
		[13]	[47]			
WiFi Connectivity		[70]	[70]	[71]		
		[71]	[71]			
Notif. Mode		[70]	[70]	[71]		
		[91]	[91]			
		[66]	[71]			
		[71]				
Concurrent Apps						
Pleasureability						
Ringer Mode		[70]	[70]			
		[83]				
Battery Level						
Conc. Notif						
Contrast Level						
App Usage Freq.						
Past User React.	[93]	[69]	[69]			
		[70]	[70]			
		[83]				
Notif Settings	[109]					
Phone Attendance		[66]	[70]			
		[70]				

Table A.1

	User Personality	User Interest	Phone Location	Social Situation	Social Expectation
General	[110]		[26]	[54]	
				[78]	
				[38]	
				[26]	
App Name	[71]			[70]	[83]
				[71]	
App Category				[70]	[82]
Notif. Content	[71]	[25]		[71]	[4]
Notif. Freq.				[98]	[4]
					[82]
Notif. Rem. Freq.				[91]	[4]
Notif. Sentiment					
Other Party	[71]			[70]	[4]
				[91]	
				[71]	
				[98]	
Urgency of Notif.	[71]			[71]	[4]
Notif. Relevance	[71]		[63]	[71]	[4]
WiFi Connectivity	[71]			[70]	
				[71]	
Notif. Mode	[71]		[63]	[54]	[4]
				[70]	[83]
				[91]	
				[71]	
Concurrent Apps					
Pleasureability					[4]
Ringer Mode				[70]	[83]
Battery Level					
Conc. Notif					
Contrast Level					
App Usage Freq.					
Past User React.				[70]	[83]
Notif Settings					
Phone Attendance				[70]	

Table A.2

	Location	User Emotion	User Mood	Proximity	Future Activities	Luminosity
General	[54]	[78]	[110]			
	[78]					
	[20]					
	[26]					
	[110]					
App Name	[70]			[70]		[71]
	[71]			[71]		
App Category	[70]			[70]		
Notif. Content	[69]			[71]		[71]
	[71]					
Notif. Freq.	[98]	[98]			[98]	
Notif. Rem. Freq.	[91]				[91]	
Notif. Sentiment						
Other Party	[70]	[98]		[70]	[91]	[71]
	[91]			[71]	[98]	
	[71]					
	[102]					
	[98]					
Urgency of Notif.	[71]			[71]		[71]
Notif. Relevance	[71]			[71]		[71]
WiFi Connectivity	[70]			[70]		[71]
	[71]			[71]		
Notif. Mode	[70]			[70]	[91]	[71]
	[91]			[71]		
	[71]					
Concurrent Apps						
Pleasureability						
Ringer Mode	[70]			[70]		
Battery Level						
Conc. Notif						
Contrast Level						
App Usage Freq.						
Past User React.	[69]			[70]		
	[70]					
Notif Settings						
Phone Attendance	[70]			[70]		

Table A.3

1. At what kind of place were you when the notification arrived?
   Answer: A place type as specified in chapter 4 in table 4.3.
2. At what kind of place were you when the notification was removed? (if coordinates differ from coordinates assessed at *arrival time*)
   Answer: A place type as specified in chapter 4 in table 4.3.
3. How did you primarily feel shortly before the notification arrived?
   Answer: One of the 16 emotions of the GEW v. 3.0.
4. How intense did you feel [chosen emotion]?
   Answer: Value from 1 *not intense* to 7 *very intense*.
5. How did you primarily feel after reading the notification?
   Answer: One of the 16 emotions of the GEW v. 3.0.
6. How intense did you feel [chosen emotion]?
   Answer: Value from 1 *not intense* to 7 *very intense*.
7. What kind of activity were you engaged in when the notification arrived?
   Answer: An activity type as specified in chapter 4 in table 4.2.
8. Were you doing this activity alone?
   Answer: Choose either *not alone* or *alone*.
9. How meaningul/emotional was the activity?
   Answer: Value from 1 *not meaningful/emotional* to 7 *very meaningful/emotional*.
10. How formal was the activity?
    Answer: Value from 1 *not formal* to 7 *very formal*.
11. Did you notice the notification?
    Answer: Choose either *yes* or *no*.
12. Who sent the notification?
    Answer: An other party as specified in chapter 4 in table 4.5.
13. How interesting is the content?
    Answer: Value from 1 *not interesting* to 7 *very interesting*.
14. How urgent is the notification?
    Answer: Value from 1 *not important* to 7 *very important*.

List A.1: Daily Questionnaires before the pilot study

A.2 Licenses

A.2.1 Google-Places-Api-Java License

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A.2.2 Emoji-Java License

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A.3 Hypotheses

The following hypotheses are inferred from our qualitative evaluation in section 7.1. The checkmarked hypotheses are those which we were able to investigate in section 7.2 and verify using our data.

H1 The time has an influence on the perceived importance of a notification. ✓

H2 The application which triggered a notification influences the perceived importance of a notification. ✓

H2.1 The application which triggered a notification influences the interestingness of a notification.

H3 The application category of the application which triggered a notification influences the perceived importance of a notification. ✓

H2.1 The application category of the application which triggered a notification influences the interestingness of a notification. ✓

H4 The location of the user influences the perceived importance of an incoming notification. ✓

H5 The notification sentiment has an influence on the perceived importance of a notification. ✓

H5.1 The sentiment of a notification has an impact on the emotion of the user. ✓

H6 The interest of a user influences the perceived importance of a notification.

H6.1 The situational interest of a user relates to the perceived importance of a notification. ✓

H6.2 The individual interest of a user relates to the perceived importance of a notification.

H7 The emotions of the user influence the perceived importance of a notification. ✓

H7.1 A relation between the reaction emotion and the perceived importance of a notification exists. ✓

H7.2 The intensity of the user's emotions influences the perceived importance of a notification. ✓

H7.3 A change of emotion before and after noticing a notification indicates the importance of a notification. ✓

H7.4 A change of both emotion and emotion intensity before and after noticing a notification indicates the importance of a notification.

H7.5 The emotion is related to the current activity. ✓

H8 The current activity influences the perceived importance of a notification. ✓

H8.1 The current activity is a more influential factor than the time or location.

H9 The social situation, whether a user is in company or not, influences the perceived importance of a notification.

H9.1 The specific kind of company influences a user's perceived importance of a notification. The specific kind refers to the type of company the user is in, e.g. whether they are in company of friends, strangers, colleagues, etc.

H10 The formality of the activity influences the perceived importance of a notification. ✓

H11 The meaningfulness or emotionality of an activity influences the perceived importance of a notification. ✓

H12 The other party of a notification influences the importance of a notification. ✓

H12.1 Work-related other parties carry an objective importance.

H12.2 Other parties which represent close people, e.g. immediate family, close friends, etc. do not necessarily carry objective importance but subjective/personal importance. As an instance, a friend might just write about their favourite series which is objectively not important but can contain a lot of personal relevance due to special interpersonal relations.

H13 Whether the user is using the phone when a notification arrives or not, influences the perceived importance of the incoming notification.

H13.1 Smartphone users feel annoyed by high influx of notifications after a break from using their phones.

H14 The concurrent application which is used when a smartphone user is using their phone influences the perceived importance of an incoming notification. ✓

H14.1 The immersion and engagement towards the concurrent application influence the perceived importance of a notification.

H15 The battery level influences the perceived importance of a notification.

H15.1 Smartphone users have a certain threshold. When the battery level falls below this threshold, the user will be more selective of accepting notifications.

H16 The internet connectivity influences the perceived importance of a notification.

H17 The personality of a user influences the perceived importance of a notification.

H18 The energy level of a user influences their perceived importance of a notification. A user who is tired and exhausted might not feel as ecstatic about a notification as a user who has more energy.

H19 The language of a notification in relation to the user's language proficiency in that language influences their perceived importance of a notification.

H20 The discrepancy between the content of the notification and the content the notification leads to influences the perceived importance of a notification.

H21 The urgency of a notification influences the perceived importance of a notification.

H22 The culture of a person influences their perceived importance of notifications. For instance, P17 and P23 who come from cultures with strong family ties but have different ways of exercising these relations.

H23 The current country where the user lives influences the perceived importance of notifications. As mentioned by participant P29, their notification behaviour changed a lot once they moved from their birth country to Germany.

H24 The profession of a user influences their perceived importance of a notification. P17 who works in the field of IT has to look at a screen the whole day and thus do not wish to receive a lot of notifications in the evening or night and are more acceptant of voice messages. Thus, we speculate a link between the profession and the perceived importance.

A.4 Statistical Results

First Category	Second Category	Adjusted p-Value	Effect Size r
Education	Maps & Navigation	0.024*	-1.049***
Game	Voice & Text Messenger	0.000***	-0.208*
Game	Email	0.000***	0.442**
Photography	Maps & Navigation	0.000***	0.881***
Forum	Lifestyle	0.000***	-0.591***
Forum	Maps & Navigation	0.000***	-0.812***
Forum	Clock	0.000***	-0.341**
Forum	Tools	0.000***	-0.407**
Forum	Text Messenger	0.000***	-0.494**
Game	Maps	0.000***	-0.591***
Game	Lifestyle	0.000***	-0.489**
Forum	Voice & Text Messenger	0.000***	-0.204*
Game	Text Messenger	0.000***	-0.482**
Game	Tools	0.000***	-0.364**
Forum	Email	0.000***	0.459**
Photography	Text Messenger	0.000***	-0.384**
Photography	Email	0.000***	0.357**
Forum	Kong	0.001**	-0.163*
Game	Clock	0.001**	-0.304**
Game	Kong	0.002**	-0.155*
Forum	System	0.002**	-0.172*
Photography	Lifestyle	0.004**	0.506***
Game	System	0.005**	-0.161*
Photography	Voice & Text Messenger	0.013*	-0.146*
Forum	News & Magazines	0.028*	-0.461**
Forum	Browser	0.036*	0.382**
Photography	Tools	0.038*	-0.313**
Forum	Travel & Local	0.043*	-0.418**
Social	Text Messenger	0.000***	-0.418**
Other	Email	0.000***	0.317**
Other	Text Messenger	0.000***	-0.359**
Social	Voice & Text Messenger	0.000***	-0.193*
Social	Email	0.000***	0.375**
Social	Maps & Navigation	0.001**	0.393**
Social	Lifestyle	0.001**	0.345**
Social	Tools	0.003**	-0.274*
Other	Maps & Navigation	0.004**	0.422**
Productivity	Maps & Navigation	0.007**	-0.725***
Other	Voice & Text Messenger	0.010*	-0.141*

Table A.4: Pairwise comparison of application categories in regards to importance, part 1

First Category	Second Category	Adjusted p-Value	Effect Size r
Productivity	Text Messenger	0.016*	-0.296*
Other	Lifestyle	0.033*	0.319**
Social	Clock	0.036*	-0.224*
System	Text Messenger	0.000***	-0.203*
System	Email	0.000***	0.171*
Kong	Text Messenger	0.000***	-0.184*
Kong	Email	0.001**	0.153*
Music & Audio	Text Messenger	0.003**	-0.296*
Music & Audio	Maps & Navigation	0.017*	0.478**
System	Voice & Text Messenger	0.020*	-0.106*
Music & Audio	EMail	0.035*	0.257*
System	Maps & Navigation	0.041*	0.150*

Table A.5: Pairwise comparison of application categories in regards to importance, part 2

First Application	Second Application	Adjusted p-Value	Effect Size r
Discord	Android MMS	0.000***	0.748***
Discord	Facebook Messenger	0.000***	-0.458**
Discord	Gmail	0.000***	-0.544***
Discord	Hangouts	0.000***	-0.806***
Discord	WhatsApp	0.000***	-0.292*
Discord	WeChat	0.000***	-0.804***
Discord	Sony SMS	0.000***	-0.710***
Discord	Samsung SMS	0.000***	-0.673***
Discord	Telegram	0.001**	-0.227*
Discord	Skype	0.001**	-0.702***
Viber	Microsoft Outlook	0.002**	0.774***
Discord	Signal	0.002**	-0.627***
Discord	Microsoft Outlook	0.000***	-1.052***
Samsung Mail	Microsoft Outlook	0.000***	0.864***
Samsung Mail	Hangouts	0.008**	0.741***
Samsung Mail	WeChat	0.008**	-0.688***
Yahoo Mail	Microsoft Outlook	0.021*	0.692***
Samsung Mail	Android MMS	0.038*	0.600***
WhatsApp	Microsoft Outlook	0.000***	0.335**
Telegram	Microsoft Outlook	0.000***	0.336**
Facebook Messenger	Microsoft Outlook	0.000***	-0.462**
K-9 Mail	Microsoft Outlook	0.008**	-0.614***
Line	Microsoft Outlook	0.028*	-0.577***
Gmail	Microsoft Outlook	0.003**	-0.425**
Telegram	WeChat	0.055	-0.187*

Table A.6: Pairwise comparison of applications of the broader category *Communication*

First Category	Second Category	Adjusted p-Value	Effect Size r
Forum	Kong	0.000***	-0.301**
Clock	Voice & Text Messenger	0.000***	-0.372**
Clock	Email	0.000***	0.508***
Time	Text Messenger	0.000***	0.536***
Time	Kong	0.000***	0.472**
Tools	Kong	0.000***	0.339**
Other	Kong	0.000***	0.297*
System	Voice & Text Messenger	0.000***	-0.336**
System	Email	0.000***	0.287*
System	Text Messenger	0.000***	-0.308**
System	Kong	0.000***	0.467**
Social	Kong	0.000***	0.252*
Tools	Voice & Text Messenger	0.000***	-0.247*
Forum	Voice & Text Messenger	0.000***	-0.246*
Forum	Text Messenger	0.000***	-0.495**
Time	News & Magazines	0.000***	0.486**
Tools	Text Messenger	0.000***	0.396**
Lifestyle	Kong	0.000***	0.235*
Forum	Email	0.000***	0.471**
Other	Voice & Text Messenger	0.000***	-0.214*
Tools	Email	0.000***	0.368**
Forum	News & Magazines	0.000***	-0.736***
Game	Kong	0.000***	0.202*
Other	Text Messenger	0.000***	-0.374**
Travel & Local	Kong	0.000***	0.202*
Other	Email	0.000***	0.346**
System	News & Magazines	0.000***	0.410**
Music & Audio	Kong	0.000***	0.180*
Voice & Text Messenger	Kong	0.000***	0.132*
Lifestyle	Text Messenger	0.000***	-0.343**
Other	News & Magazines	0.000***	0.430**
Lifestyle	Voice & Text Messenger	0.000***	-0.171*
Photography	Kong	0.000***	0.171*

Table A.7: Pairwise comparison of application categories in regards to interest, part 1

First Category	Second Category	Adjusted p-Value	Effect Size r
Social	Voice & Text Messenger	0.000***	-0.159*
Productivity	Kong	0.001**	0.168*
Lifestyle	Email	0.001**	0.317**
Social	Text Messenger	0.001**	-0.270*
Lifestyle	News & Magazines	0.001**	-0.493**
Time	Social	0.002**	0.263*
Browser	Kong	0.002**	-0.157*
Time	Browser	0.002**	0.297*
Forum	Entertainment	0.002**	0.640***
Business	Kong	0.004**	-0.155*
Time	Entertainment	0.004**	0.326**
Travel & Local	Text Messenger	0.007**	0.293*
Forum	Video Players & Editors	0.009**	-0.578***
Social	Email	0.009**	0.242*
Forum	Browser	0.009**	0.412**
Game	Text Messenger	0.011*	-0.273*
Travel & Local	News & Magazines	0.016*	0.448**
Travel & Local	Voice & Text Messenger	0.018*	-0.141*
Clock	Video Players & Editors	0.020*	-0.299*
Game	Voice & Text Messenger	0.022*	-0.138*
Photography	News & Magazines	0.026*	0.518***
Social	News & Magazines	0.028*	0.303**
Forum	Social	0.028*	-0.301**
Travel & Local	Email	0.032*	0.268*
Game	News & Magazines	0.038*	-0.381**
Calendar	Kong	0.038*	-0.137*
Photography	Text Messenger	0.042*	-0.282*
Productivity	News & Magazines	0.047*	0.488**

Table A.8: Pairwise comparison of application categories in regards to interest, part 2

First Emotion	Second Emotion	Adjusted p-Value	Effect Size r
Apathy	Relief	0.000***	-0.132*
Apathy	Contentment	0.000***	-0.152*
Apathy	Disappointment	0.000***	-0.164*
Amusement	Love	0.000***	-0.324**
Amusement	Interest	0.000***	-0.226*
Joy	Disappointment	0.000***	0.278*
Joy	Love	0.000***	-0.267*
Joy	Interest	0.000***	0.222*
Amusement	Disappointment	0.000***	-0.321**
Apathy	Pleasure	0.000***	-0.116*
Apathy	Love	0.000***	-0.137*
Apathy	Interest	0.000***	-0.196*
Joy	Relief	0.006**	-0.204*
Apathy	Shame	0.008**	-0.102*
Amusement	Relief	0.009**	-0.234*
Apathy	Compassion	0.010*	-0.100*
Amusement	Shame	0.038*	-0.25*
Anger	Love	0.040*	-0.449**
Joy	Shame	0.042*	-0.203*
Contentment	Love	0.028*	-0.150*
Contentment	Disappointment	0.037*	-0.142*
Joy	Contentment	0.053	0.119*
Pride	Love	0.055	0.502***

Table A.9: Pairwise comparison of emotions

First Emotion	Second Emotion	Adjusted p-Value	Effect Size r
Joy	Shame	0.000***	-0.289*
Apathy	Shame	0.000***	-0.179*
Apathy	Sadness	0.000***	-0.194*
Apathy	Relief	0.000***	-0.266*
Apathy	Compassion	0.000***	-0.132*
Apathy	Contentment	0.000***	-0.229*
Apathy	Disappointment	0.000***	-0.259*
Amusement	Love	0.000***	-0.529***
Amusement	Interest	0.000***	0.221*
Amusement	Shame	0.000***	-0.363**
Amusement	Sadness	0.000***	-0.293*
Amusement	Relief	0.000***	-0.398**
Joy	Disappointment	0.000***	0.291*
Joy	Love	0.000***	-0.429**
Joy	Relief	0.000***	-0.300*
Anger	Love	0.000***	-0.509***
Amusement	Contentment	0.000***	-0.181*
Amusement	Disappointment	0.000***	-0.388**
Disgust	Love	0.000***	-0.669***
Apathy	Pleasure	0.000***	-0.182*
Disgust	Shame	0.000***	-0.648***
Apathy	Love	0.000***	-0.289*
Apathy	Interest	0.000***	-0.303**
Apathy	Guilt	0.000***	-0.148*
Apathy	Fear	0.001**	-0.127*
Amusement	Guilt	0.001**	-0.289*
Amusement	Pleasure	0.001**	-0.243*
Joy	Interest	0.001**	0.148*
Anger	Shame	0.001**	-0.383**
Anger	Relief	0.001**	-0.301**
Disgust	Relief	0.001**	-0.368**
Apathy	Pride	0.001**	-0.127*
Apathy	Joy	0.001**	-0.120*
Anger	Disappointment	0.002**	-0.292*
Disgust	Disappointment	0.002**	0.362**
Apathy	Anger	0.017*	0.106*
Amusement	Compassion	0.018*	-0.247*
Joy	Sadness	0.025*	-0.201*
Amusement	Pride	0.031*	-0.240*
Disgust	Guilt	0.032*	-0.489**

Table A.10: Pairwise comparison of reaction emotions, part 1

First Emotion	Second Emotion	Adjusted p-Value	Effect Size r
Joy	Guilt	0.035*	0.218*
Contentment	Love	0.000***	-0.292*
Interest	Love	0.000***	-0.220*
Pleasure	Love	0.000***	0.387**
Hate	Love	0.001**	-0.499**
Contentment	Relief	0.003**	-0.174*
Sadness	Love	0.010*	0.341**
Regret	Love	0.013*	0.448**
Contempt	Love	0.016*	-0.474**
Admiration	Love	0.020*	-0.424**
Interest	Shame	0.048*	-0.141*
Amusement	Fear	0.052	-0.228*

Table A.11: Pairwise comparison of reaction emotions, part 2

First Control Change Type	Second Control Change Type	Adjusted p-Value	Effect Size r
High2Apathy	Low2High	0.000***	0.252*
High2Apathy	High2Low	0.000***	-0.457**
Apathy2High	High2Low	0.000***	-0.213*
High2Apathy	Apathy2Low	0.000***	-0.457**
Apathy2High	Apathy2Low	0.000***	-0.253*
Same	High2Low	0.000***	0.136*
Same	Apathy2Low	0.000***	0.164*
High2Apathy	Apathy2High	0.001**	-0.170*
High2Apathy	Low2Apathy	0.001**	-0.287*
Low2High	Apathy2Low	0.001**	-0.216*
Same	Low2High	0.001**	0.075
Low2High	High2Low	0.013*	-0.193*
Same	Apathy2High	0.019*	0.060
Same	Low2Apathy	0.024*	0.062

Table A.12: Pairwise comparison of changes of emotion control

First Valence Change Type	Second Valence Change Type	Adjusted p-Value	Effect Size r
Pos2Apathy	Pos2Neg	0.000***	0.246*
Pos2Apathy	Apathy2Neg	0.000***	0.233*
Same	Pos2Neg	0.000***	0.085
Pos2Apathy	Neg2Pos	0.000***	0.279*
Same	Apathy2Neg	0.000***	0.079
Pos2Apathy	Apathy2Pos	0.000***	-0.188*
Same	Apathy2Pos	0.000***	0.098
Same	Neg2Pos	0.001**	0.079
Pos2Apathy	Neg2Apathy	0.028*	0.219*

Table A.13: Pairwise comparison of changes of emotion valence

First Other Party	Second Other Party	Adjusted p-Value	Effect Size r
System	Superior	0.000***	0.332**
Average Friend	Superior	0.000***	-0.396**
System	Close Friend	0.000***	0.245*
Application	Close Friend	0.000***	-0.182*
Application	Other	0.000***	-0.162*
Application	Peer	0.000***	-0.100*
System	Other	0.000***	0.257*
Immediate Family	Superior	0.000***	-0.472**
Application	Superior	0.000***	-0.203*
Stranger	Superior	0.000***	-0.473**
Acquaintance	Superior	0.000***	-0.723***
Acquaintance	Close Friend	0.000***	-0.331**
Acquaintance	Other	0.000***	-0.538***
Average Friend	Other	0.000***	-0.262*
Close Friend	Superior	0.000***	-0.281*
Partner	Superior	0.000***	-0.424**
Acquaintance	Peer	0.001**	-0.365**
Application	Average Friend	0.002**	-0.089
Application	Partner	0.002**	-0.089
System	Peer	0.003**	0.155*
Immediate Family	Other	0.004**	-0.297*
Peer	Superior	0.004**	-0.378**
Partner	Other	0.006**	0.264*
Acquaintance	Partner	0.013*	-0.242*
Acquaintance	Average Friend	0.025*	-0.202*
Extended Family	Superior	0.036*	-0.419**
System	Partner	0.049*	0.121*

Table A.14: Pairwise comparison of other parties

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