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Adding Expressiveness to Smartwatch Notifications Through Ambient Illumination

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ABSTRACT

The ongoing miniaturization of technology provides the possibility to create more and more powerful devices in smaller form factors. One characteristic of this development is smart wearable devices, such as smartwatches, which open up new possibilities for mobile human-computer interaction. While recent research has revealed that these devices are mainly used to display notifications, the very small screen size can be a hindrance. Consequently, explicit user interaction is, for example, required to browse through notifications to get an overview of them. The authors present an alternative by providing an aggregation and filtering approach to better handle notifications. Furthermore, they investigated several display concepts based on a self-built smartwatch prototype equipped with twelve full-color LEDs to present notifications through ambient illumination. Derived from a user study with twelve participants, the work concludes with guidelines that could be employed when designing notification systems.

KEYWORDS

Ambient Illumination, LED, Notification, Notification Filtering, Smartwatch

INTRODUCTION

In recent years, the market for wrist-worn smart devices has seen a drastic increase. Not only fitness trackers, such as the Fitbit, but especially more advanced devices such as the Samsung Gear series or the Apple Watch contributed to this increase in interest by consumers. Even though we have seen various advancements that allow for more complex in- and output modalities, they still suffer from a rather short battery life and are still limited in terms of computational power and display capabilities. Meanwhile, the software side has undergone drastic advancements lately, with an increase in third-party applications, but it is still questionable how users will benefit from this development. For example, Pizza, Brown, McMillan, and Lampinen (2016) found in their video analysis of 1009 uses of the Apple Watch that the most common one (~50%) was to simply glance at the watch face. This of course raises the question, what are the main benefits of these devices compared to their analog counterparts?

Besides displaying the time, notifications are another primary use case (Schirra & Bentley, 2015). Especially for quick glances, the wrist has proven to be a well-suited location, that allows for easy

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perception of changes and sufficiently fast reaction to them (Ashbrook, Clawson, Lyons, Starner, & Patel, 2008). Shirazi and Henze's (2015) analysis of notification techniques across mobile devices showed that users base their decision for whether a certain notification should be displayed not only on the importance of the notification, but also on the output device. Their work implies that the user not only needs a system to filter and control the notification flow of their mobile devices, but also a way of choosing suitable modalities for their notifications.

While a variety of research has focused on novel interaction techniques for smartwatches (e.g. Kerber, Krüger, & Löchtefeld, 2014; McIntosh et al., 2016), most current devices are still based on conventional touch input or utilize additional mechanical inputs (Kerber, Kiefer, & Löchtefeld, 2016). But those input techniques come with the drawback of requiring both hands to interact with the device (Kerber, Schardt, & Löchtefeld, 2015; Kerber et al., 2016) While gestural input has become a standard on Android Wear, and may seem like a valid alternative especially as it only requires one hand to control the device, the risk of false positives creates a need for a gesture delimiter (e.g. Kerber, Schardt, & Löchtefeld, 2015). Compared to these advances only very little work has focused on how to convey and manage notifications on such devices (e.g. Ashbrook, Clawson, Lyons, Starner, & Patel, 2008; Gouveia, Pereira, Karapanos, Munson, & Hassenzahl, 2016; Hwang, Song, & Gim, 2015). Typically, notifications are just shown in a linear way – one by one – and switching between them requires a dedicated user interaction. Additionally, currently only very limited possibilities to cluster and filter notifications effectively exist for smartwatches.

In this paper, we try to approach the problem from a slightly different angle. Instead of focusing on novel interaction techniques to deal with (maybe even unnecessary) notifications, we contribute by investigating novel filtering and visualization techniques for smartwatch notifications. Based on our custom-built, energy-efficient smartwatch prototype we explore how the combination of a low-resolution display and an ambient illumination frame, consisting of 12 RGB LEDs around it, can be utilized to communicate notifications more effectively. Additionally, we developed an application that allows users to effectively filter and prioritize the notifications that will reach the smartwatch in the first place. Based on the results of two user studies that explored the two aspects of this prototype we present a set of guidelines that can be transferred easily to current mass-market devices.

RELATED WORK

Since the first digital LED watch, the Hamilton Pulsar P1, was presented in 1972, many technical developments have been introduced in the area of smart watches. The IBM Linux Watch (Narayanaswami et al., 2002) laid the foundation for many aspects of today's commercial smartwatches, with most of them providing high-resolution displays, often equipped with touch functionality. While the ongoing miniaturization of technology made this development possible, there are also a number of open problems, e.g. regarding battery life, or those resulting from the very small screen size. Not only might it be complicated to interact with the devices due to occlusions or the so-called fat finger problem (Siek, Rogers, & Connelly, 2005), but it is also hard to convey information at a glance. Considering for example notifications, which are one of the most common tasks today's smartwatches are used for (Schirra & Bentley, 2015), none of the currently available wearable operating systems provides a quick overview feature as we are used to from smartphones with their large screens. To overcome limitations of the small screen size, in particular scientific work investigates different output possibilities. Gouveia, Pereira, Karapanos, Munson, and Hassenzahl (2016) investigated the design space for glanceable behavioral feedback on smartwatch watchfaces with respect to user engagement and physical activity. However, as their study focused on glanceable communication of bodily activity, their results cannot directly be adapted to general smartwatch notifications. Bolle, De Croon, and Duval (2015) explored three different methods to respond to notifications in a faster manner and to extend micro-usage by either offering input through on-screen buttons, tapping the edges of the device or by drawing gestures on the screen. Their evaluation showed that applying such techniques increased the micro-usage on smartwatches by 5% while it decreased on the smartphone, so effectively shifting workload from the phone to the smartwatch.

With Wearable Tactile Displays (Lee & Starner, 2010), a wearable prototype with three vibration motors arranged in a triangle was presented to overcome problems such as increased distraction when using a smartphone to receive notifications. Based on the parameters starting point, direction and intensity of the vibration, as well as temporal patterns, 24 vibrating patterns were investigated to convey information. After a 40 minute long training phase, recognition accuracies of up to 99% could be achieved. Pasquero, Stobbe, and Stonehouse (2011) presented a haptic wristwatch prototype that is able to deliver feedback due to haptic stimuli. In two experiments, the authors showed that the device can be used for tactile notifications as well as to convey numerical data, e.g. to get an indication of unread emails in a user's inbox. To achieve a reasonable accuracy, the number of pulses per second should be limited to three while rough estimations can be delivered with up to nine pulses per second. The Harmonious Haptics system by Hwang, Song, and Gim (2015) uses a similar approach and provides rich tactile feedback by simultaneously using vibration motors of an Android Tablet and a connected Android Wear smartwatch. The authors presented a prototype system that uses nine tactile patterns, e.g. to create the illusion of a moving force during a file transfer between both devices, but did not evaluate their system yet. Cauchard, Cheng, Pietrzak, and Landay (2016) developed with ActiVibe a set of vibrotactile icons designed to represent progress of activity tracking through the values 1 to 10. Their icon set reached a recognition rate of 88.7% during an in-the-wild study. As it is highly targeted to activity monitoring, it is so far unclear how it can relate to general notifications. Ion, Wang, and Baudisch (2015) presented a prototype with a physical tactor that is moved accross the user's skin. Their approach allowed participants to recognize tactile shapes significantly better than using a vibrotactile array of comparable size. One of the advantages the presented systems provide are the eyes-free interaction possibilities which may solve problems arising from the small display space. However, the approaches cannot really target the issue of not being able to get a quick overview while still being interested in at least some details. It is for example possible to get a rough estimate of the number of unread emails within some seconds, but it is not easily possible to get to know how many of them are from a specific contact without requiring more interaction time.

Using ambient light feedback to convey additional feedback on the frame of devices has been quite popular ever since Phillips introduced the Ambilight system. In 2014, Löchtefeld, Lautemann, Gehring, and Krüger even built a tablet version of it. Their qualitative user study showed that participants rated the additional feedback channels as highly attractive and desirable. Pohl, Medrek, and Rohs (2016) explored a subtle notification technique for smartwatches that used light scattering through the wearer's skin as a feedback modality. With their prototype, the authors aim at providing a more natural and less disruptive way to provide feedback. However, the system is not designed as a stand-alone approach, but rather a low-fidelity addition to information displayed on the smartwatch display. Fortmann, Müller, Boll, and Heuten (2013) investigated the integration of LEDs into jewelry to discreetly display simple information. A similar concept has recently been picked-up by Samsung with its new lifestyle band Charm (Samsung, 2016). Based on large-scale user studies, Harrison, Horstman, Hsieh, and Hudson (2012) investigated sets of light behaviors, i.e. how devices communicate their internal state using light. From the 24 examined light behaviors, only 3.8 are typically used on average, with the most common ones being rather simple, such as on/off or blinking and fading. For five informational states, e.g. receiving a notification or transmitting data, the authors tried to identify clearly recognizable light behaviors such as flashing to indicate a new notification. In summary, it could be shown that point light sources can encode more information than expected and provide a reasonable basis for further research.

Instead of having a full-featured smartwatch, the approach of augmenting ordinary watches with single smart components has also been investigated. Xu and Lyons (2015) proposed such a design, in which they equipped a standard watch with three LEDs as icons for phone, calendar, messages and an additional one for other applications. To add more expressiveness to the message notification, colors could be assigned for different contacts to directly indicate who sent a message. In a second prototype, the authors went one step further towards a more sophisticated smartwatch by integrating twelve LEDs in a circular arrangement. Instead of using hands to display the time, a single LED was used to indicate the hour and an illuminated arc to show the minutes.

Regarding the presentation aspect, we follow in the same direction as Xu and Lyons, but instead of relying on the twelve LED ring alone, we equipped our prototype with an additional low-power display to extend the visualization possibilities. Apart from the actual presentation, we also target the aforementioned problem of not having an overview of all notifications at a glance. To address this issue, we apply two concepts. First, we implemented a pre-filtering and aggregation mechanism to simplify the notification handling even before it comes to displaying notifications on the smartwatch. With the help of this approach, the user can get more control over the torrent of notifications, with the goal to reduce distractions and interruptions from their primary task. Second, we investigate different visualization strategies to be able to add more expressiveness when using the twelve LEDs. To achieve this goal, we make use of LED position and color, light intensity as well as temporal patterns.

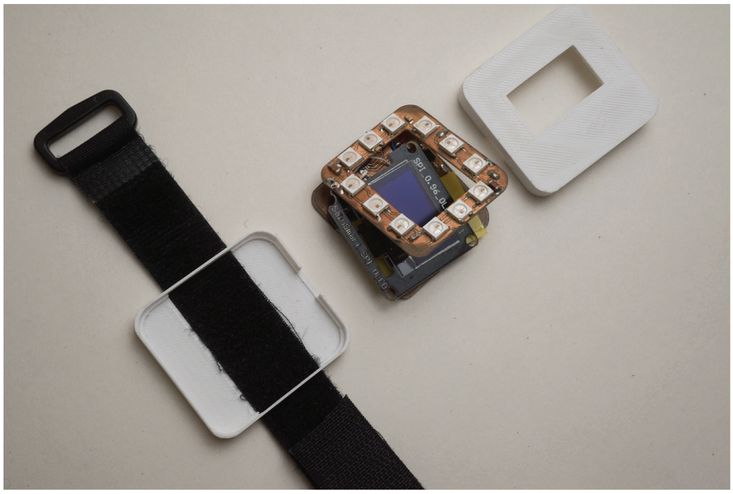
CONCEPT AND PROTOTYPE

Considering the standard approach for how notifications are currently presented to the user, we often see an arrangement following a timeline concept, i.e. notifications are stacked based on the time they were issued. As a variant of this, notifications are first grouped by the respective app and then ordered by time. A typical notification consists of a title, the content text, a notification icon, and the time it was issued or last updated. Although the following parts mainly focus on Android as the operating system, the underlying concepts are easily transferable to other kinds of notification systems. Starting with Android 5.0, the user has been given at least a little control over notifications: It is now possible to either completely block notifications for a given app or allow all notifications to be shown. Moreover, apps can also be given the permission to send notifications even if the device is in "do not disturb" mode. The Android notification system also provides a possibility to assign notifications a priority value – a feature that is only rarely used by apps and more or less hidden from the user, e.g. there is no possibility to define "Send only notifications with high priority to my smartwatch."

Therefore, we decided to develop a notification filter application for Android, that allows the user to create a set of conditions on which to base his notification preferences – named preconditions. Depending on these conditions, notifications would either be filtered out or distributed to the chosen device. The conditions consist of the application to which they would be applied - if they should be applied to all applications the user can choose the "wildcard" to simply match them all - and can have further criteria such as their minimal priority or a string that they contain. As priority levels are not consistently used by third-party apps, we suggest instead to filter by adding corresponding text, e.g. set the application to "Hangouts" and then adding a filter text such as "John Doe" will filter all Hangout messages by this person, and either show them or not. Additionally, the user can select how the notifications will be delivered to him – termed effects. The user can choose between visual or tactile cues created by either the smartwatch or the mobile phone. Our application provides a set of vibro-tactile patterns, display notifications and activated LEDs.

We created our own custom hardware prototype that consisted of a low-resolution display and twelve RGB LEDs that were arranged around the display hidden beneath a 3D-printed casing. The hardware of our prototype can be seen in Figure 1. It features an 8-bit microcontroller from Atmel's AVR family which is also used in the Arduino platform. It is supported by a Bluetooth module for communication with an Android smartphone. The whole mainboard was custom-designed for this prototype. Additionally, it also features a low-power 0.96 in OLED display with a resolution of 128 x 64 pixels. The LED frame around the display consists of twelve WS2812B RGB LEDs which are arranged in clock-face manner. To protect the electronic parts of the smartwatch in daily use and to attach a wristband to the device, a suitable plastic casing with dimensions 45x41x11 mm

Figure 1. Hardware components of our prototype



was 3D-printed. This is still within dimensions that are quite comparable to current commercial smartwatches. The completely assembled prototype can be seen in Figure 2.

The clockwise arrangement of the LEDs allows to visualize notifications in several ways. Not only can we use simple temporal patterns (e.g. blinking LEDs) but also arrange them spatially around the display e.g. depending on importance. Furthermore, the colors and the intensity of the LEDs can convey additional properties of the filters set by the user. To give an example: If the user receives three WhatsApp messages, one way of visualizing this would be to have three LEDs light up, where the color could imply the sender (detected by the text set for the notification) and the intensity would represent the importance of the single message. Another way to convey this information could be to have only a single LED (corresponding to only this single application) light up in a temporal fashion with the same indications as before. But also the arrangement of LEDs around the display could indicate the sender, independent from the application. If for example the user receives messages or

Figure 2. Completely assembled prototype device

emails from the same sender, these could be indicated by lighting up an LED at a certain position (e.g. three o'clock) in a short time interval where the color would represent the application. Figure 3 shows some visualizations.

The application running on the smartphone employs two background services, one that controls the Bluetooth communication with the watch and one that filters the incoming notifications. The user interface of the application makes it possible to control the different output mechanisms on the watch, such as LED color, LED position and the blinking frequency independently for each filter (compare Figure 4). Additionally, the user can choose whether or not the display should provide additional information such as the title of the notification. As one notification could possibly fit several filters, those can be ordered by priority. This will ensure that the first matching filter will be applied and those following will be ignored (see Figure 5). To further ease the process of creating a filter, we implemented an additional Unfiltered Notification View which displays the last ten notifications that

Figure 3. Possible visualizations making use of color, spatial arrangement, and showing additional information on the low-resolution display

Figure 4. Detail settings for a specific filter

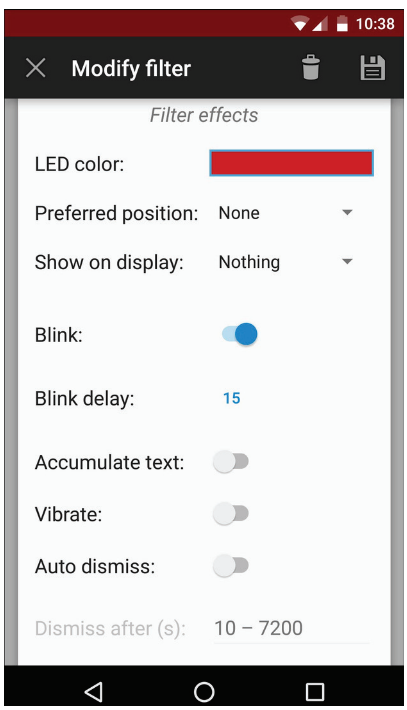
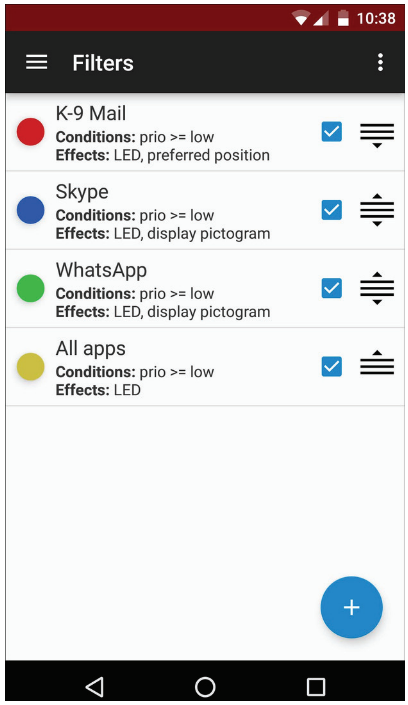


Figure 5. Overview of created filters and their priorities



did not match any filters (see Figure 6). From this, the user can select one as a template to easily set up new filters.

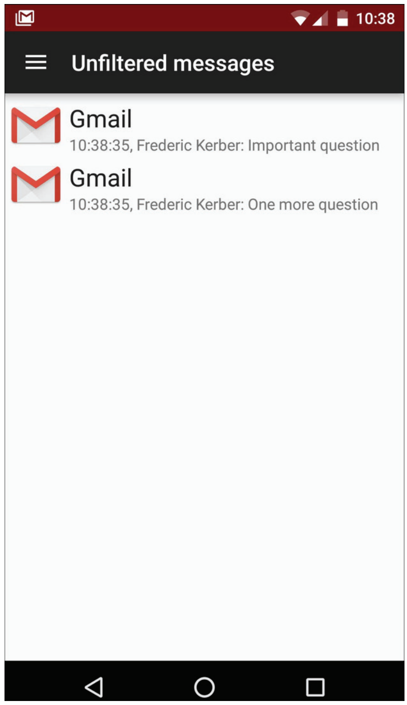
USER STUDY

To evaluate our concepts, we conducted a two-part user study. Following the partitioning of the concept, we first focused on the notification filter system including prioritizing notifications, while the second part of the study dealt with possible visualizations for notifications as well as other pieces of information including their presentation using our prototype. We recruited twelve participants (three female) aged between 21 and 38 years with an average age of 25 years. All participants had a background in computer science as well as prior experiences with touch-enabled devices such as smartphones or tablets. Furthermore, five of them also had experiences with smart wearable devices, i.e. smartwatches or similar devices such as fitness trackers that are able to present notifications to their wearers.

Notification Filter and Prioritization System

With the first part of our user study, we wanted to assess the properties of our filtering and prioritization system from a user's point of view, i.e. whether the concept is correctly understood and considered usable. To get a better understanding of the participants' background with respect to smart wearable devices and notification systems, we first conducted a pre-session questionnaire. After the introductory questionnaire, we explained the general concept of providing an alternative notification system that permits filtering and prioritizing notifications as well as visualizing these notifications using multi-color LEDs on our smartwatch prototype. We prepared 14 tasks which were used to guide the participants through our application, e.g. the following: "Set up a filter for notifications from a specific

Figure 6. View of unfiltered notifications to create filters from



sender and assign the LED at the one o'clock position as its preferred notification position". In the post-evaluation questionnaire, we utilized the After Scenario Questionnaire, the System Usability Scale, and further questions with a direct relation to the completed tasks to assess the users' experiences.

Results

Based on the results of the pre-session questionnaire, we could see that more than 80% of the participants were interested in having a clearer way to deal with multiple notifications on their devices. Possible improvements mentioned by the participants include combining multiple notifications into a condensed one, aggregation based on the sender, and having prioritization options. Regarding the assessment of a notification's relevance at a glance, the participants were undecided – half of the participants found it easy, whereas the other half had a neutral attitude or mentioned problems. However, all but one participant agreed that considering meta-information such as the sender's name is already sufficient to estimate the notification's importance.

All participants consider smartwatches as an improvement when it comes to displaying notifications, especially as they find reading them to be more convenient. Eight people stated that there is no need to take out their smartphone anymore when notifications are displayed on the smartwatch. It was also mentioned that retrieving notifications can be done more discreetly. However, the participants with smartwatch experience were rather unsatisfied about how the devices deal with displaying multiple notifications. All expressed their interest in having a better way to represent (multiple) notifications on a wearable device. In contrast to the results considering smartphones, four of the five smartwatch owners find it hard to detect a notification's importance at a glance when displayed on a smartwatch. In particular, the fact that there is no overview of current notifications, and instead one has to swipe between multiple notifications, was reported by three participants.

According to the answers of the post-session questionnaire, all participants were satisfied with the ease of completing the tasks – on a scale from -3 (not satisfied at all) to +3 (completely satisfied); eight participants gave the maximal rating (min = +1, max = +3, median = 3). Also, the task completion times were satisfying, with the highest rating achieved seven times (min = +2, max = +3, median = +3). None of the participants had any problems with understanding our presented filtering concept and all stated that they liked it (8x +3; 4x +2; median = +3). Also, the straightforward way to work with the filters and the immediately visible effects on the prototype device were complimented. Several participants found the filters to be a way to assign notifications a more personal note and to have a greater influence on what is sent to them. On the other hand, one participant also mentioned that the effectiveness of the filter concept strongly depends on the defined filters and another mentioned that the number of filters should not be too high, as it might be hard to distinguish their effects otherwise. The rating of the overall usability by the System Usability Scale had an average value of 87.3 (median 87.5) which can be considered as excellent (Bangor, Kortum, & Miller, 2009).

Ambient Illumination

In the second part of our user study, we focused on possible visualization for eight scenarios making use of our prototype device and its possibilities for ambient illumination. First, we gave the participants a short introduction into the features of the prototype's LED frame, i.e. displaying RGB colors, blinking with different frequencies, coarse fading, or pulsing. We then handed out a questionnaire presenting eight scenarios (see below) and the participants' first task was to think about how they would visualize these given the possibilities of the LED frame. Second, we presented a number of proposals for each of the scenarios, and the participants had to rank them based on their adequacy. Lastly, the self-created visualization of the first part was to be included in the ranking. With this approach, we aimed at getting an understanding of good ambient visualizations through our multi-color LED frame.

Results

All but one participant agreed that an LED frame around a watch face could help them recognize, manage and understand multiple notifications at the same time (min = -1, max = +3, median = +2.5 on a scale from -3 = not at all to +3 = absolutely). Similarly, all but the same one participant found the presented LED visualizations easy to understand (min = -1, max = +3, median = +2). Ten of the participants were of the opinion that meta-information such as the sender or the involved app can be conveyed via the LED frame (min = -2, max = +3, median = +2). Several mentioned that they were already used to the general concept, as their smartphone already contains one multi-color notification LED, but at the same time criticized the fact that the color cannot be controlled as is the case with our prototype.

We now first show the eight scenarios along with their most preferred (+) and least preferred (-) visualizations. For cases in which two visualizations ranked approximately equally, we list both. Afterwards, we present insights that could be gained by analyzing the participants' choices:

S1: Five new emails:

+ Five active LEDs of the same color; the color indicates the email program;
+ One LED is steadily active and turned off and on again five times in a row;
– The light intensity of one LED gives a rough hint at the number of new emails, i.e. the brighter it is, the more emails;
– One LED at a specific position is turned on and the color gives a rough hint at the number of emails, e.g. from green (few) to yellow to red (many);

S2: One message from Alice and one from Bob:
+ Two active LEDs with different color; the color indicates the person that sent the message;
– One active LED at a specific position toggles between two colors; the color indicates the respective person, while the position indicates the email program;

S3: One email and one instant message:
+ Two active LEDs with different color; the color depends on the application;
– Two active LEDs; their positions indicate the application;

S4: Showing the time – hours and minutes:
+ Differently colored arcs to indicate hours (in 12h mode) and minutes (in 5 minute steps);
+ Two differently colored LEDs to indicate hour and minute;
– Fibonacci encoding: First and second LED mean 1, third LED means 2, etc.; LED color shows that it refers to the hour, the minute or is used for both;

S5: Reminder of an alarm in ten minutes:
+ One active LED at the ten-minute (two o'clock) position;
+ Two consecutive LEDs are activated (indicating two five-minute steps);
– Ten consecutive active LEDs;

S6: Important interruption, for example for a call:
+ All LEDs are blinking;
– One LED is blinking fast;

S7: Reminder of an alarm in ten minutes and receiving a call:
+ One active LED at the 10 minute position and a chaser overriding this LED whenever it passes its position;
– All LEDs are blinking;

S8: Progress of a file download:
+ An arc of active LEDs as percentage indicator; the full circle means 100%;
– One blinking LED where the phase when the LED is turned on decreases with increasing percentage of the downloaded file.

Based on the rankings, we see that the participants were more comfortable with the visualization of discrete numbers instead of seeing only a rough estimate, whenever possible. In contrast, for higher numbers the idea of using single LEDs for a multiple of a certain number is preferred, e.g. if one LED indicates 5 minutes, two stand for 10 minutes. The "round" nature of the LED frame also gives the possibility to use it as a percentage indicator (cf. **S8**). In addition to something like file downloads, visualizations for a step counter or daily activity level are also imaginable. As these visualizations are typically long-lasting, participants commented that they should be shown with low brightness and could possibly be overridden by other, more important information. In compliance with this, participants suggested changes in light intensity only infrequently and for notifications with low or medium priority. Also the blink frequency should be low so as not to distract the wearer. In general, fading was perceived as less distracting and should be preferred over blinking, which is considered more aggressive and should only be used if direct user interaction is required (cf. **S6**). When there is the need to display notifications in parallel (e.g. in situations such as **S7**), it was considered acceptable that more important ones override other ongoing notifications for a short time. In situations that involved more than one person or app (cf. **S2** and **S3**), participants preferred indication via different LED colors over different LED positions as a distinguishing element.

In most of the cases, the participants' visualization created in the first task of the user study strongly matched the proposals we came up with in the ranking task. To give a specific example, in **S1** seven participants suggested turning on five consecutive LEDs. However, especially for **S4** and **S5**, other meaningful suggestions have also been brought up, e.g. because they found 5-minute steps not precise enough. As an alternative, they suggested adding light intensities, colors or increasing fading speeds for the LEDs.

DISCUSSION

From our evaluation in connection with the participants' comments, some clear requirements emerge that will ensure that the experience and interaction with notifications on smartwatches is pleasant for the user. The first thing that became easily evident is that a mechanism to filter notifications is desired by users. This is also underlined by current developments around the Android OS notification system, where users are granted more freedom with every new release. Our participants highlighted the importance of being able to filter notifications from certain persons in their address book. While it is already possible in Android, the process of managing those contacts is not quite straightforward and often is not consistent between applications.

One feature that is currently not yet implemented in Android OS but was desired by our participants is the possibility to define what modalities (auditory, tactile or visual) are used to notify the user and how those should be presented. In particular, choosing what visual means are used seems quite important to our users. In our study users preferred symbols and colors over text. While we first thought this was due to the rather small font size on our display, when asked, participants stated that instead of reading they would rather have a representation that is interpretable at a glance, which is in line with prior work (Ashbrook, Clawson, Lyons, Starner, & Patel, 2008; Gouveia, Pereira, Karapanos, Munson, & Hassenzahl, 2016; Pizza, Brown, McMillan, & Lampinen, 2016). Contrary to this, the participants preferred discrete numbers instead of rough estimates. This means that they would rather choose to light up several LEDs instead of one blinking in a temporal fashion. In terms of spatial arrangement, they still preferred notifications of similar types (e.g. same app or same person) to be grouped.

CONCLUSION AND FUTURE WORK

To overcome the need for explicit interaction that current smartwatches require to have a glance at incoming notifications, we provide an aggregation/filtering approach as well as several displaying concepts based on a self-built, power-efficient smartwatch prototype with twelve full-color LEDs around a low-resolution display. The results of our study indicate that users desire to have more control over what notifications are shown to them and how they are visualized. Additionally, we derived a number of guidelines on how to visualize notifications that can be applied to current commercial smartwatches, as well as which filtering methods should be available.

Android Watchface Implementation

Although our laboratory study already revealed interesting insights, it would also be interesting to see how people interact with the filter concept and the possible visualization strategies in their everyday lives. As this is not easily possible with our self-built prototype (e.g. due to power restrictions), we implemented the same concept as Android Wear watchface which we plan to bring to the Google Play Store (see Figure 7). It also features twelve LED positions and a middle area that can be used in the same way as we implemented in our prototype. In contrast to our laboratory study, also aspects like the low-colored ambient mode and its effects w.r.t. notification perception have to be taken into

Figure 7. Design concept for the Android watchface as well as its realization on a LG G Watch R

account. Through a long-term in-the-wild evaluation using this watchface, we hope to be able to assess the benefits of our concept in more depth. This will include a quantitative evaluation for e.g. response times and needed interactions to react to the notifications. Furthermore, we want to extend the concept to other types of wearables such as fitness bands.

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