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
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