
Glance Awareness and Gaze Interaction in Smartwatches

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Abstract

Smartwatches are widely available and increasingly adopted by consumers. The most common way of interacting with smartwatches is either touching a screen or pressing buttons on the sides. However, such techniques require using both hands. We propose glance awareness and active gaze interaction as alternative techniques to interact with smartwatches. We will describe an experiment conducted to understand the user preferences for visual and haptic feedback on a “glance” at the wristwatch. Following the glance, the users interacted with the watch using gaze gestures. Our results showed that user preferences differed depending on the complexity of the interaction. No clear preference emerged for complex interaction. For simple interaction, haptics was the preferred glance feedback modality.

Author Keywords

Wearable computing; gaze input; haptic feedback;

ACM Classification Keywords

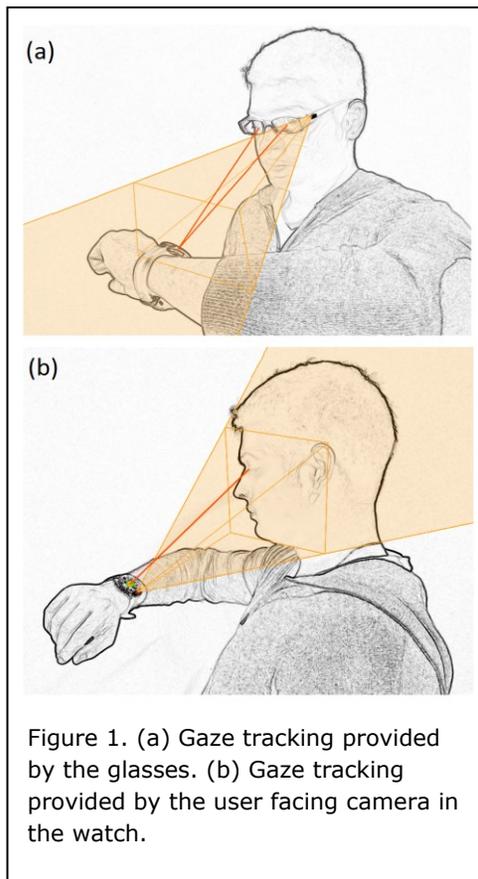
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Wearable computing devices such as smartwatches cater to our need for accessing information quickly and

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conveniently. However, they also introduce new challenges in interaction. Firstly, the screen size is limited. Secondly, the interaction technique should be flexible to support scenarios where some physical and cognitive resources are occupied in other tasks. “*Glanceability*” (i.e., providing all the relevant information in a glance with minimal user input) is considered an important design paradigm for wearable display devices like the smartwatch [8].

We propose that smartwatches benefit from being aware of the user’s glances and also from active gaze interaction. Smartwatches that know when the user is looking at the device display can automatically provide important information that is relevant to the current use context without any user input. Furthermore the watch can also know when the information has been viewed. Smartwatches which support active gaze interaction can enable flexible, hands-free, and ubiquitous interaction.

The most common techniques to interact with commercial smartwatches are pressing buttons on the sides and touching the screen. However, the display objects/buttons are often small for the fingers and fingers may also occlude the display. Many other more expressive methods of interaction have been proposed in the research community. For example, Facet [7] used multiple independent touchscreen display segments to enable more sophisticated interactions. The Gesture watch [4] and Hoverflow [6] used mid-air gestural interaction above the wristwatch. Xiao et al. used a multi-degree of freedom mechanical interface to twist, tilt and click the watch face [11]. WatchIt used a touch-sensitive watch strap for interaction [9]. Knibbe et al. proposed using the back of the hand as an

interactive touch surface extension for the watch [5]. All these techniques require the use of the non-wearing hand for the interaction.

Knibbe et al. also proposed using hand and finger gestures on the wearing hand to interact with the watch [5]. Such interactions do not need both hands, but gesture interfaces are vulnerable to false recognitions, unless used together with an “activate” feature. Such “activate” features are also employed in commercial smartwatches. For example, Samsung Galaxy Gear uses the hand-raising gesture to activate the screen.

We envision two scenarios that provide gaze-tracking capability in watches. Firstly, the user would be wearing gaze-tracking capable smart glasses that are wirelessly connected to the watch (Figure 1a). Secondly, the watch would have a camera facing the user to track the eyes (Figure 1b). The second method could be usable when high gaze-tracking accuracy is not required. Many commercial wristwatches already have an outward facing camera (e.g., Samsung Galaxy Gear II).

An existing challenge in using gaze-tracking is to provide appropriate feedback to gaze events. The wristwatch form factor allows visual, auditory and haptic feedback. Auditory feedback may not be appropriate in all scenarios. Providing visual feedback to gaze events is plausible, but it is challenging in small display devices that need to save the screen real estate. Many popular smartwatches are already equipped with haptic actuators (e.g., the Pebble watch) which can vibrate to inform of an incoming call or notification. Haptics is also known to be a feasible and effective feedback modality for gaze events [2, 3].



Figure 2. (a) Menu Navigation application. (b) An example notification with the clock bar in purple color providing visual feedback for glance.

In the following section, we describe an experiment to understand and compare user preferences for using visual or haptic modalities to provide “glance” feedback *i.e.* feedback when the user is looking at the device, to confirm its readiness for subsequent interaction. We also report the users’ subjective opinions on using gaze-based interaction on wristwatches. We conclude by presenting different ways of using gaze-based interaction in smartwatches and combining it with other available modalities for more natural usage.

Experiment

The experiment was designed to resemble an everyday scenario in which the user looks at the watch to perform an action, the watch provides either visual or haptic glance feedback (depending on the condition) and the user proceeds with subsequent interaction using gaze gestures. Gaze gestures were chosen as they are known to be more robust to tracking inaccuracies than dwell-based methods and are suitable for interaction with small objects on the display [1].

We implemented two applications: a menu application with horizontal navigation and item selection using gaze gestures (Figure 2a), and a notification application, which presented users with haptic notification of events (incoming calls, messages *etc.*) at random intervals of time (Figure 2b). The main objective was to understand possible differences in the user’s subjective evaluation between the two feedback conditions (*i.e.*, visual or haptic) and between the two applications. In the menu navigation task, the participants were required to perform multiple gestures to accomplish the task. For the notification task, the participants were only required to perform a single gesture. We anticipated that the complexity of

subsequent interaction would have an effect on how the users perceive the benefit of glance feedback. The secondary, and more general objective was to understand the user’s perception of using gaze-based interaction on smartwatches.

Apparatus

The prototype wristwatch was built on the Microsoft .NET Gadgeteer 4.2 platform [10] using FEZ Raptor mainboard and N18 color display module (128x160 pixels, 1.8 inches). We used the Ergoneer Dikablis head mounted gaze tracker along with the prototype wrist device to simulate a gaze-tracking capable smartwatch. A visual marker was placed adjacent to the watch display for easy recognition of the position of the watch using the scene camera on the tracker (Figure 3). The display was attached to a layer of soft foam for comfortable wearing. A linear resonant haptic actuator (Precision Microdrive C10-100) was mounted on the layer of foam between the display and the skin to provide haptic feedback. The gaze tracker was connected to a Windows 7 laptop which recognized the gaze events and sent commands for updating the watch display to the FEZ Raptor using a USB connection.

Gaze Gestures

We used two stroke off-screen gaze gestures as used by Kangas et al. [2]. Using off-screen gestures made the input area larger than the display area of the watch. Each gesture started from the display of the watch. The first stroke of a gesture moved over the edge of the display in leftward, rightward or upward direction. The second stroke returned back to the display. Three gestures were used based on the direction of the first stroke: *LEFT*, *RIGHT* and *UP* gestures. We used an 800 milliseconds time-out for a

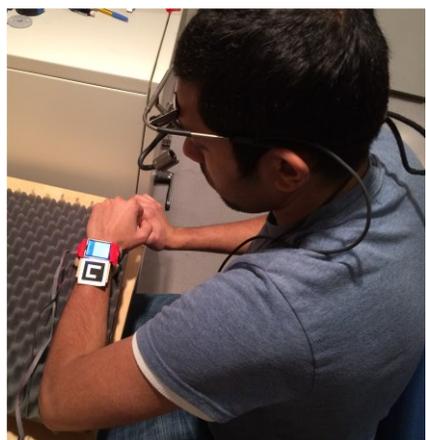


Figure 3. Experiment setup using the Ergoneer Dikablis gaze tracker and the prototype wrist device.

gesture completion to differentiate between normal eye movement and gaze gesture commands. The time-out value was set based on pilot tests.

Glance feedback conditions – Haptic and Visual

A momentary visual or haptic glance feedback was provided as soon as the gaze tracker detected a gaze sample on the watch display. For visual feedback, the clock bar turned from grey to purple for 500 milliseconds (Figure 2). The feedback was given again for any subsequent glance following a minimum of 1.5 seconds of gaze outside the display. The haptic feedback was designed to resemble a short tap by using a duration of 30ms and a driving signal of 175Hz sine wave. The delay between a user glance and visual or haptic feedback was measured using a camera-based technique. The delay was approximately 150ms for visuals and 200ms for haptics. Both delays were within the 250ms limit for natural association of gaze events and haptic feedback [3].

Participants

12 volunteer participants from the university community (6 male, 6 female) with a median age of 23 years (range: 20-42 years) took part in the study. None of the participants had previous gaze-tracking experience.

Procedure

Participants were introduced to the gaze tracker, the prototype wristwatch and the experiment. Next they signed an informed consent form and filled in a background questionnaire. After calibrating the gaze tracker, the haptic and visual feedbacks were played a few times to ensure that they were easy to notice. The participants were instructed to keep their hand on the

arm rest (as shown in Figure 3) but were free to move their head.

All participants used the menu application first. The task was to navigate to a specific menu item (using *LEFT* and *RIGHT* gaze gestures) and select the item (using *UP* gesture). The list was in alphabetical order and cyclical. After a successful selection, the system would pause for three seconds, before automatically returning to the menu. During this pause, the participant was given a piece of paper with the name of the item to select next. This required the user to look away from the watch display and ensured that they received glance feedback for the next interaction. In each feedback condition, the participant was asked to perform 10 menu item selections. The menu navigation task was followed by the notification task. Participants looked away from the watch display and then received a series of 10 haptic notifications. The haptic pulse was 100ms long. As soon as the notification was received, the participants looked at the display, received the glance feedback and then viewed the notification using *RIGHT* gesture. The system waited for a random period of 8-10 seconds before sending the next notification. After each condition, participants rated the interaction in terms of ease of use, comfort and confidence using 7-point Likert scales. In both tasks, the order of feedback conditions was counterbalanced.

Results

Figures 4a and 4b show the subjective evaluation results of menu navigation and notification based tasks, respectively. There were no clear differences in the ratings between visual and haptic glance feedback in the menu navigation task. The overall user preference was also mixed. 4 participants preferred haptics, 6

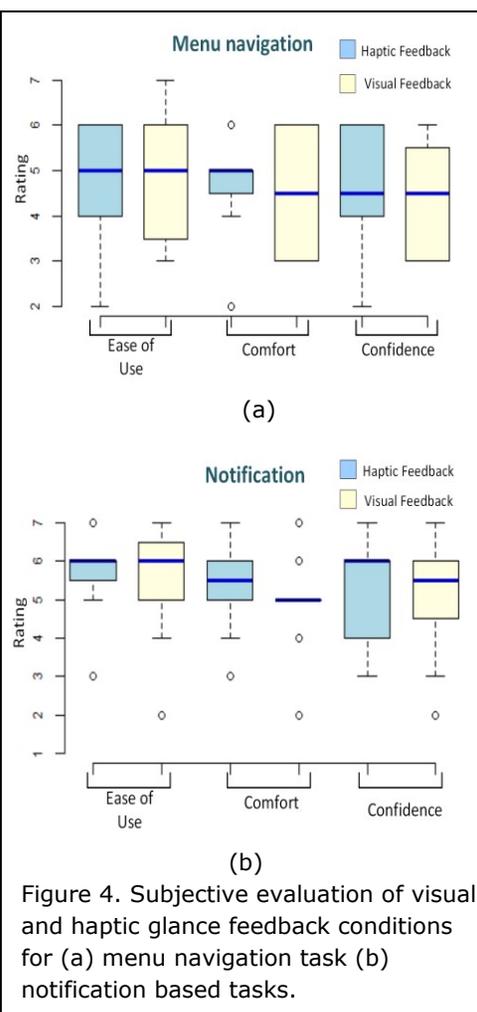


Figure 4. Subjective evaluation of visual and haptic glance feedback conditions for (a) menu navigation task (b) notification based tasks.

preferred visual feedback and 2 participants stated that both modalities worked equally well. In the notification based task, however, a majority of participants (9/12) preferred haptic glance feedback, 2 preferred visual feedback, and 1 stated that both modalities worked equally well. The Wilcoxon signed-rank test showed that the participants rated haptic feedback as significantly more comfortable ($p < 0.05$) in the notification task. Participants who preferred haptics commented:

P6: "Haptics was more clear and noticeable"

P2: "[With haptics] it was easier to make sure that eye contact was registered."

P11: "Vibration felt more natural"

Participants who preferred visual feedback felt that visual feedback was more appropriate because the user is already looking at the display. Two participants also reported the multiple vibrations in the notification-based task as distracting. When asked which of the two tasks they would like to perform with eyes, 9 out of 12 participants preferred the simple notification based tasks over the complex menu navigation task. The remaining 3 participants preferred to do both. In general, participants felt positive about gaze-based interaction on smartwatches.

P3: "[With gaze based interaction] you do not need to use your hands. Gazing is easier and faster in some scenarios."

Discussion and future work

In this paper, we presented a study of a gaze-based interaction in smartwatches. The interaction was rated positively and our results suggest that it is a practical interaction modality with such devices. Participants

preferred to do simple and occasional tasks with gaze rather than continuous tasks. Haptics was the preferred feedback modality for glance events in the notification-based task. In the notification-based task, there was more text content on the display and this may have affected the subjective evaluation of the visual feedback condition. Providing visual feedback to gaze events can be difficult in small screen devices with rich display content. Haptics can be useful in such scenarios to offload the visual channel resulting in a more comfortable interaction. The current study showed that the combination of gaze input and haptic feedback could be beneficial in smartwatches and encourages further research in more natural usage environment.

The length and complexity of the gaze gesture interaction may have influenced the perceived usefulness and choice of the one-time glance feedback. Further research is required to understand the effect of glance feedback on objective measures like task completion time and error rate. In our study, the accuracy of gaze-tracking was maintained as high as possible by recalibrating the tracker between tasks whenever required. However, in a mobile environment, the accuracy of tracking may deteriorate with time. Further study is required to understand its effect on the task and glance feedback preferences.

There exist challenges to incorporate glance awareness and gaze-tracking into smartwatches. Such devices would need a continuously active gaze-tracking sensor (on the watch or the glasses), which would increase battery usage. The camera viewing angle would pose limitations on the positioning of the device in relation to the head. The limited processing power may induce delays in detecting the gaze, affecting the interaction.

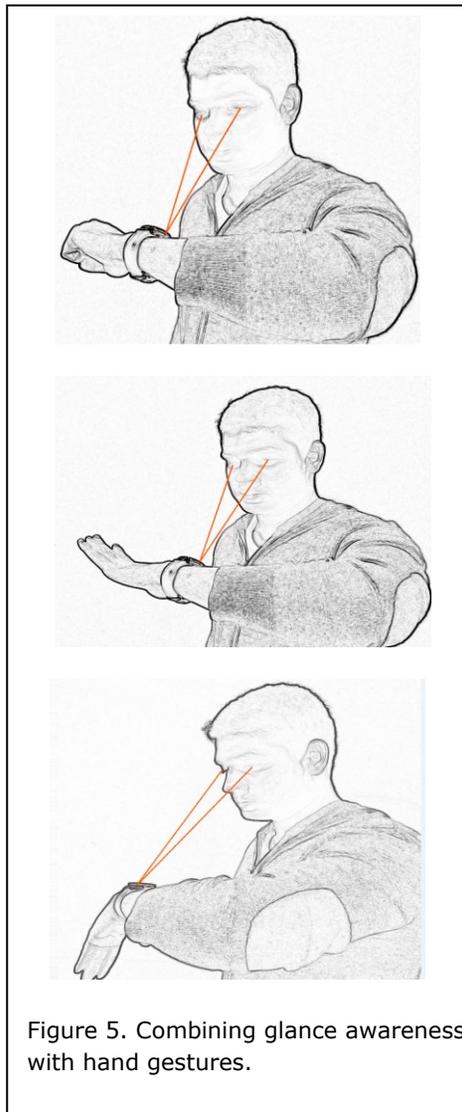


Figure 5. Combining glance awareness with hand gestures.

Despite the technical challenges, we feel that gaze-tracking in such devices could open up exciting and natural usage scenarios. Some of which are presented below:

Display activation upon user glance: The watch may dim the display when the user is not looking at the device. Such techniques not only reduce battery usage but also enhance information security.

Auto-scrolling of text and dynamic notification playback: The device may automatically scroll long messages, or display different notifications one after the other, without user input.

Automatic deletion of notifications: The watch can automatically remove already seen notifications.

Discrete hands-free interaction with the watch: The user could do gaze gestures to perform simple occasional tasks, like accepting an incoming call.

Gaze-only interfaces limit the complexity of interaction. In future, we plan to study natural ways of combining gaze-based interaction with other available interaction modalities in the wristwatch for more complex tasks. Figure 5 shows possible ways of combining glance awareness and gestures with the wearing hand.

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