

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

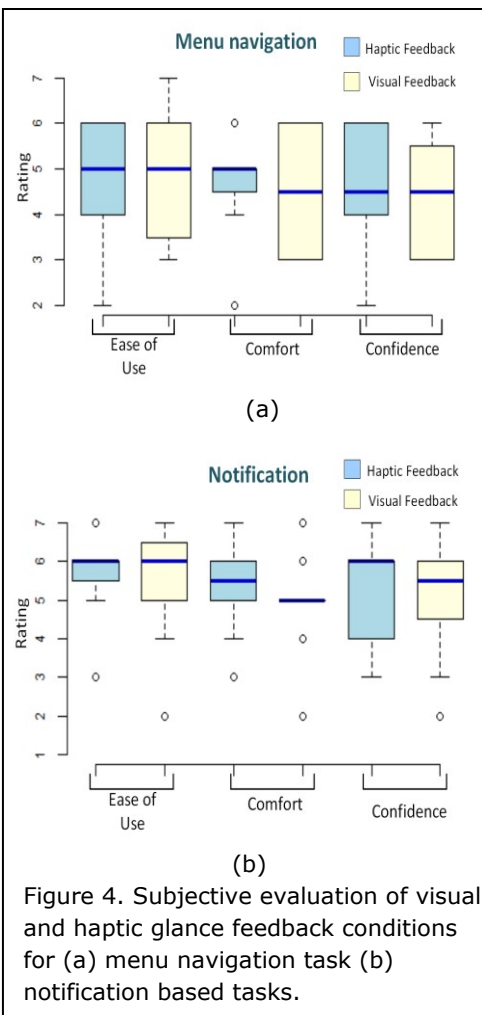


Figure 4. Subjective evaluation of visual and haptic glance feedback conditions for (a) menu navigation task (b) notification based tasks.

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.

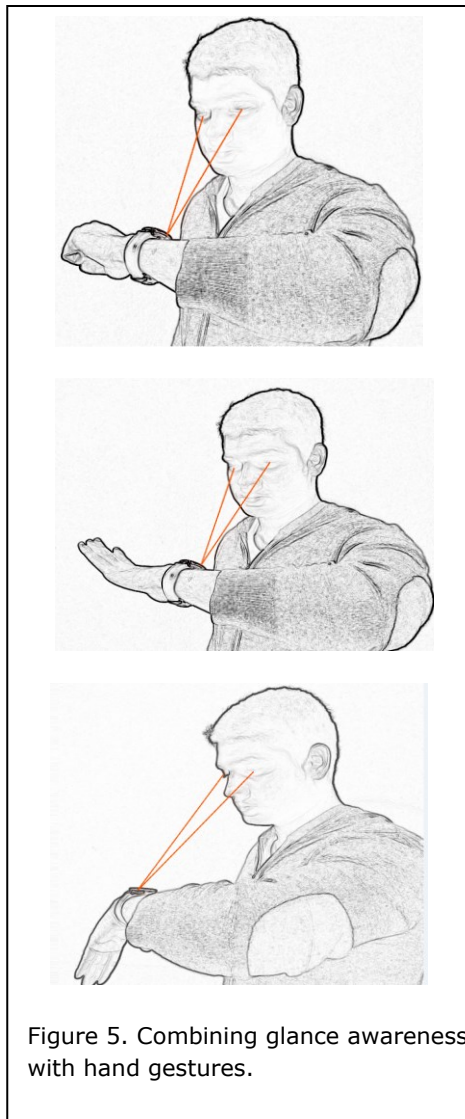


Figure 5. Combining glance awareness with hand gestures.

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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