Peripheral Information Displays Using Vibro-Tactile Stimuli

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Abstract
We conducted an initial attempt to study the boundaries of peripheral perception using vibro-tactile stimuli. For three days, we exposed 12 subjects to a continual vibration pattern created by a mobile device worn in the trouser pocket. In order to guarantee that the stimuli would not require the subjects' focal attention, they were asked to set the vibration intensity to just above their personal detection threshold when sitting still. At random intervals, the vibration stopped. Participants were asked to acknowledge these events as soon as they noticed. Our findings reveal that only 16.7% of events were acknowledged within one minute, and participants reported not to be annoyed by the signal in more than 95% of the events. These results provide first evidence that vibration patterns can form non-annoying, light-weight information displays, which can be consumed at the periphery of attention.

Author Keywords
Ambient User Interfaces; Peripheral User Interfaces; Haptics; Vibro-Tactile; Awareness Interfaces

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces;

Background and Motivation

Ambient display or *peripheral display* refers to an information display that is designed to convey information in the periphery of the user's attention. Such displays can be used to keep people aware about important but non-critical status information (e.g. weather, amount of unread messages) concurrent to a focal, primary task on which the user needs to focus (e.g. reading a paper, composing an email). Ideally, information can bypass focal attention, so users will even not be aware of the ambient display, but at the same time stay aware about the information it conveys.

Peripheral vision and ambient soundscapes have been proposed to implement such interfaces ([3], [5]). For example, when first mentioning the ambientROOM, Ishii & Ullmer [3] discuss the use of the sound of raindrops and varying the light in the room to convey the number of visits to a web page. However, the use of hearing and vision may not always be appropriate, as signals may interfere with other visual and auditory interfaces, may violate its users privacy, and add to a general cacophony of visual and auditory signals in our increasingly computerized environment.

Consequently, MacLean has suggested *putting haptics into the* ambience [4]. Many haptic sensory signals are already processed subconsciously. For example, Wang et al. [6] have shown that artificially created touches can be processed concurrent to listening to a story and deepen the connectedness with the storyteller.

A study that is closer to our work is that of Hemmert [2]. He explored the use of continual vibration as a means to make phones convey an "*I'm here, and everything is fine*" status message. Six people were asked to carry a mobile phone in the pocket, which continuously created heartbeat-like vibration pulses. A timer was set to let the phone "*die*" every 10-15 minutes, i.e. to turn off the vibration. As soon as they noticed, participants had to "*revive*" the phone by taking it out of the pocket and pressing a key. In more than half of these "death" events, participants reacted within only 60 seconds. Hemmert reports that "*many users in our test group were quickly annoyed by the pulse, only few got used to it*", so it remains unclear whether the vibro-tactile stimulus actually entered the periphery of the participants' attention.

In this work-in-progress, we advanced Hemmert's work by making sure that the vibration cue does not enter focal attention or become annoying. Since vibro-tactile actuators are ubiquitous and found in almost every phone, exploring their feasibility is still worthwhile. We report from a pilot study, in which 12 participants, for up to three days, were exposed to a continually repeating, gentle and steady vibration pattern. We provide evidence indicating that vibration cues can enter the periphery of human perception.

Methodology

We conducted a field study to investigate the following two hypotheses:

- H1: if the vibration intensity is set by users according to their lowest personal detection threshold, they will eventually "forget" the vibration.
- H2: despite "forgetting" the vibration, users will notice changes in the vibration patterns within a reasonable amount of time.

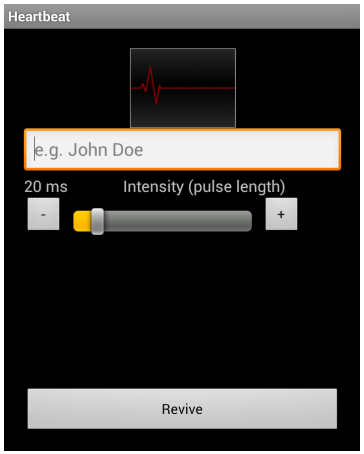

Figure 1 Main view at Death Event

Figure 2 Questionnaire shown when subjects pressed the Revive Button

Apparatus & Stimulus

We used common smartphones, since they provide the necessary actuator, the sensors, and the capabilities to capture data and collect participants' feedback on-the-fly. The phone models used in this study were *Nexus One* and *Nexus S* (weight: 130g, dimensions: 123.9 x 63 x 10.9 mm, OS: Android).

Design

Similarly to Hemmert's work [2], we used the phone's built-in vibration motors to create a heartbeat-like vibration pattern. Nevertheless, our study design has a number of methodological differences when compared to [2], tailored at exploring the feasibility of creating a peripheral display.

First, we fine-tuned the "heart beat" pattern during the pilot test. The chosen pattern consists of two short pulses separated by a 500 ms pause. The pause between two "heart beats" was 5 sec. Our pilot testers considered this to be a calm and soothing pattern.

When using continual vibration, the added energy consumption of the vibration actuator needs to be considered. Hence, we tested the battery consumption of our setup and found that it reduces the battery life by 2.4 – 5%[1], which is acceptable for this study.

Another key difference in our study is the participants' proactive role in initially adjusting the vibration intensity according to their personal perception threshold. They were allowed to alter the vibration intensity throughout the study to make sure it wouldn't enter their focal attention. This was performed by operating a graphical slider on the phone screen (see Fig. 1)to manually adjust the driving time of vibration motors. By driving the motors for a few ms only, vibrations with lower-than-max intensity were created. We asked participants to keep the intensity at a level where they just barely perceive the vibration when not moving.

The third significant difference in our study is related to the detection of whether the vibration is perceived in the periphery of the user's attention. By taking the stimulus away—*Death Event*, participants could only notice its absence if it already was in their (peripheral or focal) attention.

Hence, while [2] generated Death Events randomly every 10-15 minutes, we opted for a longer time range of 15-60 minutes to avoid generating anxiety and expectation. Furthermore, in the case of a Death Event, a button with the label "*revive*" became visible and participants were asked to acknowledge the event by pressing the button. Conversely to [2], in our study the revive button triggered a short questionnaire (shown in Fig. 2), which allowed us to collect contextual factors via subjective feedback. Participants were asked to rate the agreement to the following statements in a three-point Likert scale:

- *I noticed at once when the vibration stopped*
- *I reacted immediately once I noticed*
- *In the last minutes, the vibration was annoying*
- *The device was pressed tightly against the skin*

Finally, we used the phone sensors to also log additional contextual factors. Our pilot tests showed that the perception of the vibration is strongly impeded

[1] Full description available at http://pielot.org/?p=1178.

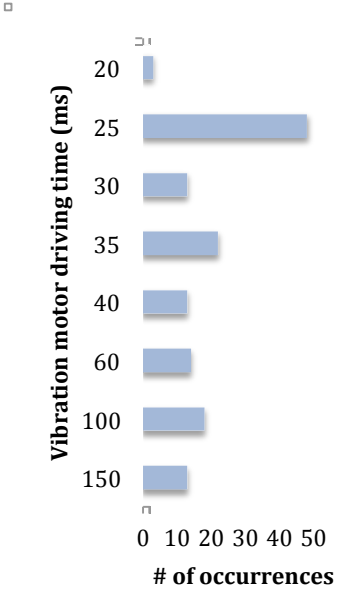

Figure 3 Histogram of Vibration Intensities prior to Death Events

by movement and the social context. As soon as our pilot testers started moving, the vibration was not perceptible anymore. Additionally, in social situations, e.g. at lunch, the perception degrades, too. Hence, one minute before each death event, we used the phone sensors to record the level of activity, i.e. the normal vector of the acceleration along all three axes in m/s^2, and the average noise level in dB via the phone's built-in microphone.

Participants

We recruited 12 participants (7 male) with an average age of 26.9 years old (SD = 4.1). They all worked with information technology in a multinational company and used to carry a smartphone on a daily basis.

Procedure

We briefed each participant individually. First, we informed them that we were trying to investigate, whether vibration can be perceived peripherally. Then, we asked participants to test different vibration intensity settings and to identify the intensity that they just barely could perceive when sitting still. We demonstrated a Death Event and walked them through the questionnaires. Finally, we advised participants to continually keep the phone in their trouser pocket; whenever necessary, they could simply take it off and shut down the vibration application (developed for the study). Otherwise, the participants were asked to go on with their daily routines. They were also encouraged to contact us and give us feedback at any point during the study. By the end of the third day, we briefly interviewed them in an open interview.

Results

We collected data from 234 Death Events. Since the study took place during everyday activities, participants did not always carry the phone next to their body and they neither could always react immediately after perceiving a Death Event. Hence, we filtered out cases when participants did not fully agree to: (1) "*I reacted immediately once I noticed [that the vibration stopped]"* (82 instances), and (2) "*The device was pressed tightly against the skin"* (11 instances). In the following, we focus our analysis on the remaining 144 Death Events. Figure 4 shows the participants' responses to the "revive" questionnaire.

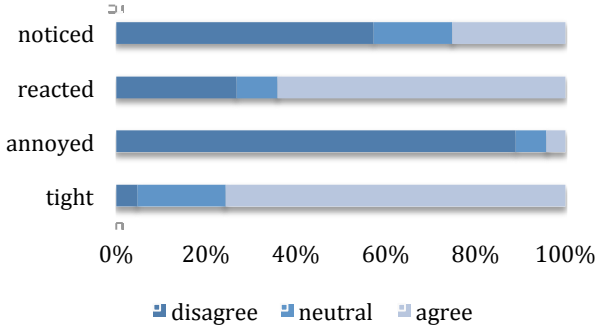

Figure 4 User rating of statements after Death Event. *Annoyed* and *Noticed* responses are filtered to only represent events where participants could perceive the phone well (tight = 3) and reacted fast (reacted = 3) to the Death Events.

Participants largely disagreed with the statement "*In the last minutes, the vibration was annoying"* in 128 (88.9%) of the valid Death Events. Hence, the vibration cue was hardly considered annoying.

For the majority of the considered Death Events, participants did not agree to the statement "*I noticed at once when the vibration stopped*" (56.9% disagree, 17.4% neutral, 25.0% agree). Hence, most of the time, the participants were subjectively not aware of the vibration when it stopped.

Figure 5 shows how fast participants acknowledged Death Events. In average, participants acknowledged a Death Event in 13.5 minutes (Mdn = 6.7, SD = 18.7). 24 (16.7%) events were acknowledged within 1 minute and 88 (61.1%) within 10 minutes. All but three (97.9%) events were acknowledged within 1 hour.

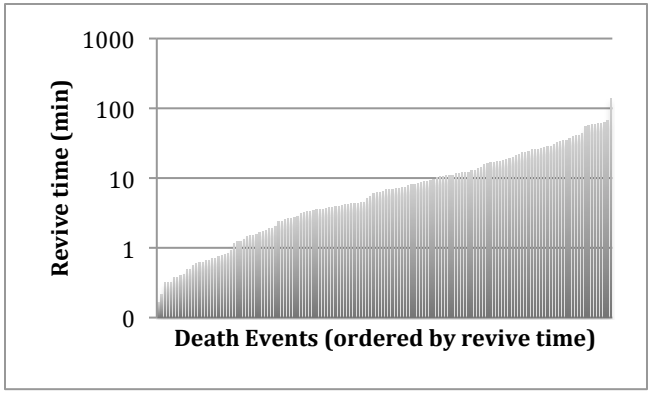

Figure 5 Time span between Death Event and its acknowledgment by the participants (*revive time*)

Regarding external factors, we checked for correlations between the measured factors and the time to revive the phone. To our surprise, we neither found a significant correlation between revive time and level of activity (Pearson's r = -.023, p =.79), nor noise level (Pearson's r = .095, p = .26).

Participant Feedback

Among the main observations collected face-to-face with participants during and after the study, we highlight at least three points:

First, it appears that *users can get used to the vibration pattern*. Only 3 participants stated they initially focused a lot on the vibration, but got used to it over time. 5 participants reported that the perception of the vibration diminishes with time. Hence, it appears that people get used to the vibration and start to blend it out of their focal attention. Nevertheless, we could not find any significant correlation between individual usage time and how fast participants subjectively and objectively reacted to Death Events.

Second, we observed that *perception strongly depends on context*: 5 participants noted that the perception of the vibration strongly depends on the level of activity. The more active they are (walking, running) the less likely they are to perceive the vibration. 3 participants added that being busy with other things, e.g. meeting people for lunch or being focused on work, made them forget about the vibration altogether.

And finally*, vibration can be considered tiring.* In fact, only 2 participants stated that they found the vibration tiring, while other 2 participants reported that they actively had to pay attention to it at times.

Discussion

We collected 234 events of which 144 were used for analysis. Of the Death Events, the majority was acknowledged within 10 minutes. The participants hardly reported to be annoyed on the vibration. Most of the time, the participants felt that they did not notice

the event immediately. There were no statistically significant correlations between the logged contextual factors and how fast participants acknowledged events.

These results support H1 (*participants will get used to vibration*). Moreover, our findings with the "revive" questionnaire reveal that participants rarely considered the vibration to be annoying, and that they rarely felt that they immediately noticed Death Events. These are good indicators that participants are usually unaware of the vibration. We can therefore conclude that the vibro-tactile cue hardly attracted the participants' focal attention.

Conversely, we have less conclusive evidence regarding H2 (*users will remain aware about changes in the vibration*). Two thirds of the Death Events were acknowledged within 10 min, however, some events also went undetected for up to more than one hour. We conclude that users were at least at time peripherally aware about the vibration. However, we could not identify contextual factors that influence the perception.

In Hemmert's study [2], participants reacted much faster to the absence of the cue, but they also reported to be annoyed in general. This indicates that in his study, the vibration cue was more often in the focal attention of the participants, whereas it was not in our study. Thus, the results of our study add evidence to the body of knowledge that goes beyond [2].

Conclusions

We have provided evidence that continual vibration patterns can be consumed in the periphery of attention. The data indicates that our subjects were aware, but not focused on the vibration cues.

This means that vibro-tactile stimuli have the potential to create private peripheral user interfaces. Future research needs to explore, how to apply this knowledge in meaningful ways, as well as how different contextual factors impact in the perception.

Acknowledgments

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References

[1] Consolvo, S. & Towle, J. Evaluating an ambient display for the home. In *Proc. CHI*, ACM, 2005.

[2] Hemmert, F. Ambient Life: Interrupted Permanent Tactile Life-like Actuation as a Status Display in Mobile Phones. *Proc. Ambient Information Systems. Colocated with Ubicomp*, 2008.

[3] Ishii, H. & Ullmer, B. Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proc. CHI*, ACM, 1997.

[4] MacLean, K. E. Putting Haptics into the Ambience. In *IEEE Trans. Haptics*, 2009, 2, 123-135.

[5] Messeter, J. & Molenaar, D. Evaluating ambient displays in the wild: highlighting social aspects of use in public settings. In *Proc DIS, ACM,* 2012.

[6] Wang, R., Quek, F., Tatar, D., Teh, K. S. & Cheok, A. Keep in touch: channel, expectation and experience. In *Proc. CHI*, ACM, 2012, 139-148.