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Supporting the Mobile Notification Process through Tactile Cues Selected using a Paired Comparison Task

Huimin Qian
UMBC
1000 Hilltop Circle
Baltimore, MD 21250, USA
huimin1@umbc.edu

Ravi Kuber
UMBC
1000 Hilltop Circle
Baltimore, MD 21250, USA
rkuber@umbc.edu

Andrew Sears
Rochester Institute of Technology
20 Lomb Memorial Drive
Rochester, NY 14623, USA
andrew.sears@rit.edu

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Abstract
The process of checking mobile notifications can be challenging when the user is engaged with another task that requires him/her to monitor the path ahead (e.g. running, driving). Developing expressive tactile feedback to communicate key components of the message would enable users to decide whether to attend to the notification, or to continue with the on-going activity. We describe the design of a paired-comparison task to determine how to map tactile parameters to characteristics of incoming messages. Early findings from a field study highlight the promise offered by multi-parameter tactile cues designed using mappings identified from the paired-comparison task, even when distracters are present.

Author Keywords
Tactile interfaces

ACM Classification Keywords
H.5.2. User Interfaces: Haptic I/O.

Introduction
Mobile notifications alert users to the presence of incoming calls, messages or emails. Difficulties can be faced attending to notifications, if the user must

interrupt an on-going activity where the eyes are focused on the path ahead (e.g. running, driving).

The tactile channel offers considerable potential for delivering information to the user, so that he/she can determine whether to continue with the existing task or to temporarily stop/leave the environment to respond to the notification. However, limited tactile design guidance targeting the needs of mobile users, can lead to designers arbitrarily selecting tactile cues to represent various interface objects and events, which must then be explicitly learned by the user.

In this paper, we describe a study to map the parameters of tactile feedback to characteristics of messages, using a paired-comparison task. The aim is to determine the most effective way to communicate messages to individuals who are temporarily impaired by the situation or environment.

Related Work

While metaphorical associations can be made between audio and corresponding icons (e.g. sound of camera shutter when selecting an icon to take a photo), MacLean [4] suggests metaphors do not always scale well to tactile displays. This is, in part, attributed to the limitations of mobile tactile hardware. Furthermore, tactile cues are often chosen arbitrarily by interface designers, with limited consideration of the time or effort needed to learn the mappings.

In order to develop meaningful mappings, researchers have attempted to elicit design ideas from users through focus groups [7]. The resulting discussions can lead to improved prototypes, or trigger the development of new tactile design ideas. However, describing tactile phenomena can present a challenge, due to our limited vocabulary for touch-based terms.

Paired-comparison tasks have been used as a method for determining the relationships between information mappings and individual parameters in the audio and tactile modalities. Parameters such as rhythm, texture and tempo played an important role when given a specific type of information to transmit [3]. Walker et al. [8] examined ways to communicate temperature, pressure, velocity and size through audio to better represent scientific terms. The study raised some interesting research questions. For example, if an association is made between the frequency of a sound and temperature, will increasing the frequency result in a proportionate increase in the temperature reported by participants.

We use a similar method to the one described by [8], to better identify ways to communicate notifications using tactile feedback.

Method

A study was designed to examine the ways in which tactile parameters could be mapped to characteristics of messages. The message characteristics were determined in a pilot study where mobile device users identified the most important features that they would wish to extract when receiving a notification (e.g. relationship with sender, urgency of message, frequency of contact with sender, size of message).

To widen the range of cues, tactile feedback was distributed from the mobile device to different positions on the body. A prototype was developed using a Dell Streak tablet (Figure 1), Arduino technology, and two

Figure 1. Dell Streak tablet (www.dell.com)

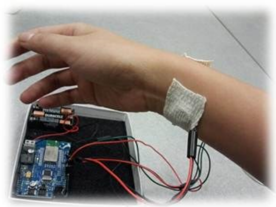

Figure 2. Prototype to distribute tactile feedback to wrist via pancake motors

pancake motors for this purpose. The motors were affixed to either side of the wrist using medical tape (Figure 2). A laptop computer was used to present visual stimuli to participants and to record responses.

Twenty volunteers (aged 18-29) who had not participated in our earlier studies were recruited. None of the participants reported issues with auditory or tactile perception.

Table 1: Design of 16 Sets of Tactons

Set	Duration	Interval	Intensity	Location
1	Long	Long	Strong	Volar
2	Long	Long	Strong	Dorsal
3	Long	Long	Weak	Volar
4	Long	Long	Weak	Dorsal
5	Long	Short	Strong	Volar
6	Long	Short	Strong	Dorsal
7	Long	Short	Weak	Volar
8	Long	Short	Weak	Dorsal
9	Short	Long	Strong	Volar
10	Short	Long	Strong	Dorsal
11	Short	Long	Weak	Volar
12	Short	Long	Weak	Dorsal
13	Short	Short	Strong	Volar
14	Short	Short	Strong	Dorsal
15	Short	Short	Weak	Volar
16	Short	Short	Weak	Dorsal

A series of screens were presented to participants via the laptop. Each screen contained two square buttons, labelled 'A' and 'B', each of which was associated with a randomly-selected four-parameter tacton selected from an earlier study examining human perceptual limitations (Table 1). Two values of each parameter were presented. These included duration (800ms/200ms [6]), interval (800ms/200ms [6]), intensity (2.1g and 255 Hz / 0.65g and 128 Hz), and spatial location (volar/dorsal site [1]), resulting in a total of 16 unique tactons (Table 1). When participants moved the cursor over these buttons, a vibration was presented via one of the pancake motors.

Table 2: Pairs of Cue Questions

Characteristic	Cue Questions
Relationship with message sender	Q1. Which tacton best represents something that is closer? Q2. Which tacton best represents something that is further?
Urgency of the message	Q3. Which tacton best represents something that is less urgent? Q4. Which tacton best represents something that is more urgent?
Contact frequency with message sender	Q5. Which tacton best represents something that is less frequent? Q6. Which tacton best represents something that is more frequent?
Size of the message	Q7. Which tacton best represents something that is smaller? Q8. Which tacton best represents something that is larger?

Pairs of cue questions were developed for purposes of the study using guidance from [8]. For each trial, one cue question would be presented near the top of the screen, asking participants to determine whether Tacton 'A' or 'B' would be most suitable for conveying a particular notification characteristic (see Table 2). Tactons 'A' and 'B' would only differ by one parameter (e.g. while the duration, interval and location may remain the same, Tacton 'A' may have a stronger / weaker intensity compared with 'B'). The study was fully-factorial in design, with all participants experiencing all tacton combinations for all eight cue questions. The trials were presented in a randomized order, lasting between 60-90 minutes. After completion of the task, participants were asked to describe their experience, identify the one or two tactile mappings they found to be the most intuitive, and explain the reasoning behind their decisions.

Coding of Results

Similar to the study by Walker et al. [8], for each dimension pair (message characteristic and tactile parameter), a signed preference score was determined for each participant. If longer vibrations were judged better for representing longer messages while shorter vibrations were found to better communicate shorter messages, the individual preference score would be +8. A score of -8 would be given if representations met the other extreme (i.e. shorter vibrations better representing larger messages). Scores between +8 and -8 indicated a weaker preference.

Results and Discussion

The aggregated results shown in Table 3 suggest that specific tactile parameters were judged to better represent characteristics of messages, compared with others. For example, intensity was selected most often by participants to communicate urgency (+7.0). More specifically, stronger-feeling vibrations were found to signal the need to respond to the message urgently, while weaker cues appeared to indicate that time could be taken before the user responds to the notification.

Discussion with participants after the task revealed that vibrations presented with shorter intervals better represented more frequent contact with the sender, enabling the user to better determine the identity of the sender and whether the message was important enough to react to immediately. Participants suggested that it may be difficult to passively monitor longer intervals between stimuli as they may be distracted during this process.

Interval was found to be a potential method of communicating the size of the message (+4.0). However, duration was found to lend itself better to communicating this concept (+6.6), particularly if the attachment was so big that it would take a long period of time to download. Using duration to communicate the time needed to perform a task is not uncommon. For example, Hoggan et al. [3] report that participants found duration to be suitable for communicating progress updates especially for longer lasting stimuli (2 seconds).

Table 3: Average results from trials

	Location	Intensity	Interval	Duration
Relationship with sender	6.9 Good	5.4 Okay	3.4 Poor	3.9 Poor
Urgency of the message	5.5 Okay	7.0 Good	4.5 Okay	3.1 Poor
Contact frequency with sender	3.0 Poor	4.0 Okay	6.0 Good	4.1 Okay
Size of the message	2.7 Poor	2.4 Poor	4.0 Okay	6.6 Good

Location of presentation was judged to be the most effective method for communicating relationship with the sender (+6.9). It was also thought to be an appropriate method for conveying urgency of the message (+5.5). Hoggan et al. [2] suggest that presenting cues in sequence at different locations (e.g. in a circular motion pattern) could offer promise when communicating progress updates. Our future work should aim to examine the patterns that could be used for the purpose of communicating message content without overloading the user or causing annoyance if too long in duration.

In an earlier study where participants were asked to design their own multi-parameter tactile cues [5], difficulties were faced determining mapping trends due to the diversity of prototypes developed. In contrast, the signed preference scores from the paired-comparison task offered an effective method to determine preference among participants, enabling us to identify appropriate mappings to integrate with a tactile interface.

Field-Based Study: Current and Future Work

To extend our work, we conducted a longitudinal study to determine the efficacy of tactile cues using mappings identified from the paired-comparison task. Field studies examining tactile perception are rarely performed, due to the complexities of presenting cues and gathering responses from participants. However, field studies provide a method of determining how distracting factors may impact perception and interpretation. They also allow learning curves to be assessed [2].

Table 4: Tactile cue design for longitudinal study

	Set 1	Set 2
Relationship with sender	Location	Interval
Urgency of the message	Intensity	Duration
Contact frequency with sender	Interval	Location
Size of the message	Duration	Intensity

A within-subjects comparison study was designed where six participants (aged 20-67) have been presented with two sets of tactile mappings over a two week period (one week per set). The cues presented are shown in Table 4. Set 1 includes the design of tactile cues that received the highest preference scores in the earlier study, while Set 2 includes the parameters that received the lowest preference scores.

Participants were provided with forty minutes of training to become familiar with the meanings associated with the tactile cues. We shadowed participants at points during the first three days when a new condition was presented. During this time, participants experienced a total of 96 tactons (16 unique tactons presented twice per day for three days) when performing a range of tasks, including idling, walking, typing, and driving through a closed course.

Participants were asked to identify the meaning associated with the tactile cues, which could be recorded by the experimenters, and to describe the perceived level of cognitive workload associated with performing the task (Likert scale 1-5). If the experimenters were not present, participants were asked to record a message on their phone indicating the vibration presented along with details about the context (i.e. perceived while walking) and the environment (i.e. loud shopping mall). They were asked to record these messages at the safest opportunity. Driving tasks were performed under supervision of the experimenter. On the seventh day for each condition, a recall test was performed.

Preliminary results show that recognition rates vary considerably by interaction type. For example, the highest recognition rates were observed when participants were idling (M: 73.8%). Recognition rates decreased when performing another activity at the same time (Typing: 61.7%, Walking: 53.8% and Driving: 36.3%). Simultaneously, levels of perceived cognitive workload increased as more attention-demanding tasks were performed where vigilance of the wider environment/path ahead was required (Typing: 3.3, Walking: 3.8 and Driving: 4.9).

Findings suggest that cues designed using the highest preference scores were recognized with a greater level of accuracy, (Set 1 - M: 59.7%, SD: 16.4%) and less cognitive workload (M: 3.5, SD: 1.0), compared with lower preference scores (Set 2 – Recognition rate - M: 48.1%, SD: 16.0%; Cognitive workload (M: 4.1, SD: 0.7). To determine memorability, a recall test was performed four days after tactons were last presented. Findings showed that tactons from Set 1 (M: 79.0%, SD: 9.4%) were recalled with greater levels of accuracy, compared with Set 2 (M: 57.3%, SD:13.7%).

Preliminary findings from our longitudinal study suggest that using the paired-comparison task for purposes of tactile design can offer promise when integrated with an interface, even when distracters are present, as tactons composed using parameters with a higher preference score were recognized with greater levels of accuracy and less cognitive workload. However, as levels of cognitive workload were found to be high when performing specific tasks (e.g. driving in a closed course: 4.9), future research should investigate whether cues can be more appropriately designed to support recognition/workload in higher-risk scenarios where attention is diverted to multiple sources.

Conclusion and Future Work

The paired-comparison task provided an effective method to map tactile parameters to characteristics of incoming messages. Cues with higher preference scores were recognized with greater levels of accuracy, compared to those with lower preference scores. In terms of future work, we aim to examine whether rates of recognition can be improved through introducing additional tactile parameters (e.g. waveform). Resulting tactons will again be evaluated in the field to determine their efficacy when distracters are present.

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