Feel Who's Talking: Using Tactons for Mobile Phone Alerts

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Abstract
While the sense of touch is capable of processing complex stimuli, the vibration feedback used in mobile phones is generally very simple. Using more complex vibrotactile messages would enable the communication of more information through phone alerts, however it has been suggested that phone vibration motors are not capable of presenting complex messages. This paper reports a study investigating the use of Tactons (tactile icons), presented using a standard mobile phone vibration motor, to represent mobile phone alerts. The recognition rate of 72% achieved for Tactons encoding two pieces of information is comparable to results achieved in a previous experiment with a high specification transducer, indicating that it is possible to communicate multi-dimensional information in mobile phone alerts. These results will help designers to understand the possibilities offered by standard phone vibration motors for communicating complex information.

Keywords
Tactile icons, Tactile displays, non-visual interaction, mobile computing, mobile phones.

ACM Classification Keywords
H5.2. User Interfaces: Haptic I/O.

Introduction

Vibrotactile displays have been featured in mobile phones for many years, but the vibrations used in these devices are very simple and do not fully exploit the potential of vibration as a means of communication. Vibration alerts generally consist of a simple buzz to alert users to incoming calls or messages, or to upcoming calendar appointments. Manufacturers have recently started to go beyond these simple alerts in their products. For example, some Nokia phones feature vibration patterns which accompany MIDI ringtones, Immersion has developed VibeTonz technology for enhancing ringtones and games in mobile phones [1], and Motorola has its own Audio-Haptic approach enhancing ringtones with haptic effects using a multifunction transducer [4]. In addition, the Digital Pen by Nokia [2] also uses vibration for user interface features such as indicating battery status and confirming actions.

Although the possibilities of more complex vibrotactile feedback are now receiving attention, most of these tactile patterns are designed simply to enhance the audio feedback, and there have been no formal studies on how best to design a set of distinguishable vibrotactile messages that can be understood in isolation, when presented without audio feedback. Using vibrotactile feedback alone allows information to be communicated discretely without disturbing others, and can be used to alert users in noisy environments. The goal of this research is to develop a set of distinguishable vibrotactile messages which could be used to customise incoming call alerts.

Tactons are structured, abstract, tactile messages which can be used to communicate information non-visually [3]. Using Tactons for mobile phone alerts could enable tactile-only communication of complex information. In addition to caller information, Tactons could indicate the type of call or message being received, or the priority of the call.

A previous study by Brown et al [3] investigated the design of Tactons to represent mobile phone alerts. The results of that experiment showed an overall recognition rate of 71% for Tactons encoding two parameters of information, indicating that Tactons could be a successful means of communicating information about phone alerts. However, the device used in that study was a specialized device (C2 Tactor from Engineering Acoustics Ltd, www.eaiinfo.com) which is not featured in standard mobile phones.

It has been stated that standard phone vibration motors may not be suitable for communicating complex information, as they do not offer subtle control due to their limited bandwidth and high latency [5, 8]. This paper describes a study in which Tactons encoding multi-dimensional information were presented using a standard phone vibration motor in order to discover what levels of performance can be achieved, and to see how these results compared to those achieved on a high specification device. These results will help designers to understand the possibilities offered by standard phone vibration motors for communicating complex information.

Tactile Device

The device used in this study was a mockup of a widely used mobile phone (Nokia 8210), containing a standard phone vibration motor. The vibration motor is a small DC motor featuring an eccentric weight in the shaft. These vibration motors typically vibrate at frequencies around 130Hz [8]. In this study the full speed of the vibration motor was 10800 RPM (180 Hz).

Tacton Design

Nine Tactons were created to represent alerts which might occur when a message or a call arrives on a mobile phone. Two pieces of information were encoded in each Tacton: the type of alert (voice call, text message, or multimedia message) and the priority (low, medium or high) of the alert. The types of alert were represented by three rhythms which had been shown to be distinguishable in a previous study [3]. Each rhythm was made up of a different number of pulses, with the voice call rhythm made up of seven short pulses, the text message rhythm of four longer pulses, and the multimedia message of one short pulse and one very long pulse.

Two different vibrotactile parameters were tested to encode the priority attribute of the Tactons. Tactile "roughness" was shown to be a successful parameter for Tactons by Brown et al [3], however the amplitude-modulated waveforms used to create these roughnesses could not be reproduced on the phone motor. An approximation of roughness was created by using different speeds of on-off pulses. A "smooth" stimulus was created by using a constant vibration. To create a "rough" sensation, pulses of 10 milliseconds were repeated with 10 millisecond pauses in between, while the "very rough" sensation was created using 30 millisecond pulses, followed by 30 millisecond pauses (Figure 1). This exploits the high latency of the vibration motor, as the slow reactions to changes in the input signal result in a signal which resembles those created by amplitude modulation (Figure 2).

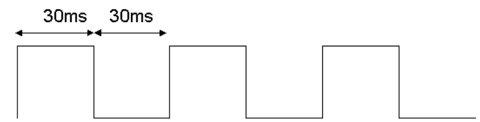

figure 1: The on/off input to the vibration motor for the "very rough" stimulus.

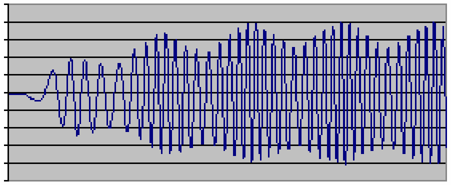

figure 2: The output of the Phone presenting a "very rough" stimulus, measured using a laser vibrometer.

The second parameter tested to encode the priority attribute was the intensity of the vibrations. Earlier studies suggest that perceived intensity is correlated with the velocity of the vibration, and that velocity is affected by frequency and the weight of the counter-weight [7]. Since the counterweight was not changed in this study, only frequency affected the perceived intensity. The frequency of the phone vibration motor is controlled by adjusting the supply voltage.

Experimentation indicated that values below 0.93 Volts were not produced reliably by the vibration motor, so 0.93V was chosen as the lowest value, 1.38V as the maximum value, and 1.16V as the mid way point.

It has been suggested that intensity is an unsuitable parameter for Tactons as a vibration which is too strong could be unpleasant, while a vibration which is too weak might make it difficult to detect other parameters [3]. However, pilot testing indicated that the intensity levels chosen for this study were all perceived to be pleasant, and that it was intuitive that the more important an alert was, the stronger it would feel.

Aim and Hypotheses

The aim of this experiment was to identify recognition rates for Tactons presented on a phone vibration motor and to compare these to results achieved with the more expensive, specialized C2 Tactor. The two conditions in this experiment are referred to as the Phone Roughness condition and the Phone Intensity condition. Since the experimental design and stimuli used in this study are based on those used by Brown et al [3], the results can be compared to those from their C2 experiment (where vibrotactile roughness was used to encode importance).

The hypotheses were as follows:

1. Performance will be lower in the Phone Roughness condition than in the Phone Intensity condition (since pilot studies indicated a problem with roughness perception).
2. Performance on the phone (in both conditions) will be lower than on the C2 due to the limited bandwidth of the device.
3. There will be no significant differences in performance for type (encoded in rhythm) between the three conditions as rhythm presentation should not be affected by the device or the parameter used to encode intensity.

Experimental Design and Procedure

16 participants took part in this study. All participants were staff members of Nokia Research Centre, aged between 23 and 43 (10 male, three female) During the experiment the phone was held in the participant's non-dominant hand, and the participants wore headphones to block noise from the device.

The experiment consisted of two conditions (*Phone Roughness* and *Phone Intensity*) and the order of these two conditions was counterbalanced. There were 54 tasks in each condition, with each Tacton presented 6 times during a condition. In each task the Tacton was presented 4 times, with a one second gap between presentations. The user responded by ticking boxes to indicate the type and priority of the Tacton.

Before starting the experiment users were able to try out the Tactons for themselves for up to 10 minutes, and then to attempt nine tasks like those in the experiment itself in order to learn to use the interface.

Results

During the experiment, data were collected on the number of correct responses to the type (rhythm) and priority (roughness/intensity) of each Tacton. Percentage correct scores were calculated for each individual attribute (type and priority) and for the complete Tactons. These three sets of data were analysed individually and compared across conditions using analyses of variance (ANOVAs) and post hoc Tukey tests. These data sets were also collected by Brown et al [3] in their experiment on the C2 Tactor therefore a comparison can be made between the two conditions in this study and their C2 experiment.

The results showed overall Tacton identification rates of 52% and 72% for the Phone Roughness and Phone Intensity conditions respectively, while the C2 experiment had an overall recognition rate of 71% (Figure 3). The ANOVA for the complete Tactons showed a significant difference in performance between conditions ($F(2, 431)=19.79$, $p<0.005$). Hypothesis 1 can be accepted as post-hoc Tukey tests revealed that performance was significantly better in the Phone Intensity condition than the Phone Roughness condition (T=-5.56, p<0.005). Hypothesis 2, however, cannot be accepted as post-hoc Tukey tests revealed that, while performance was significantly better in the C2 condition than in the Phone Roughness condition (T=5.33, p<0.005), there were no significant differences between performance in the phone intensity condition and the C2 experiment (T=-0.23, p=0.97).

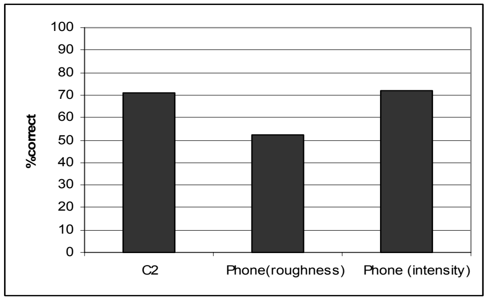

figure 3: Identification rates for complete Tactons by condition

The results for type (rhythm) identification showed identification rates of 93% in the Phone Roughness condition and 95% in the Phone Intensity condition. The C2 experiment had found identification rates of 93% for type. The ANOVA showed no significant differences between any of the conditions (F(2, 143)= 0.4, p= 0.67) supporting Hypothesis 3.

The results for priority showed identification rates of 55% for the Phone Roughness condition, and 75% for the Phone Intensity condition, with the C2 experiment finding a recognition rate of 80% (Figure 4). The ANOVA showed a significant difference in performance between conditions (F(2, 143)= 15.74, p<0.005).

Hypothesis 1 can again be accepted as post-hoc Tukey tests revealed a significant difference between the Phone Roughness condition and the Phone Intensity condition (T=-4.281, p<0.005). While there was a significant difference between the Phone Roughness condition and the C2 experiment (T=5.282, p <0.005), there was no significant difference between the Phone Intensity condition and the C2 experiment (T=1.00, p=0.58) therefore Hypothesis 2 cannot be accepted.

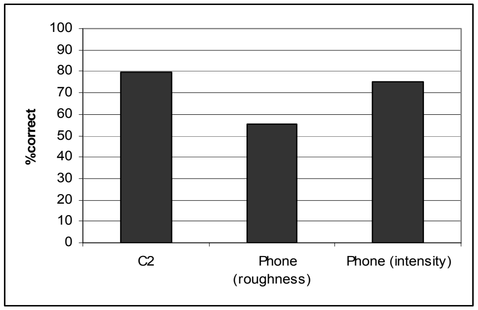

figure 4: Identification rates for priority attribute by condition

Discussion

These results are very promising for presenting Tactons via phone vibration motors. The overall recognition rate of 72% (when intensity is used to encode priority on the phone) compares favorably to the 71% rate achieved on the C2 Tactor. In addition the results for rhythm (95%) and intensity (75%) are also comparable to those achieved for the individual parameters in the C2 experiment. On the other hand, when roughness is used to encode priority the results are significantly worse (52% overall, and 55% for roughness), therefore roughness should not be used as a Tacton parameter when using mobile phone vibration motors.

It might be possible to improve intensity recognition. Due to the ramp up time taken to reach the full vibration speed, the motor does not reach full intensity when very short pulses are presented [6]. As a result, in rhythms where pulses are very short (e.g. voice call) the intensity will feel lower. Using rhythms with longer pulses would avoid this problem and possibly improve performance. In addition, there was no formal preliminary study to choose the best intensity levels, therefore it may be possible to select more appropriate intensity levels, and thus improve performance.

During the study users held the phone in their hand, whereas in a real situation the phone would be more likely to be in a pocket. The ability of users to discriminate rhythms and intensity level may be reduced when the phone is not in the hand. In addition in a real application the user's full attention would not be on the tactile alerts. Therefore future work should investigate identification rates when the phone is in a pocket and the user is engaged in another task.

Conclusions

This paper presented an experiment evaluating the use of Tactons for mobile phone alerts, presented using a standard mobile phone vibration motor. When Tactons encoding two pieces of information (type and priority of alert) were created by encoding information in rhythm and intensity, recognition rates of 72% were achieved. These results are comparable to those achieved for two-dimensional Tactons presented on a high-price vibrotactile transducer. Using Tactons in mobile phone alerts would enable more information to be transmitted in these alerts, and offer personalization features, such as assigning personalized vibration "ringtones" to different callers.

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