Multimodal Affective Feedback: Combining Thermal, Vibrotactile, Audio and Visual Signals

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ABSTRACT

In this paper we describe a demonstration of our multimodal affective feedback designs, used in research to expand the emotional expressivity of interfaces. The feedback leverages inherent associations and reactions to thermal, vibrotactile, auditory and abstract visual designs to convey a range of affective states without any need for learning feedback encoding. All combinations of the different feedback channels can be utilised, depending on which combination best conveys a given state. All the signals are generated from a mobile phone augmented with thermal and vibrotactile stimulators, which will be available to conference visitors to see, touch, hear and, importantly, *feel*.

CCS Concepts

• Human-centered computing~User interface design • Human-centered computing~Haptic devices

Keywords

Emotion; feedback; temperature; vibration; audio; abstract visual.

1. INTRODUCTION

Emotional displays are complex and multifaceted, including facial expressions, vocal elements, gestures/body movements, tactile (touch/push/squeeze) and thermal (hug, hold hands) sensations. Research in HCI has looked at how some individual modalities can convey affective information [7–9] but they are only capable of conveying a limited range of emotional meaning by themselves. As emotion is multimodal (visual, auditory and tactual), it is important to study how multiple modalities might combine, to provide a wider range of emotional expressivity and so support better emotional communication in HCI. This demonstration will showcase the feedback designs that we are using in our novel research on truly multimodal affective feedback. It combines four different channels: thermal, vibrotactile, audio (vocal) and abstract visual, and the demo will involve attendees holding a mobile phone that can output all four channels, for them to interpret, and feel, affective signals.

In the absence of physical presence during digital communication, emotion needs to be conveyed through different means. In synchronous communication, facial expressions can be conveyed through video and voice through audio, but these signals are limited and devoid of tactile cues and people with visual impairments miss these visual cues when communicating both digitally and in-person. During asynchronous communication, such as text-based messaging, emotion is frequently conveyed using stylised facial expressions such as "emoji" characters, but these can be difficult to interpret [3]. They are also very different to real emotional signals: rich facial expressions, body movements, sound (e.g., laughter), touch (e.g., pushing) and temperature (e.g., holding hands).

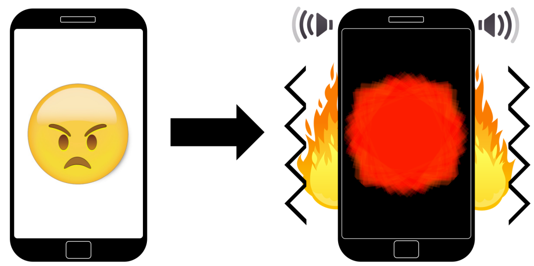

Figure 1: We expand existing ways of conveying emotion in digital communication with multimodal feedback.

People with visual impairments miss out on visual affective signals, which are particularly relied upon in digital communication, such as emoji above, as well as video calls and image sharing. Emoji are described textually by accessibility software, such as "grinning face with smiling eyes" and "loudly crying face". Therefore, people with visual impairments may benefit the most from expressive affective displays, to convey information lost from facial expressions and gestures. Digital media, such as TV and movies, could also be augmented with affective feedback, not just for people with visual or hearing impairments, but for mainstream audiences also, to increase the impact and enjoyment of content.

2. FEEDBACK DESIGNS & HARDWARE

The most common conceptualisation of emotion is the two-dimensional *valence* (V; emotional pleasantness) and *arousal* (A; emotional activation/excitation) model, as most of the variance in emotional experience is described by these factors. By taking subjective V-A ratings, researchers can measure the perceived emotion being conveyed by different media or experiences. When combining the feedback modalities, we chose to combine stimuli with a range of positions within the model. Specifically, we chose stimuli from each modality that represent each quadrant of the model, to measure the effect of both *complimentary* combinations (stimuli from same quadrant) and *conflicting* combinations (from opposing valence/arousal values) on the perceived emotionality.

All the feedback is presented from software running on a mobile phone (see Figure 2). Thermal feedback is presented using a Peltier-based device [7] that can produce warming (up to 45°C) and cooling (to -20°C) stimuli, at 1°C/sec or 3°C/sec, from two 2cm^2 modules attached to the back of the phone. The device connects over Bluetooth and is battery-powered. Vibrotactile feedback is produced by a TactileLabs Haptuator Mark II that is also attached

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to the back of the phone. It is driven by audio files played through the headphone jack and, using a splitter cable, audio feedback is also played via the headphone jack to a small external speaker. Visual feedback is displayed on the phone's screen.

2.1 Thermal Feedback

The thermal stimuli are based on the dimensional distribution from Wilson *et al.* [7]. The feedback designs are based on perceptual research that shows warm stimuli feel more intense and less pleasant than cool stimuli, and that increasing the extent of temperature change, or the ROC, increases the strength of sensation and makes it less pleasant/comfortable. There are also inherent links between emotion and thermal sensation [2], making it a key component of the conceptualisation and experience of emotion and these qualities can be leveraged to convey different affective qualities [7].

Figure 2: Device used for demonstration: Android phone with 2 x 2cm^2 Peltier devices and Haptuator Mk II on the back.

2.2 Vibrotactile Feedback

With the ubiquity of vibrotactile actuators in mobile and consumer devices, most research looking at conveying emotion non-visually has used vibration. In summary, short or quick vibrotactile pulses, or longer overall patterns, are viewed as highly arousing [5,9]. The carrier frequency and amplitude both influence valence and arousal simultaneously, with increases in either parameter increasing both [5,9]. Producing vibrations of different texture, e.g., by increasing "roughness" [5] increases arousal and decreases valence [9]. To support the validation and generalization of previous research findings, the vibrotactile signals used in our research and this demonstration were taken from a comprehensive analysis of the emotional content in vibrations by Yoo *et al.* [9], to compare the bandwidth of our multimodal affective feedback to their single modality.

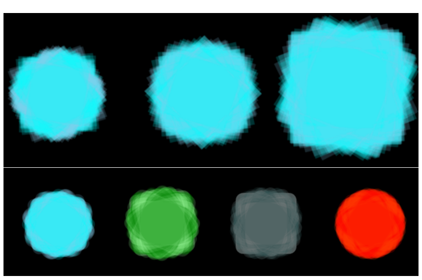

Figure 3: Example abstract visual designs. Top: different sizes of jagged amoeba. Below: different colours of smooth amoeba.

2.3 Abstract Visual

There are inherent associations of colour and shape to affective qualities which have been leveraged to create visual feedback in HCI [6]. Our visual designs are from Wilson *et al.* [8], who expanded the design of the "pulsing amoeba" [6]: a circular coloured shape with smooth or jagged contours that expanded and contracted to different sizes at different speeds. Using large, differently-coloured stimuli limits visual complexity, increases accessibility for people with low vision and is applicable across display sizes.

2.4 Audio

Psychologists identified the spectral components of vocalisations that convey different emotions [1] and used these to create "affective bursts": short (1-2 sec), non-speech vocal utterances that can reliably convey a small range of affective states. The research was extended to create "musical bursts" [4] which retain the emotionality of music, but in short bursts. Our demonstration uses both, as different burst types are better at conveying different emotions.

3. EXAMPLE FEEDBACK DESIGNS

As different emotions are associated with different senses/modalities, we can combine two to four feedback channels as is appropriate to convey a range of affective states to conference attendees. A small number of examples that attendees will experience are shown in Table 1, based on existing research findings [1,4,5,7–9].

Table 1: Example modality combinations for affective states.

Emotion	Vibration	Thermal	Visual (amoeba)	Audio
Affection	Short, low-amplitude, low-frequency	Slightly warm ~34°C	-	-
Sadness	-	Cool ~26°C	Grey, small, smooth, slow pulse	"sob" burst
Anger (Figure 1)	Long, high-amplitude, high frequency	Very warm ~38°C	Red, large, jagged, fast pulse	"angry" burst
Surprise	Long, high-amplitude, mid-frequency	-	-	"gasp" burst
Relaxed	-	-	Green, large, smooth, slow pulse	"pleased" burst

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