Tactile Experiences

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Abstract

A simple touch can result in a profound and deep experience. Tactile communication has been used in information displays or to increase the entertainment value of arcade and pc games. The study of communication of emotion via tactile stimulation started only recently. We have built an emotion jacket as a research prototype to study the communication of emotions with vibrotactile stimulation. We recreated bodily feelings related to emotional experiences (e.g., a shiver down one's spine) as tactile stimulation patterns and showed that these emotion patterns, in a movie-viewing context, can increase emotional immersion with the content being viewed.

1 Introduction

Being touched can be a very powerful experience and its effects can range from a scary and unnerving unexpected hand on a shoulder, to a soothing, relaxing massage, or to a reinvigorating hug, with many more gradients in between [1]. The tactile modality, contained within the human skin, is the largest sensory modality (in terms of surface) that humans have. In the womb it starts to develop the earliest of all other senses and is most developed at birth [2]. This strong and old connection between tactile sensations and the intimacy and safety of the womb could be considered one of the reasons why a touch can evoke such powerful emotions. Touches sooth and arouse infants, and a touch can also regulate an infant's state [3]. Touches may even be a basic need like food, water, or sleep [4]. Following the principle of equipotentiality, it may be that touch is a particularly strong medium for children to communicate their (emotional) state [3].

Compared to modalities like vision and audition, scientific study of the properties of the tactile sensory system, and its communicative abilities in particular, was scarce for a long period of time [3]. Recently, Van Erp and colleagues used the information processing properties of the tactile modality to create informative tactile displays to provide additional navigational cues to airplane and helicopter pilots. They successfully used tactile stimulation to prevent overloading the visual and auditory senses that are already highly taxed in a cockpit context [4,5].

To improve the quality of the experiences that they generate, the entertainment industry has been using the tactile modality for some time. One can think of the arm-wrestling machine or a racing simulator with force feedback in its steering that can both be found in any arcade hall. More recently, the availability of tactile stimulation systems for personal entertainment systems like game consoles and pc's has increased [5,6]. The available technology ranges from simple rumblers and force feedback systems in joysticks to full torso vests containing multiple air bladders that quickly inflate upon impact in, for instance, first-person shooters [7]. Unfortunately, however, both the research into the informational properties of tactile information as well as studies investigating the effects of added tactile stimulation in entertainment context [8] neglect the aforementioned strong and intimate link between tactile stimulation and their effect on emotions.

Some work into this area can be found in interaction and design research on virtual mediated touch (see Haans *et al.* [1] for a review). A lot of that work focused on using the inherent intimacy or closeness of a touch to improve virtual communication between humans on a personal level [9-11]. The Lovebomb [12], on the other hand, provided the ability to anonymously indicate one's emotional state in public spaces and among strangers. Cramer showed that embodied agents and robots were judged less credible when their empathic responses were incongruent with that of their user and that touches from pro-active agents resulted in a less machine-like character [13]. Another work that involves connecting emotion and tactile stimulation is the Emoti-chair that uses a model of the human cochlea to provide tactile actuation based on the processing of, for instance, music [14].

The code of what makes a touch communicate a happy, sad, angry, or other emotional message is far from clear. Hertenstein and his group at the DePauw University have been working on code of tactile stimulation and emotion [2,15]. They showed that strangers could accurately (ranging from 48% to 83%) decode distinct emotions when touched by another person. Moreover, when Hertenstein *et al.* video recorded these touches and showed them to another group of participants, these participants also recognized the intended emotion with high accuracy. For specific emotions, percentages of correctly recognized emotions ranged from 38% to 71% [2].

In our own work we have taken a different approach to the study of the communication of emotion via tactile stimulation. We worked from William James' observation that every emotion has a distinct bodily reaction [16-18] and have listed various bodily reactions that are a result of an emotional experience. For instance, we considered responses like a shiver down one's spine, having butterflies in your stomach, a racing heart beat, etc. We then reversed James' idea and studied whether providing one of these bodily reactions could actually induce an emotion.

Note that it is important to stress the difference between enhancing emotional experiences compared to enhancing movie effects. For instance, in a movie scene in which Bruce Lee is surrounded by evil henchmen, one can try to enhance the experience by converting the visually presented punches and kicks into tactile sensations. This is the movie-effects approach. On the other hand, one could also try and provide a tactile experience of the anxiety that Bruce Lee feels in such a tight situation and the relief once he won the fight and survived. This latter approach of enhancing emotional experiences is the one that we have taken in the current study.

We asked whether tactally recreating these bodily reactions and using them as stimuli could enhance the emotional experience of watching movie content. By measuring psychophysiological signals that change due to changes in emotional state as well as taking questionnaire responses regarding emotional state, we measured the emotional state of viewers before, during, and after movie viewing. We expected that these responses would show responses indicative of deeper immersion when comparing a film clip without and with tactile actuation.

In the next section, we describe the emotion jacket that we developed to be able to project tactile sensations on the torso of our viewers. In section 3, the user test to evaluate our idea is briefly described and we round up with some conclusions based on our findings.

2 Body–Conforming Jacket With Tactile Actuators

The main design criteria for the emotion jacket were: ability to stimulate back and front of the human torso and arms, being battery powered, having smooth integration of electronics with the fabric for good aesthetics, good accessibility of electronics, and being light weight. The design aimed to enable projection of tactile patterns on the entire torso while keeping the electronical design low on complexity. This resulted in a jacket with 64 uniformly distributed actuators in a layout covering the entire torso with roughly 15 cm distance between neighboring actuators (see Figure 1).

A stretchable fabric was chosen to create a tight fit. This ensured that the actuators were close enough to the skin for the best tactile sensation possible. Small, medium, large, and extra large vests were built to accommodate different sizes.

2.1 Electronics Design

For the actuators we opted for pancake–shaped (coin type) generic eccentric rotating–mass (ERM) motors because they were light weight, thin, and inexpensive compared to other offerings. A disadvantage is that we were limited to vibrotactile stimulation only. The ERM motors are glued onto the back of custom-made PCB's that were connected to the segment-driver PCB's using thin flexible wires. Each segment-driver PCB controlled 4 motors.

The driver segments were daisy chained to form a serial bus that starts and terminated at a custom–made interface PCB. This PCB combined the SPI-bus from the external USB-to-SPI interface with the

power supply line from the two AA batteries. The electronics design was a compromise between number

Figure 1. Outer lining (left) and jacket turned inside-out showing the inner lining with electronics and wires (right-hand panel). Red (thicker) wiring is the serial bus that connects all segment drivers and provides communication and power; white (thinner) wiring connects motor PCB's to the respective segment driver.

of cables, number of drivers and the limit of the (flexible) cabling in terms of throughput of current (Watts).

The jacket was operated on 2 AA-sized batteries. With rechargeable batteries that each deliver 2500 mAh, the jacket had an operational lifetime of 1.5 hours when continuously driving 20 motors at the same time.

2.2 Textile Integration

The jacket consisted of two layers: an outer lining and an inner lining. The PCB's were sewn onto the inner lining using holes along their outer perimeter and were then covered by the outer lining for protection and aesthetics. At the bottom side of the torso and at the end of the sleeves the linings were not sewn together for easy access to the electronic components. The photograph on the right of Figure 1 shows the shirt inside-out, exposing the PCBs and wires. The total weight of one vest, including electronics and batteries, was approximately 700 grams.

2.3 Designing Tactile Stimuli

The actuators in the jacket are controlled from a PC using a LabVIEW™ (National Instruments, Austin, TX, USA) software interface that was developed in–house. The whole system has been principally designed to be able to use a 10 ms resolution for specifying changes in the tactile stimuli; in practice, we often reverted to a 20 ms resolution.

The LabVIEW application allowed us to generate tactile stimuli on various levels of granularity. First, we created different types of shapes. Shapes have, in principle, an unlimited duration and the amplitude specified for each 10 ms step reflects the intensity of the vibration of the motors. Example shapes are sine waves, block waves, sawtooth waves, etc. Thus, shapes define the vibration intensity over time, and are the building blocks for patterns.

Patterns specify at what point in time a particular motor has to render the given shape. An example pattern is a series of sine wave shapes that run from the left wrist over the shoulder to the right wrist. Patterns thus define the spatial and temporal distribution of vibrations over the torso.

Finally, these patterns were played back on the emotion jacket at predetermined times. For the present study, most of the patterns were based tactile sensations that are linked to common sayings like having butterflies in your stomach, or having a shiver down one's spine.

3 User Study

So, starting with James' idea that each emotion has a distinct bodily component [16-18], we tried to recreate these bodily sensations to see whether they could be used to induce an emotion. We set up a user test in which participants had to view clips of movie content that was validated to elicit a certain emotional response. We created tactile emotion patterns for each of these clips, on the one hand, by reverting to common wisdoms like shivers down one's spine, a racing heartbeat, exploding with anger and, an arm around your shoulders, or a sigh of relief (etc.). On the other hand, we also created patterns that were specific to particular movies.

Fourteen participants (age range from 24 to 58, 4 females) viewed each clip in two versions: first the original version without tactile emotion patterns and on a second viewing the emotion patterns were projected onto their body. The participant(s) wore the vest during both viewings. The presentation order of the clips was randomized, although we made sure that each clip was first shown without tactile actuation.

Before and after each movie clip, the participants had to self-rate their emotional state using the Self-Assessment Manikin (SAM; [19]) which is a pictorial questionnaire that can be used to assess the positivity/negativity, level of arousal, and level of dominance/potency of an emotion. We also used a questionnaire that was employed in earlier work to determine immersion experiences in TV applications. This questionnaire included elements of emotional experience and immersion [20]. We expected that the after measurement would show indications of increased emotions (for instance, by a higher score on the arousal scale).

During the viewing, psychophysiological responses related to changes in emotional changes were recorded. Examples of these responses are the electrodermal response, heart rate, skin temperature, or respiration [21-25]. Again, we expected that these responses would shower larger deflections (i.e., indications of stronger emotional experiences) when the participants were viewing the movie clips with the emotion patterns present.

3.1 Questionnaire Data

The data of the SAM did not show that participants indicated higher positive states for positive clips when emotion patterns were present during viewing. Similarly, we did not find an effect of increased emotional arousal during movie viewing with emotion patterns present. Because we used a 5-point SAM, we presume that this absence of significant findings was due to the limited number of options to indicate changes. That is, the effects of the additional tactile emotion patterns appeared to be rather subtle and required a more detailed scale that enabled scoring of fine-grained differences.

For the immersion questionnaire, we obtained several significant effects that indicated that participants felt more involved in the movie viewing. Participants had more intense experiences, felt more drawn into the movie scenes, and felt that all senses were stimulated at the same time (see Table 1). Note that, interestingly, a question from the immersion questionnaire that explicitly taxed the experience of emotions did not reach the level of significance. We will return on this point in the discussion.

Table 1. List of relevant questions from the immersion questionnaire [20] with average scores (on a 5–point scale) for the actuation absent and actuation present conditions. * indicates significantly different from actuation absent at $p < 0.05$.

Item	Question	Absent	Present
7	My experience was intense.	2.68	3.04*
8	I had a sense of being in the movie scenes.	2.32	2.67*
12	I felt that all my senses were stimulated at the same time.	2.03	2.59*

3.2 Psychophysiological Responses

We observed significant effects on two of the three psychophysiological responses that we recorded. For skin-conductivity, we found higher levels of conductivity (indicative of higher arousal) in the viewing condition when the emotion patterns were present. Because this applied to all clips, it most likely reflected a generic increase in arousal due to the tactile stimulation itself (i.e. ignoring the emotional communication of the tactile stimulation).

More interesting was the statistically significant interaction showing that the increase in skin conductivity due to the presence of emotion patterns was different for the various movie clips. Figure 2 shows that for three clips, we observed stronger increases in skin conductivity than for the other clips. Interestingly, these clips were all intended to evoke negatively valenced emotions.

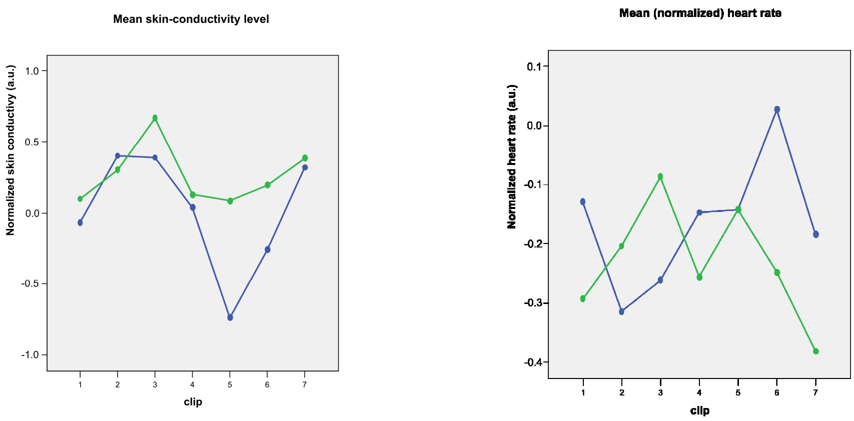

Figure 2. For all clips the effect of Actuation on skin–conductivity level (left panel) and heart rate (right panel). The blue line is for actuation absent; the green line is for actuation present. On the x-axis, the clips are numbered and ordered from left to right as: Braveheart, When Harry met Sally, Jurassic park III, The lion king, My bodyguard, Silence of the lambs, and Tom & Jerry. On the y–axis are the normalized physiological measurements.

For heart rate (Figure 2, right-hand panel), we observed a similar differentiation over movie clips of the effect of the added tactile emotion patterns. In this case a correlation with the valence of the clips for which we observed significant changes in heart rate, was not evident because one clip evoked positive emotions whereas another clip evoked negative emotions. Instead, it appeared as if the emotion patterns in these clips replicated increases in heart rate that the actors portrayed in the scenes.

4 Conclusions

The user study that we carried out showed that the addition to movie clips of emotions patterns that are projected on the torso using tactile actuators, results in a stronger or emotionally more immersive movie viewing experience. A few findings deserve some attention.

First, we did not observe a change in emotional state using the SAM of Bradley and colleagues [19]. We have already highlighted that this may have been due to a response scale that was not sufficiently granular to capture subtle changes in emotional state. However, a question from the immersion questionnaire that specifically asked for emotional experience also did not change in a statistically significant way. So did we change emotional state after all? In our view, we have, because a lot of subjective feedback from our participants that was not captured using formal questionnaires, indicated that they truly felt stronger immersion in the movie content when the emotion patterns were present. This is corroborated by the psychophysiological data. So, regarding subjective feedback, it is apparent that the questionnaires that we have chosen were not optimal in terms of level of granularity. The subtlety of our effects may require finer granularity than the questionnaires could deliver. In follow up studies it may even be necessary to select other questionnaires than we employed here.

The other point for discussion is that the psychophysiological recordings show that the emotion patterns, on average, have the strongest effects on negatively valenced clips. This may be a side effect of the type of tactile actuator that we chose. As we already mentioned, we were limited to vibrotactile stimulation due to our choice for eccentric rotating-mass motors. It is exactly this type of tactile stimulation that is often used for alerting functions, for instance, in cell phones. Therefore, it may be that these types of actuators are better suited for negatively valenced emotions because these emotions have an alerting and arousing function. It is clear that we need to study the efficacy of individual emotion patterns and that further detailed study of the design of the emotion patterns is needed to confirm or contradict this hypothesis.

On a higher level, we conclude that our findings highlight that it is possible to convey an emotional communication via relatively simple tactile technology. This corroborates the findings in the work of Hertenstein and colleagues on the code between tactile communication of emotional messages [2,15]. Our work shows that common wisdoms or sayings regarding bodily effects of emotions can actually be used to generate tactile stimuli that can trigger (or at least enhance) emotions. In our case, it still is the case that we require other content to set an emotional context. However, Hertenstein's findings that people can accurately decode a touch as an intended emotional communication shows that in principle our tactile stimuli could evoke emotions without a surrounding emotional context.

To conclude, by exploiting relatively simple and cheap tactile technology, we have been able to evoke strong psychological effects that show in increased emotional immersion during movie viewing. This finding shows that it is feasible to tactally enhance the emotional experiences of movie clips. This is a very useful addition to the enhancing of movie special effects using tactile stimulation that enables perceptually and emotionally rich movie-viewing experiences. Perhaps it is not without good reason that we say "I was touched" after having experienced a powerful emotion!

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