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# Mood Glove: A haptic wearable prototype system to enhance mood music in film

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ABSTRACT

This is an exploratory work aimed at enhancing mood music in film entertainment. We present the design and implementation of a haptic wearable prototype system which aims to amplify mood music in film through haptic sensations (vibrotactile feedback). This approach also could potentially have implications for hearing-impaired audiences, providing a new enriched emotional experience while watching a movie. This paper reports on a set of three studies conducted to assess whether vibrotactile stimuli are able to enhance moods. Preliminary findings show that vibrotacile stimuli at low intensity and low frequency induce a sense of calmness in users, whereas vibrotactile stimuli at low intensity but higher frequency increased excitement. The combination of high intensity and high frequency vibrotactile stimuli heightened tension on the other hand. These findings support our position that vibrotactile feedback could be used to enrich the emotional aspects of cinematic experience through haptic sensations.


## 1. Introduction

Film is a multimodal form of entertainment which blends together moving pictures, dialogue, background sounds and music score to tell a story and to create an experience for audiences; it is a form of inclusive art through which filmmakers design viewers' experience. Films, or movies, can be deconstructed into the elements of: motion pictures, dialogue (or subtitles), ambient sounds, and film music. Whilst motion pictures and dialogue are descriptive and narrate the story, ambient sounds provide additional information on the surroundings, and film music can convey and clarify the emotional significance of a scene [1].

Over the years techniques have been developed to enhance the film experience through stimulation of the visual and auditory senses (e.g. 3D film to create the illusion of depth perception, and stereo sound for multidirectional perspective), raising the question of whether it is possible to further enrich the film experience through stimulation of other senses. In his enquiry into narrative film music, Simon Frith [1] writes about the purpose of music according to Wagner, who argued that the purpose of music was *"to amplify what can't be shown"*, adding that what can't be shown is what we call 'atmosphere' or 'mood' [1].

This work explores the possibility of enriching the film experience through haptic sensations, through enhancing moods in film music. By haptic this work refers to kinesthetic and cutaneous stimulation as described in Eberhardt et al. [2]. The term *mood* refers to a temporary feeling or state of mind. *Mood music* in this study refers to the pervading tone, atmosphere or feeling induced or suggested by the music. In film, mood music is non-diegetic [3].

### 1.1. Music in film entertainment

Film entertainment relies on the combination of vision and hearing to create an experience that engages the minds and emotions of audiences [3]. Music is an integral part of the film experience, and even before sound, filmmakers worked closely with musicians to empower music to lead and define the images [4]. From a study conducted to assess the impact of music on perceived emotions in film, Parke et al. [5] observed that changing the music in a movie clip could alter audiences emotions, which lead this study to deduce that music in a movie acts on the way people feel.

Film music composer Boswell [6] suggests that there are two ways of using music in a movie:

1. To convey the same emotions evoked by the movie scene (e.g. gloomy scene with sad music) to intensify a particular emotion;

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2. To draw the opposite emotions drawn by the movie scene (e.g. gloomy scene with happy and calm music), to attenuate an emotion, e.g. accompanying a vivid horror scene with an uplifting music score to make the scene tolerable to watch for the audience.

Film music is therefore an integral part of the film experience as it communicates emotions that cannot be conveyed through visual images alone. Moreover, some argue that it should be accessible to everyone enjoying this form of entertainment. Therefore even though sign language and captioning make speech more accessible for deaf movie lovers, subtitles are unable to convey diegetic sounds and music, thus those not able to hear are left out [7].

### 1.2. Sound, vibrations, and touch

When watching a movie, the primary senses involved are vision and hearing. What about other senses? Could these complement or enhance audience experience if stimulated? Artists and researchers have previously explored the association between sound and vibrations. For example the ongoing collaborative research project Music for Bodies [8] is dedicated to the making of new 3D music and physical interfaces that allow people to enjoy music as vibrations directly through their bodies. During the making of Sonic Bed Scotland 2007, the artist of Music for Bodies explained in an interview that the real idea of the project was to create music that people are listening through their bodies, rather than just a listening experience [9]. Evelyn Glennie, a deaf solo percussionist, in her "Hearing" essay explains how hearing is essentially a specialized form of touch [10]. She discusses how sound is simply vibrating air which is picked up by the ear and converted into electrical signals. The signals are then interpreted by the brain. Glennie adds that hearing is not the only sense that can do this, but touch can also.

The sense of touch therefore represents an interesting possibility to explore in movies. More broadly, haptic interface research mostly focuses on assertive technologies for people with hearing and visual impairments. Haptic interfaces have proven to enhance the musical experience of users with hearing impairment, as the studies in [7,11], which presented the design of a vibrating haptic chair. Karam et al. in [12] proposed a sensory substitution technique called The Human Cochlea (MHC) for presenting music as multiple distinctive channels of vibrotactile stimuli, with the aim of exploring techniques for communicating emotional information from music using a tactile display. The prototype resulting in [7] had vibrotactile components embedded into the back of a canvas chair to produce vibrations that reflected the music and corresponded to instruments, voices, and melodies of the music. Nanayakkara et al. [11] proposed the use of their haptic chair alongside a computer musical display to provide users with informative visual effects corresponding to music features (pitch, amplitude, key changes, and timbre).

Haptic interfaces and vibrotactile stimuli are also commonly used in mobile phones, in other mobile devices such as hand held tablets, and in wearables to provide discrete alerts. Furthermore, they are also used in various forms of entertainment to enhance physical events, such as car crashes and collisions. Haptic features have been studied for the last two decades for communicating emotions (*affective haptics*), and wearable technology introduced another possible research approach for affective computing. In recent years a number of studies proposed various affective haptic wearables (see Eid and Osman [13] for an overview of recent developments in the field), however in our research we focus specifically on affective haptic wearable devices for entertainment, especially film. In particular, we focus on: how haptic sensations could be designed to enhance or integrate the film experience; plus whether vibrotactile stimuli used in cinema could become integral part of the film experience, and if so, then how.

## 2. Affective haptics in film entertainment

Previous work in technologies for entertainment include the vibrotactile display for movie viewing enhancement, which was proposed by Lemmens et al. [14] in form of a wearable jacket. The tactile jacket contained 64 coin motors distributed on the torso, allowing viewers to experience what the main character in the movie was experiencing. The study assumed that distinct emotions are accompanied by different bodily reactions, and suggested that a desired emotion could be induced by triggering the corresponding bodily reaction. The proposed prototype system influenced viewers emotions, by trying to recreate specific bodily reactions (e.g. shivers down the spine) through haptic stimulation, in order to incite the wearer in feeling a certain emotion (e.g. fear). A different version of the tactile jacket in [14] was proposed by Dijk et al. [15], with the design of a personalized tactile actuation blanket to intensify the movie experience. Both these systems [14,15] were based on video or audio features extraction. This approach aims at enhancing the effect of a physical event in a movie (e.g. car crash) to increase the sense of presence of viewers.

Special effects are used by artists to enrich user experience in various forms of entertainment (e.g. movies, games, shows, etc.) [16]. For example in a recent study Israr et al. [16] acknowledged that haptic feedback has become a new addition to this toolbox of special effects, and attempted to enrich storytelling with the addition of haptic sensations. The study describes a *feel effect* as a synthetically created haptic pattern that enriches media content through vibrations on users' skin, providing artists with a feel effects library to generate expressive haptic content for their media. Authors in [16] used the back as the surface for stimulation, however they identified the low density of receptors in this area to constitute a limitation. In [14,16] the system's haptic features relied on the mental interpretation between physical events and bodily reactions. The work in [16] highlights the growing interest and possibly the need in developing more expressive haptic sensations for media enhancement.

A thorough overview of research in affective haptics is provided in Eid and Osman [13], where authors also discuss affective haptics for gaming and entertainment. Their work reports various studies in the field, recognizing that the literature available up to date on the use of haptics in gaming and entertainment focus on augmentation of audio-visual contents. Eid and Osman [13] reckon that price and complexity of haptic interfaces constitute a limitation in a wide use of affective haptics in gaming and entertainment, as also the lack of a corpus of haptic "*keys*" to induce emotional changes.

In our work we attempt to address these issues and needs by designing haptic sensations intended at amplifying mood music in film. Moreover, opposed to the chair systems in [7,11], we propose the design of an affordable haptic wearable prototype system. This design choice is for the freedom of movement and portability of the users. Also, it is to include the device into the personal space of the user, in accordance with Steve Manns' definition of wearable computer [17], acting as extension of the wearer, enhancing and creating new personal HCI experiences.

## 3. The Mood Glove haptic wearable prototype

We designed and developed Mood Glove, a wearable prototype system, to attempt to enrich the movie experience by enhancing moods in film music through haptic sensations. A design challenge of this work, was to choose the area of the body to stimulate with

**Fig. 1.** Glove prototype. Back of the glove (left), and palm (right).

vibrotactile feedback. The review on measures, capabilities and limitations of tactile sensitivity for the human body reported in Myles and Binseel [18] assisted this process. In the tactile modality review, hands and soles of the feet were the body regions reported to be the most sensitive to vibrations due to the high density of receptors in those areas. The findings instructed the design decision of this study in developing a wearable prototype for the hand, as identified as the most sensitive body area. However, this work does not exclude trialing different body regions in future studies.

### 3.1. Technology employed

The electronics employed in building the prototype for the studies presented in this paper are: LilyPad Arduino SimpleSnap Board ATmega328; conductive thread; 8 LilyPad Vibe Boards with 20 mm outer diameter and 0.8 mm PCB (printed circuit board) thin. The vibration motors present on the vibe board are 310–101 10 mm Shaftless Vibration Motor 3.4 mm button type, with a voltage range of 2.5–3.8 V, a rated speed of 12000 rpm, vibration amplitude 0.8G, and weight as little as 1.2 g. The main board together with 5 vibe boards were mounted on the back of the glove, and the remaining 3 vibe boards on the palm of the glove (see Fig. 1).

## 4. Evaluating Mood Glove

To explore whether haptic sensations could be designed to suggest moods, we undertook a set of three studies:

1. Movie selection and edit of video clips, followed by a study to build a small database of affective movie clips based on the film score, to be used at a later stage;
2. Iterative user-centered design study of affective haptic patterns;
3. A study to evaluate the use of the haptic patterns identified in study 2 together with the movie clips selected in study 1.

### 4.1. First user study: Film clips annotation

In order to test whether haptic patterns can convey or enhance the mood music of a movie, an affective movie clip corpus was required consisting of clips labeled according to the emotion conveyed in the mood music. The following database collections were examined as possible sources for the corpus: the Emotional Movie Database (EMDB) [19], and Film Stim [20]. However, these were discarded after review as unsuitable. The aim of this study is to enhance the mood in the film score, and in the case of the clips in the EMDB, no audio is provided which deemed the clips unsuitable. In the case of the Film Stim database, the clips are in French rather than English, and with no subtitles which where also deemed unsuitable since the studies are carried out with English speaking participants. Furthermore, the Film Stim selection is based on the affective content of the narrative as in most of them there is no music which is also unsuitable as discussed. From our review of available database collections, it was found that at present there is no standard corpus of affective movie clips where the affective indexing referred to the musical score of the clip.

As a result of establishing the lack of suitable movie clips as discussed above, it was necessary for the purpose of this study to develop a new corpus of appropriate movie clips. One possible approach that was considered, was to identify emotion in movie clips through using current audio–video analysis techniques to automatically classify using affective content analysis - the automated extraction of the affective content information from audiovisual signals [21]. Works in the field of automated extraction of affect in film comprise [22–25,21]. This type of approach was ruled out however. Affect is highly subjective as also acknowledged in [21]. Moreover, this work centers around the feelings and mood evoked in the audience by the film score in a clip, rather than the classification that a computer algorithm performs on extracted multimedia information. Therefore, this study adopted a manual labeling approach as used in Soleymani et al. [26], opposed to automated extraction methods. Through the self-assessed annotation of the feelings elicited by the film score in the clips, this study aimed to obtain a dataset of movie clips that reliably represented the mood music in the scene.

Over 40 short movie clips were extracted from the following movies: Edward Scissorhands (1990), Memento (2000), Amélie (2001). The film clips were selected based on the nature of their film score. For instance, literature on Film Art and Film Music discusses the score in Edward Scissorhands by music composer Danny Elfman in detail [27]. Elfman explains how the storyline in the film was told from the internal viewpoint of one central character, with the music provided according to this viewpoint. The music for the movie was considered *"very sappy and romantic and emotional"* [27] which was suitable for our purposes. Memento and Amélie clips were selected as suitable companion clips, since both films featured in a previous study on the effect of music on perceived emotions conducted by Parke et al. [5]. Furthermore, following analysis of the screen plots and musical score, it was established that the storyline of both is also told from the interior standpoint of one character. The film scores therefore also reflect the feeling of the central character in each, i.e. yearning and adrift in Memento, and journey and discovery in Amélie. Moreover, all edited clips featured different points in the film storyline where the music score lead the images, with limited or no dialogue at all, which was also deemed appropriate for the current work.

A pilot study with 10 volunteers was run to evaluate the valence and arousal of the movie clips. Participants individually watched all clips and self-rated the prevailing feeling or mood from the clip in terms of valence and arousal on a modified version of the Self-Assessment Manikin (SAM) [28,29]. SAM is a non-verbal picture-oriented assessment technique used by psychologists to assess the pleasure, arousal, and dominance associated with a person's emotional response to an object or event. This study used a modified version of SAM as previously used by Soleymani et al. [30], which excludes the dominance (or control) dimension, as the dominance factor is not present in our study. The two dimensions of SAM used in this study (see Fig. 5) are the valence (top panel), with the mannequin ranging (left to right) from very pleasant to very unpleasant (right side); and the arousal (bottom panel), with the mannequin ranging (left to right) from energized, excited to calm or peaceful. The coding scale used for the mannequin (not shown to participants) was the following for each of the two panels, from left to right: 2, 1, 0, −1, −2.

The clips in Table 2 were the clips that over two third of the volunteers agreed on the prevailing mood of the scene, and were therefore chosen to feature in the third user study.

### *4.2. Second user study: affective haptic patterns*

This section reports on the study conducted to assess whether a set of proposed vibrotactile stimuli were able to suggest moods to people wearing the prototype without movie clips.

As described in Section 3.1, 8 motors were mounted on the glove (also see Fig. 2 for a schematic representation). In an exploratory pilot that took place before the second user sudy, two distinct vibrotactile designs were formulated (see Fig. 3). 8 volunteers took part in the pilot and were asked to rate their preferred pattern from 10 randomly designed patterns. The two most preferred designs were then further developed and combined with different motors Pulse Width Modulation (PWM) values, i.e. low and high duty cycle, as well as directional order. This resulted in a set of 8 vibrotactile patterns. Each pattern lasted between 10 and 15 s in duration, with PWM values that ranged between 64 and 127 (25–50% duty cycle) for the low values, and between 191 and 255 (75–100% duty cycle) for the high values. Sets of patterns followed left to right directional order, whilst other patterns used right to left.

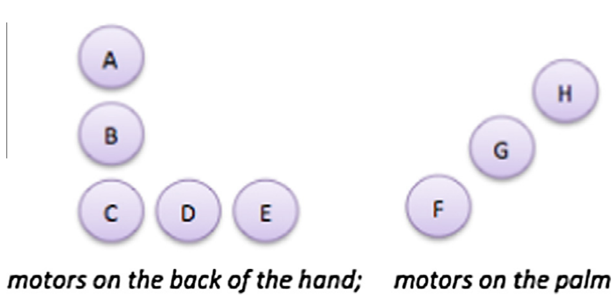


**Fig. 2.** Motors representation on the glove.

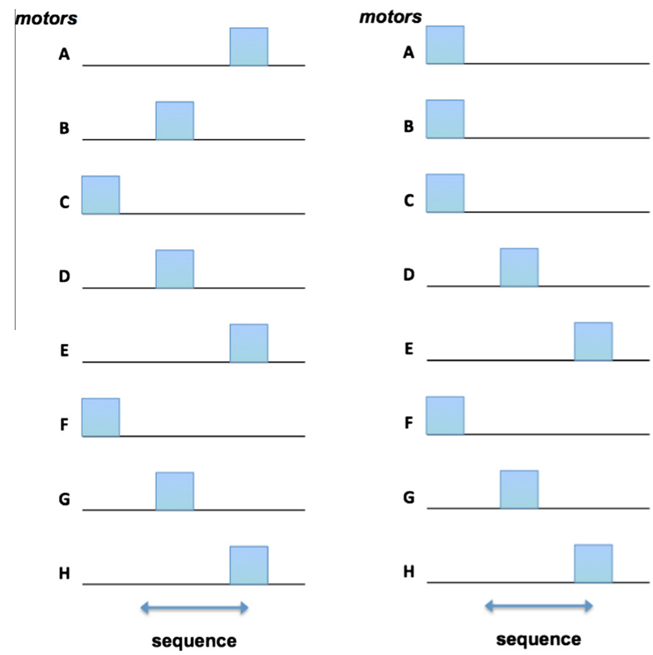


**Fig. 3.** Vibrotactile designs: Left design used for patterns 1, 3, 5, 7; right design used for patterns 2, 4, 6, 8. The above is a schematic of the sequence in which actuators played. It does not express PWM duty cycle nor time.

Vibrotactile patterns 1–4 also used a directional order of left to right, whereas patterns 5–8 had the opposite order of right to left. Furthermore, at times some of the actuators played simultaneously, whereas in other cases they played one at the time. Frequency of the stimuli was recreated through manipulation of the PWM signal. To simulate low frequency of the generated signal, the actuators employed were on for 400 ms followed by 500 ms of inactivity (off). For high frequency simulation instead, the actuators were on for 400 ms and off for 200 ms. Patterns had the following intensities and frequencies:

- 1 and 5 low intensity, low frequency
- 2 and 6 low intensity, high frequency
- 3 and 7 high intensity, low frequency
- 4 and 8 high intensity, high frequency

The study took place under lab conditions with 16 participants, all post-graduate students, aged from 22 to 38 years old (mean age: 27.5), recruited through advertisement at the authors' institution without any offered incentives. Each participant sat down, was briefed on the experiment and given a consent form to sign together with a demographic questionnaire to fill in. Each participant was then asked to wear the glove prototype system fitted with vibration motors, sense all 8 vibrotactile patterns and self-assess their experience in terms of pleasure and intensity using the modified version of the SAM [28,29].

To reduce ordering effects the first 8 participants were presented the vibrotactile patterns in order 1–8, whereas the other 8 participants were presented the patterns in the opposite sequence (8–1). Each participant felt each vibrotactile pattern twice, then was given 30 s to mark their experience in terms of pleasure and intensity onto the modified version of SAM (see Fig. 5). Each session lasted approximately 15 min, and all 16 participants completed the session in full.

#### *4.2.1. Results*

Following exploratory pilots, which assisted the iterative design process of the haptic patterns, the goal of this user study was to evaluate which patterns were most different. To do so, we compared the self-rated values of participants for pairs of patterns for both valence and arousal. The aim was to better understand what characteristics of the vibrotactile stimuli play a part in inducing certain feelings.

Table 3 describes the average ratings derived from the valence and arousal dimensions. The Wilcoxon Signed-Ranks Test was used as method to test the significance of the difference between the SAM's ratings for patterns' pairs of ordinal data (see Bryan-Kinns and Hamilton [31] for appropriate tests). 13 out of 28 pairs of patterns resulted significantly different in terms of valence, and 14 out of 28 possible pairs of patterns resulted significantly different in terms of arousal. Table 4 reports the results from the Wilcoxon Signed-Ranks Test for both the valence and the arousal dimensions, describing pairs of patterns which resulted significantly different. Visual representations of the arousal and valence average ratings, and confusion matrix for the pairs of patterns which reported significance differences in the Wilcoxon Signed-Ranks test are available in Mazzoni and Bryan-Kinns [32].

#### 4.2.2. Discussion

This study showed that vibrotactile patterns that resulted most reliably different were patterns: 1, 4, 5, 7, and 8. Patterns 1 and 5, and patterns 4 and 8, had the same values of PWM duty cycle for the actuators, but the vibrotactile stimuli were presented in a different sequential order. Results from this experiment indicate that the sequential order in which the vibrotactile stimuli are presented does not influence users' experience in terms of valence and arousal, suggesting instead that the key elements to contribute in shaping users' emotional response to vibrotactile stimuli are the perceived intensity and frequency of the haptic sensations. In this study, participants reliably associated vibrotactile stimuli with high intensity and high frequency (high PWM duty cycle) to high levels of valence and arousal. Vibrotactile patterns with low intensity and low frequency (low PWM duty cycle) were associated with low levels of valence and arousal. These results are consistent with the findings in Yoo et al. [33]. Furthermore some participants reported associating the vibrotactile patterns they experienced to rhythm found in music and also in ambient sounds. This correlation between vibrotactile stimuli and the mental interpretation of physical events is consistent with findings in [14]. Thus the findings have the potential to aid further work in this direction, and therefore warrants to further exploration.

Results from this user study show that vibrotactile stimuli at different levels of frequencies and intensities are able to suggest moods. Actuators intensity and frequency is controlled through manipulation of the PWM signal as in Frid et al. [34]. For further discussion of the significance of the results see [32]. This user study informed the next step of this work, in which participants sensed haptic patterns while watching movie clips, for a cross-modal experience.

### 4.3. Third user study: evaluation of haptic sensations with movie clips

The focus of this user study was to assess whether haptic sensations paired together with movie clips could enhance viewers' experience. The glove prototype was adapted to take in consideration participants' feedback in study 2 as described in Section 4.2, where users reported the vibration stimuli on the palm to tickle them. The adapted prototype removed the coin motors from the palm of the glove, leaving five coin motors on the back and rearranging them in a circle. This rearrangement was purely a design choice. Findings from early pilots of this work showed that different motors arrangement from the ones proposed, did not impact the response of participants to the stimuli. In early stages participants reported experiencing the stimuli as a whole, without being able to clearly identify different designs only based on the vibrotactile stimuli perceived on their hand. We thus consider that the rearrangement does not affect perception of the vibrotactile stimuli.

Four new haptic patterns were also designed (A, B, C, and D) to fit with the new prototype version, with same PWM signal values used in our second study, and presented in a clockwise sequential order. Our previous findings from the second user study showed that PWM values of the motors determined valence-arousal value, whereas sequential order in which the vibrotactile stimuli were presented did not influence users' emotional perception of the stimuli (as reflected in our results). Therefore we assume that the new adaptation of our vibrotactile patterns will consistently suggest same levels of valence and arousal.

Movie clips annotated in our first user study were paired with the four haptic patterns to create a cross-modal experience (see Table 1). Haptic patterns with PWM duty cycle simulating low frequency and intensity, and suggesting low valence and low arousal were paired with those clips users rated as low valence and low arousal in study 1 described in Section 4.1. The same way, haptic patterns associated with high valence and high arousal were paired with those clips participants had labeled as high valence and high arousal. This approach was chosen as we aim at amplifying the mood of certain movie scenes, not suggesting a different one.

21 participants took part in this study (10 males, 11 females, mean age: 31). Two sets of 12 short movie clips were watched under different conditions: audio movie clip (M), silent movie clip (SM), audio movie clip with haptic sensations (M + H), silent movie clip with haptic sensations (SM + H). The clips selected are described in Table 2 and covered a range of different moods, tones, actions, and imagery, but in all of them the film musical score was the prevailing element, with most movie clips having little or no dialogue at all. Each session lasted for approximately one hour, and participants' task was divided into two parts:

- part (A) watch and rate 12 audio clips with or without haptic sensations (conditions M and M + H)
- part (B) watch and rate 12 silent clips (where the audio was excluded when editing the clips) with or without haptic sensations (conditions SM and SM + H)

The task order was randomized among participants, as well as the sequential order of the clips played in each task. After watching each clip participants were asked to fill out the modified SAM also used in user study, Section 4.2, to self-rate their emotional experience. Once participants had finished rating the experience, they subsequently viewed the next clip.

**Table 1**
Haptic patterns and film clips pairing.

| Pattern | Pattern frequency | Pattern intensity | Clip | Clip mean valence | Clip mean arousal |
|---|---|---|---|---|---|
| A | Low | Low | 2 | −1 | 0 |
| | | | 7 | 0.4 | −0.2 |
| | | | 11 | −1.2 | 0 |
| B | High | Low | 1 | −0.3 | −0.3 |
| | | | 5 | 0.3 | −0.2 |
| | | | 12 | −1 | −0.3 |
| C | Low | High | 4 | −0.1 | 0.9 |
| | | | 8 | −0.3 | 1.2 |
| | | | 10 | −1.3 | 1.55 |
| D | High | High | 3 | 0.55 | 1.05 |
| | | | 6 | 1.25 | 1.21 |
| | | | 9 | 0.25 | 1.25 |

#### 4.3.1. Results

The aim of this experiment was to test whether watching movie clips accompanied by haptic sensations would result in participants self-reporting an increase of valence and arousal as opposed to watching the video clips without the haptic stimulation. Mann–Whitney was the non-parametric test for ordinal data chosen for the significance of the difference between the distributions of the two independent samples, M and M + H, and SM and SM + H. Results from ordinal test are shown in Tables 5–9.

#### 4.3.2. Discussion

The data reported in Tables 5–7 show that the addition of haptic sensations did not reflect in a significant change in valence. Arousal instead, was significantly found to heighten when the movie clips

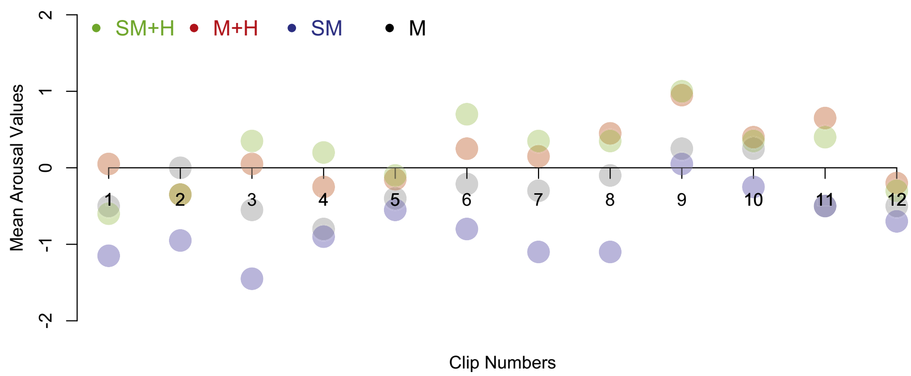


**Fig. 4.** Mean for arousal ratings.

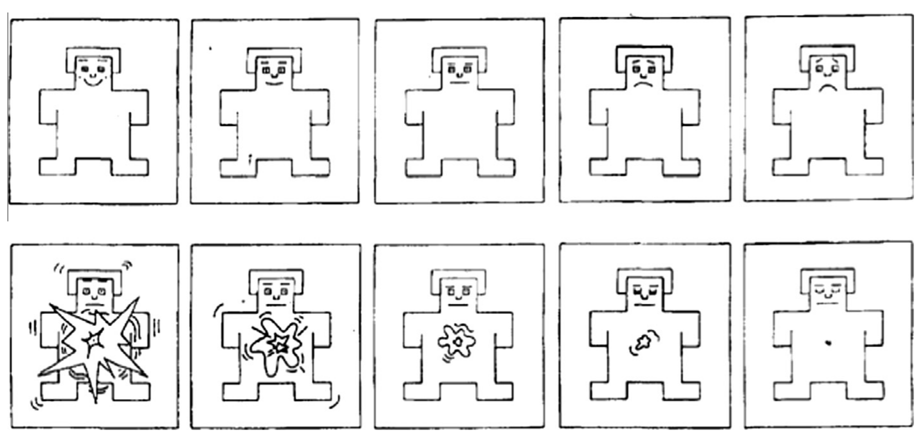

**Fig. 5.** Modified version of Sam. Top panel refers to the valence dimension, and bottom panel represents the arousal dimension. coding scale used for the mannequin (not shown to participants) was the following for each of the two panels, from left to right: 2, 1, 0, −1, −2.

**Table 2**
Movie clips description.

| Clip | Duration | Movie | Scene description | Mood |
|---|---|---|---|---|
| 1 | 00:42 | Amélie | A car drives by a road, wind makes two glasses 'dance' on a table, man erases contact from phone book. | Happy, calm |
| 2 | 00:29 | Amélie | Young Amélie watches her mum throw her goldfish in a river. It starts raining. | Calm, sad |
| 3 | 00:29 | Edward Scissorhands | It's evening, neighbors are in the streets gossiping, cars drive by. | Excitement, curiousity |
| 4 | 00:30 | Memento | A truck pulls up by an old shack, a man gets out and walks towards the shack (black and white). | Mysterious tense |
| 5 | 00:56 | Amélie | Amélie walks down the stairs in an underground station. | Happy, calm |
| 6 | 00:29 | Edward Scissorhands | Edward is in a car with Peg. They drive through a neighborhood. | Excitement curiousity |
| 7 | 01:11 | Amélie | Amélie plunging her hand into a sack of green lentils; cracking créme brûlèe; skimming stones on the river; watching from her window an old man painting in his home. | Calm |
| 8 | 00:30 | Edward Scissorhands | Peg enters Edward's house for the 1st time. | Mysterious |
| 9 | 00:51 | Amélie | Man runs into Amélie while running after a man in the train station. He runs out the station, Amélie runs after him. | Excitement, curiousity |
| 10 | 00:28 | Edward Scissorhands | Edward passes the corridor while his scratching off the wallpaper with his scissorhands. He enters the bathroom and looks at his reflection in the mirror while passing his hands against the wall. | Tense |
| 11 | 01:57 | Amélie | Phone in a phonebooth rings, a man walks by, enters the phone booth and picks up. Amélie on the other side hangs up. The man sees a metal box, he opens it and finds old belongings that bring back memories from his childhood. | Calm, nostalgic |
| 12 | 00:30 | Edward Scissorhands | Edward sees Kim and her boyfriend hugging and getting into a van together. | Calm, sad, sentimental |

are paired together with haptic sensations. These results are coherent with literature in [33]. Moreover, they confirm our initial aim, to intensify the mood of participants through the addition of haptic sensations. Fig. 4 summarizes the mean values participants gave to clips 1–12 across the different conditions SM + H, M + H, SM, and M. As visible in the graph, arousal values were higher for each clip when haptic sensations were added to the experience (except clip 2 where it overlaps with condition SM + H). This finding indicates that haptic sensations reliably intensify audience feelings, and consequently could enrich their experience.

Most participants declared to feel more engaged when they could feel the haptic sensations on their skin, especially when there was not audio. Most also reported that the haptic sensations increased their anticipation while watching the clips respect to when they watched a clip without any haptic sensations. Two potential limitations of this user study center around previous viewing, and novelty factor. More specifically, most participants had already watched the movies featured in the clips edited for the study. Whilst this could have influenced their experience due to repetition effects, this was discounted since all but three participants reported to not seen the films recently, i.e. over a year ago. Further studies will address this by taking into account a wider range of clips. Participants could also potentially have been biased by the novelty of the experience, as they all reported to have never experienced haptic sensations while watching a film, although some declared to have come across vibrotactile feedback while playing video games. Only 6 out of 21 participants declared to not enjoy special effects in entertainment. Further studies involving longer clips, and inviting previous participants back will help establish whether novelty effects are significant.

It is worth noting that qualitative data also backed up our finding of enhanced emotional experience. For instance, common comments during interviews at the end of the sessions were: *“the*

**Table 3**
Average ratings of valence and arousal dimensions (study 2).

| Pattern | Valence Avg rating | Arousal Avg rating |
|---|---|---|
| 1 | 0 | 1 |
| 2 | −0.25 | 0.5 |
| 3 | 0.1875 | 0.125 |
| 4 | −0.625 | −0.625 |
| 5 | 0.625 | 1.375 |
| 6 | −0.4375 | 0.375 |
| 7 | 0.625 | −0.0625 |
| 8 | −0.625 | −0.1875 |

**Table 4**
Ordinal data tests results (study 2).

| Patterns | Wilcoxon Signed-Ranks – valence | | | Wilcoxon Signed-Ranks – arousal | | |
|---|---|---|---|---|---|---|
| | *W* | *z* | P(1-tail) | *W* | *z* | P(1-tail) |
| 1,3 | *No significant difference* | | | 94 | 2.66 | 0.0039 |
| 1,4 | *No significant difference* | | | 105 | 3.28 | 0.0005 |
| 1,4 | −48 | −1.86 | 0.0314 | *No significant difference* | | |
| 1,7 | −48 | −1.86 | 0.0314 | 66 | 2.91 | 0.0018 |
| 1,8 | 40 | 1.76 | 0.0392 | 102 | 2.88 | 0.002 |
| 2,4 | *No significant difference* | | | 91 | 3.16 | 0.0008 |
| 2,5 | −47 | −2.07 | 0.0192 | −58 | −2.56 | 0.0052 |
| 2,7 | −64 | −2.22 | 0.0132 | *No significant difference* | | |
| 2,8 | *No significant difference* | | | 54 | 2.1 | 0.0179 |
| 3,4 | 34 | 1.71 | 0.0436 | 47 | 2.37 | 0.0089 |
| 3,5 | *No significant difference* | | | −85 | −2.65 | 0.004 |
| 3,8 | 55 | 1.9 | 0.0287 | *No significant difference* | | |
| 4,5 | −66 | −2.57 | 0.0051 | −120 | −3.39 | 0.0003 |
| 4,7 | −93 | −2.63 | 0.0043 | *No significant difference* | | |
| 5,6 | 51 | 2.57 | 0.0051 | 66 | 2.91 | 0.0018 |
| 5,7 | *No significant difference* | | | 97 | 3.03 | 0.0012 |
| 5,8 | 74 | 2.88 | 0.002 | 91 | 3.16 | 0.0008 |
| 6,7 | −67 | −2.32 | 0.0102 | *No significant difference* | | |
| 6,8 | *No significant difference* | | | 46 | 1.78 | 0.0375 |
| 7,8 | 66 | 2.91 | 0.0018 | *No significant difference* | | |

**Table 5**
Non-parametric ordinal data test results for M vs M + H *from SAM ratings* (note: significant differences are highlighted in **bold**) – (study 3).

| Pattern | Clip | Mann–Whitney Test – valence | | | Mann–Whitney Test – arousal | | |
|---|---|---|---|---|---|---|---|
| | | U | z | P | U | z | P |
| A | 2 | 56.5 | 0.23 | 0.409 | 50 | 0.66 | 0.2546 |
| | 7 | 46.5 | 0.89 | 0.1867 | 75.5 | −0.95 | 0.1711 |
| | 11 | 62 | −0.87 | 0.1922 | **81** | **−2.31** | **0.0104** |
| B | 1 | 56.5 | −0.45 | 0.3264 | 66 | −1.17 | 0.121 |
| | 5 | 37 | 0.94 | 0.1736 | 55.5 | −0.38 | 0.352 |
| | 12 | 46.5 | 0.23 | 0.409 | 58 | −0.57 | 0.2843 |
| C | 4 | 45 | 0.34 | 0.3669 | 66.5 | −1.21 | 0.1131 |
| | 8 | 55 | −0.34 | 0.3669 | 65.5 | −1.13 | 0.1292 |
| | 10 | 52 | −0.11 | 0.4562 | 51.5 | −0.08 | 0.4681 |
| D | 3 | 39.5 | 0.76 | 0.2236 | 63.5 | −0.98 | 0.1635 |
| | 6 | 52.5 | −0.15 | 0.4404 | 60.5 | −0.76 | 0.2236 |
| | 9 | 52.5 | −0.15 | 0.4404 | 63 | −0.94 | 0.1736 |

**Table 6**
Non-parametric ordinal data test results for SM vs SM + H *from SAM ratings* (note: significant differences are highlighted in **bold**) – (study 3).

| Pattern | Clip | Mann–Whitney Test – valence | | | Mann–Whitney Test – arousal | | |
|---|---|---|---|---|---|---|---|
| | | U | z | P | U | z | P |
| A | 2 | 42.5 | 0.53 | 0.2981 | 67.5 | −1.29 | 0.0985 |
| | 7 | 58 | −0.57 | 0.2843 | **80.5** | **−2.27** | **0.0116** |
| | 11 | 51.5 | −0.08 | 0.4681 | **75** | **−1.85** | **0.0322** |
| B | 1 | 66 | −1.71 | 0.121 | 65 | −1.1 | 0.1357 |
| | 5 | 40 | 0.72 | 0.2358 | 68 | −1.32 | 0.0934 |
| | 12 | 45 | 0.34 | 0.3669 | 60 | −0.72 | 0.2358 |
| C | 4 | 64.5 | −1.06 | 0.1446 | **77.5** | **−2.04** | **0.0207** |
| | 8 | 43.5 | 0.45 | 0.3264 | **83.5** | **−2.49** | **0.0064** |
| | 10 | 34 | 1.17 | 0.121 | 62.5 | −0.91 | 0.1814 |
| D | 3 | 53 | −0.19 | 0.4247 | **92.5** | **−3.17** | **0.0008** |
| | 6 | 67 | −1.25 | 0.1056 | **87** | **−2.76** | **0.0029** |
| | 9 | 40.5 | 0.68 | 0.2483 | 71 | −1.55 | 0.0606 |

**Table 7**
Non-parametric ordinal data test results for M vs SM + H *from SAM ratings* (note: significant differences are highlighted in **bold**) – (study 3).

| Pattern | Clip | Mann–Whitney Test – valence | | | Mann–Whitney Test – arousal | | |
|---|---|---|---|---|---|---|---|
| | | U | z | P | U | z | P |
| A | 2 | 51.5 | −0.08 | 0.4681 | 41 | 0.64 | 0.2611 |
| | 7 | 35 | 1.1 | 0.1357 | 67.5 | −1.29 | 0.0985 |
| | 11 | 67 | −1.25 | 0.1056 | **73** | **−1.7** | **0.0446** |
| B | 1 | 51.5 | −0.08 | 0.4681 | 46 | 0.26 | 0.3974 |
| | 5 | 37.5 | 0.91 | 0.1814 | 61 | −0.79 | 0.2148 |
| | 12 | 46.5 | 0.23 | 0.409 | 53.5 | −0.23 | 0.409 |
| C | 4 | 54 | −0.26 | 0.3974 | **76** | **−1.93** | **0.0268** |
| | 8 | 45.5 | 0.3 | 0.3821 | 61.5 | −0.83 | 0.2033 |
| | 10 | 54.5 | −0.3 | 0.3821 | 51.5 | −0.08 | 0.4681 |
| D | 3 | 27.5 | 1.66 | 0.0485 | **73** | **−1.7** | **0.0446** |
| | 6 | 47.5 | 0.15 | 0.4404 | **79.5** | **−2.19** | **0.0143** |
| | 9 | 34.5 | 1.13 | 0.1292 | 65 | −1.1 | 0.1357 |

**Table 8**
Mean and standard deviation of clips for *Valence* under conditions: M, M + H, SM, SM + H (study 3).

| Clip | M | | M + H | | SM | | SM + H | |
|---|---|---|---|---|---|---|---|---|
| | mean | SD | mean | SD | mean | SD | mean | SD |
| 1 | −0.4 | 0.8 | −0.1 | 1.22 | −0.7 | 0.715 | −0.25 | 0.755 |
| 2 | −0.7 | 0.483 | −0.85 | 0.747 | −0.55 | 0.685 | −0.65 | 0.58 |
| 3 | 0.55 | 0.687 | 0.35 | 0.669 | −0.2 | 0.423 | −0.1 | 0.738 |
| 4 | −0.1 | 0.539 | −0.3 | 0.675 | −0.35 | 0.474 | 0 | 0.707 |
| 5 | 0 | 0.866 | −0.35 | 0.883 | 0.05 | 0.725 | −0.3 | 0.856 |
| 6 | 0.85 | 0.95 | 0.95 | 0.497 | 0.4 | 0.516 | 0.8 | 0.715 |
| 7 | 0.3 | 1.059 | 0.1 | 0.994 | −0.05 | 0.725 | 0.1 | 0.658 |
| 8 | −0.35 | 0.45 | −0.35 | 0.747 | −0.3 | 0.483 | −0.45 | 0.864 |
| 9 | 0.25 | 0.602 | 0.4 | 0.658 | 0.1 | 0.737 | −0.15 | 0.883 |
| 10 | −1.1 | 0.735 | −1.05 | 0.497 | −0.6 | 0.516 | −1 | 0.707 |
| 11 | −1.1 | 0.7 | −0.55 | 1.257 | −0.55 | 1.066 | −0.4 | 1.174 |
| 12 | −1 | 0.387 | −1.05 | 0.896 | −0.9 | 0.876 | −1.1 | 0.738 |

**Table 9**
Mean and standard deviation of clips for *Arousal* under conditions: M, M + H, SM, SM + H (study 3).

| Clip | M | | M + H | | SM | | SM + H | |
|---|---|---|---|---|---|---|---|---|
| | mean | SD | mean | SD | mean | SD | mean | SD |
| 1 | −0.5 | 0.837 | 0.05 | 1.117 | −1.15 | 0.747 | −0.6 | 1.101 |
| 2 | 0 | 0.943 | −0.35 | 0.818 | −0.95 | 1.212 | −0.35 | 0.944 |
| 3 | −0.55 | 1.106 | 0.05 | 1.257 | −1.45 | 0.832 | 0.35 | 0.747 |
| 4 | −0.8 | 0.98 | −0.25 | 0.89 | −0.9 | 1.075 | 0.2 | 0.888 |
| 5 | −0.4 | 0.8 | −0.15 | 0.883 | −0.55 | 0.926 | −0.1 | 0.907 |
| 6 | −0.212 | 0.873 | 0.25 | 0.979 | −0.8 | 1.111 | 0.7 | 0.537 |
| 7 | −0.3 | 0.949 | 0.15 | 1.156 | −1.1 | 1.022 | 0.35 | 1.029 |
| 8 | −0.1 | 1.02 | 0.45 | 0.926 | −1.1 | 1.22 | 0.35 | 0.784 |
| 9 | 0.25 | 1.365 | 0.95 | 0.926 | 0.05 | 1.301 | 1 | 1.155 |
| 10 | 0.25 | 1.209 | 0.4 | 1.049 | −0.25 | 1.23 | 0.35 | 1.248 |
| 11 | −0.5 | 1.049 | 0.65 | 0.58 | −0.5 | 0.972 | 0.4 | 0.937 |
| 12 | −0.5 | 0.949 | −0.2 | 1.033 | −0.7 | 0.823 | −0.3 | 0.823 |

*vibrations helped in building up suspense*"; "*when the vibrations were more intense I felt an increase in my expectations*"; and "*the vibrations made me more excited*".

## 5. Conclusions and future work

In this paper we presented a study aimed at exploring the possibility of enhancing mood music in film entertainment through haptic sensations. Our ultimate goal is to further enrich viewers' emotional experience through cross-modality. Our study comprised three user studies: the first consisted in the extraction and emotional annotation of over 40 short movie clips; a second study, which designed multiple vibrotactile patterns and assessed users' valence-arousal response to the stimuli on their own; and a third study where movie clips were paired with haptic sensations to evaluate viewers' sentimental response in a cross-modal experience.

Results from our second experiment, conducted with 16 participants, suggested that vibrotactile stimuli played at low intensity and frequency could induce an emotional response or mood characterized by low pleasure and low intensity, where instead vibrotactile stimuli at high frequency and intensity could induce a sense of high and intense pleasure. When we extended the use of haptic sensations in a movie-watching scenario, as in our third user study, we observed that the use of haptic sensations did not alter valence. Instead, we observed that it heighten participants self-reported arousal values, resulting in a more intense mood perception of the film scene. Furthermore, participants gave positive informal verbal feedback regarding the device and the haptic sensations, with some reporting that the haptic device facilitated them in connecting with the movie clips, especially when the audio was not present. Others also reported that different haptic sensations increased their feelings of anticipation, tension, and also induced a sense of calmness. In light of these findings, this research aims to conduct further investigation to explore how to use haptic sensations in film to build up suspense and increase tension.

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## References


[1] S. Frith, Mood music, Screen 25 (3) (1984) 78–88.
[2] S. Eberhardt, L. Bernstein, D. Coulter, L. Hunckler, Omar a haptic display for speech perception by deaf and deaf-blind individuals, in: IEEE Virtual Real. Annu. Int. Symp., 1993, pp. 195–201, http://dx.doi.org/10.1109/VRAIS.1993.380778.
[3] D. Bordwell, K. Thompson, Film Art: An Introduction, ninth ed., McGraw Hill, Boston, 2008.
[4] J. Monaco, How to Read a Film: Movies, Media, and Beyond: Art, Technology, Language, History, Theory, fourth ed., Oxford University Press, Oxford; New York;, 2009.
[5] R. Parke, E. Chew, C. Kyriakakis, Quantitative and visual analysis of the impact of music on perceived emotion of film, Comput. Entertain. 5(3) http://dx.doi.org/10.1145/1316511.1316516.
[6] S. Boswell, Music in cinema: how soundtrack composers act on the way people feel, keynote speech on "Music and emotions: compositions perspectives, in: presented at the 9th Int. Symp. CMMR 2012 on Music and Emotions, London, UK, June 19–22, 2012.
[7] M. Karam, G. Nespoli, F. Russo, D.I. Fels, Modelling perceptual elements of music in a vibrotactile display for deaf users: a field study, in: Proceedings of the 2009 Second International Conferences on Advances in Computer-Human Interactions, ACHI '09, IEEE Computer Society, Washington, DC, USA, 2009, pp. 249–254, http://dx.doi.org/10.1109/ACHI.2009.64.
[8] K. Matthews, Musicforbodies, 1997. <http://www.musicforbodies.net/wiki/>.
[9] K. Matthews, The Making of Sonic Bed Scotland, 2007. <http://vimeo.com/26954210>.
[10] E. Glennie, Hearing Essay, 1993, [Online]. Available: <www.evelyn.co.uk/hearing-essay/> (last accessed: Mar. 3, 2015).
[11] S. Nanayakkara, E. Taylor, L. Wyse, S.H. Ong, An enhanced musical experience for the deaf: design and evaluation of a music display and a haptic chair, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '09, ACM, New York, NY, USA, 2009, pp. 337–346, http://dx.doi.org/10.1145/1518701.1518756.
[12] M. Karam, F. Russo, C. Branje, E. Price, D.I. Fels, Towards a model human cochlea: Sensory substitution for crossmodal audio-tactile displays, in: Proceedings of Graphics Interface 2008, Canadian Information Processing Society, 2008, pp. 267–274.
[13] M.A. Eid, H.A. Osman, Affective haptics: current research and future directions, IEEE Access 4 (2016) 26–40, http://dx.doi.org/10.1109/ACCESS.2015.2497316.
[14] P. Lemmens, F. Crompvoets, D. Brokken, J. van den Eerenbeemd, G.-J. de Vries, A body-conforming tactile jacket to enrich movie viewing, in: Proceedings of the World Haptics 2009 – Third Joint EuroHaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, WHC

'09, IEEE Computer Society, Washington, DC, USA, 2015, pp. 7–12, http://dx.doi.org/10.1109/WHC.2009.4810832.

[15] E.O. Dijk, A. Weffers-Albu, T. De Zeeuw, A tactile actuation blanket to intensify movie experiences with personalised tactile effects, in: Int. Conf. Intell. Technol. Interactive Entertain. (INTETAIN), 2010, pp. 2–3.

[16] A. Israr, S. Zhao, K. Schwalje, R. Klatzky, J. Lehman, Feel effects: enriching storytelling with haptic feedback, ACM Trans. Appl. Percept. 11 (3) (2014) 11:1–11:17, http://dx.doi.org/10.1145/2641570.

[17] S. Mann, Wearable computing as means for personal empowerment, in: Keynote presented at the 1998 International Conference on Wearable Computing ICWC-98, Fairfax VA, May 1998, 1998.

[18] K. Myles, M.S. Binseel, The tactile modality: a review of tactile sensitivity and human tactile interfaces, in: Human Research and Engineering Directorate 2007 Aberdeen Proving Ground, MD, Tech. Rep. ARL-TR-4115.

[19] S. Carvalho, J. Leite, S. Galdo-Álvarez, Ó.F. Gonçalves, The emotional movie database (EMDB): a self-report and psychophysiological study, Appl. Psychophys. Biof. 37 (4) (2012) 279–294.

[20] A. Schaefer, F. Nils, X. Sanchez, P. Philippot, Assessing the effectiveness of a large database of emotion-eliciting films: a new tool for emotion researchers, Cognition Emotion 24 (7) (2010) 1153–1172.

[21] A. Hanjalic, Extracting moods from pictures and sounds: towards truly personalized tv, IEEE Signal Proc. Mag. 23 (2) (2006) 90–100, http://dx.doi.org/10.1109/MSP.2006.1621452.

[22] A. Salway, M. Graham, Extracting information about emotions in films, in: Proceedings of the Eleventh ACM International Conference on Multimedia, MULTIMEDIA '03, ACM, New York, NY, USA, 2003, pp. 299–302, http://dx.doi.org/10.1145/957013.957076.

[23] C.H. Chan, G.J.F. Jones, Affect-based indexing and retrieval of films, in: Proceedings of the 13th Annual ACM International Conference on Multimedia, MULTIMEDIA '05, ACM, New York, NY, USA, 2005, pp. 427–430, http://dx.doi.org/10.1145/1101149.1101243.

[24] A. Hanjalic, L.-Q. Xu, Affective video content representation and modeling, IEEE Trans. Multimedia 7 (1) (2005) 143–154, http://dx.doi.org/10.1109/TMM.2004.840618.

[25] M. Xu, L.-T. Chia, J. Jin, Affective content analysis in comedy and horror videos by audio emotional event detection, in: IEEE International Conference on Multimedia and Expo, 2005, ICME 2005, 2005, p. 4, http://dx.doi.org/10.1109/ICME.2005.1521500.

[26] M. Soleymani, M. Larson, T. Pun, A. Hanjalic, Corpus development for affective video indexing, IEEE Trans. Multimedia 16 (4) (2014) 1075–1089, http://dx.doi.org/10.1109/TMM.2014.2305573.

[27] M. Russell, J.E. Young, Film Music, Roto Vision, London, 2000.

[28] M.M. Bradley, P.J. Lang, Measuring emotion: the self-assessment manikin and the semantic differential, J. Behav. Ther. Exp. Psychiatry 25(1) (1994).

[29] P.J. Lang, Behavioural Treatment and Bio-Behavioral Assessment: Computer Applications, first ed., Ablex, 1980.

[30] M. Soleymani, G. Chanel, J.J. Kierkels, T. Pun, Affective ranking of movie scenes using physiological signals and content analysis, in: Proceedings of the 2Nd ACM Workshop on Multimedia Semantics, MS '08, ACM, New York, NY, USA, 2008, pp. 32–39, http://dx.doi.org/10.1145/1460676.1460684.

[31] N. Bryan-Kinns, F. Hamilton, Identifying mutual engagement, J. Behav. Inf. Technol. (2009) 1–25.

[32] A. Mazzoni, N. Bryan-Kinns, How does it feel like? An exploratory study of a prototype system to convey emotion through haptic wearable devices, in: Proceeding of the 7th International Conference on Intelligent Technologies for Interactive Entertainment (INTETAIN) 2015, 2015, pp. 64–68.

[33] Y. Yoo, T. Yoo, J. Kong, S. Choi, Emotional responses of tactile icons: effects of amplitude, frequency, duration, and envelope, in: 2015 IEEE World Haptics Conference (WHC), IEEE, 2015, pp. 235–240.

[34] E. Frid, M. Giordano, M.M. Schumacher, M.M. Wanderley, Physical and perceptual characterization of a tactile display for a live-electronics notification system, in: ICMC SMC 2014, McGill University, 2014.