Physical Emotion Induction and Its Use in Entertainment

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Abstract It is well known that our emotional response has a relation with our bodily state, and that our bodily state can directly influence particular emotions we feel. It appears, however, that this fact has so far not had a significant influence in the entertainment industry. We first review existing work on physical emotion induction. Based on this work we present several techniques to influence emotional responses through physical means in a non-cognitive manner. The basis for the different techniques is a two-factor model of emotion: Pleasure and Arousal. Secondly, we selected 4 sets of movie clips that correspond to the 4 possible quadrants existing in the 2 factor model. Thirdly, we have implemented some of the emotion induction techniques in a physical device (interactive chair) and tested the effects on the immersiveness of the movie clips and the emotional experience of the participants.

Introduction

Humans can be emotionally influenced in many ways. The entertainment industry makes good use of this fact by using video and audio to do so. We see a film and are grabbed by the story, we hear happy, sad or tense music and our feelings respond accordingly. There is a multitude of audiovisual means to influence our emotions, but not many mechanisms to influence emotion using *physical* means.

Somehow, physical emotion induction has been largely ignored, even though psychological research clearly shows that our emotional state is at least partially dependent on our physical state.

There is of course a physical element to be found in the entertainment industry, namely the vibrating game controller. However, vibration is only used to immerse the player of a video game in the game world either by mimicking sound or emphasizing some event in the storyline of the game, like an explosion or a car crash. The same can be said for physically moving seats in certain amusement park theatres, which mimic what is seen on the screen to enhance the experience and make it more immersive. Both work well in achieving their goal, but they are not aimed at inducing a particular emotion, as music or storylines can be.

Here we report on research into the possibilities of influencing a person's emotions through physical means, in order to enhance the emotions experienced while watching a movie or playing a video game. To enhance rather than disrupt such an immersive experience, this process of physical emotion elicitation should happen implicitly, i.e. without the user being cognitively aware of any influence. Furthermore, we try to avoid any invasive means to achieve emotion elicitation. Of course, all physical measures are to some extent invasive, but the aim is to reduce this to a minimum. We therefore do not use techniques at the level of intrusion of drug application, for example.

We first review the concept of emotion, the relation between the bodily state and emotion as well as physical emotion induction. Based on this review we present different techniques to influence particular emotions, and discuss an experiment with a physical device that implements some of these techniques.

The Nature of Emotion

Emotion has long been the terrain of much research and discussion. Ever since James (1884) presented a theory stating that emotions are only the result of changes in the body, the roles played by physiology and cognition in relation to emotion have been heavily debated. Philippot et al. (2002) describe the current views on these relationships as existing in three conceptions. The first is what they call the *undifferentiated arousal model*, which states that the intensity of emotion and arousal are connected and influence one another, but remain consistent across different emotions. Furthermore, arousal must be consciously perceived and subjectively attributed to the impact of the emotional situation.

The second conception they address is the *cognitive appraisal model*, stating that the bodily changes that occur during an emotion are a function of cognitive appraisal or action readiness. Here,

changes in body state play no significant role in the elicitation of emotion.
The third and final model that Philippot et al. discern is the *central network model*. This model assumes a central neural or cognitive network that connects the various components of emotions. It argues that different emotions are associated with different changes in body state, and that changes in body state that are typical for a specific emotion will elicit that emotion and that this phenomenon, called *peripheral feedback*, occurs at an implicit level (i.e., without the person experiencing it being explicitly aware of the process). We focus on this model, as it is the most relevant in the context of implicit physical emotion induction.

Influencing Emotion

It has been shown that facial expression can increase feelings of emotion (Duclos et al., 1989, McIntosh et al., 1997). What is more, emotion-inducing facial expressions have been shown to be specific for specific emotions, a finding which supports the central network model. This was shown by Duclos et al. (1989), who also showed that emotions do not occur along the axis of a single dimension, such as pleasant – unpleasant, but are multidimensional.

Posture
The findings for emotion induction through facial expressions were hypothesized to be true for postures as well. The results of a second experiment in Duclos et al.'s research suggest that this is indeed the case, but that posture manipulations have the greatest emotional effect on people who are sensitive to self-produced cues rather than situational cues. In the latter case, a person defines his or her own feelings according to situational cues implying what they are feeling, in contrast with the former case where a person changes his or her feelings to correspond to his or her body state.

This study revealed that specific postures can be associated to fear, anger and sadness, showing the multidimensional characteristics of emotion. In earlier research, Riskind & Gotay (1982) showed a readiness to develop helplessness in a frustrating task as a result of a hunched posture. The relation of stress reactions to posture was also studied and it was shown that a slumped-over physical posture can indeed trigger stress reactions when it occurs in combination with external threat conditions, in this study presented in the form of the expectation of a difficult task for high threat and an easy task for low threat. In the first study, helplessness was developed during a frustrating task presented to the subjects after they had previously been placed in a hunched posture, but the study of the development of stress reactions showed that this can in fact occur simultaneously with a slumped-over posture, as long as an external factor explaining the emotional response is present, according to Riskind et al. (1982). In the context of physical emotion induction in entertainment, this last point is of great importance, because while for example one is watching a movie, an external factor would indeed be present to explain any experienced emotional response and physical posture manipulation may be used to enhance the emotional experience triggered by the audiovisual media.

The residual effect on persistence in a difficult task, shown by Riskind et al.'s (1982) first study seems to be countered by a study by Stepper & Strack (1993), in which they show that success at an achievement task led to greater feelings of pride if the outcome was received in an upright position rather than in a slumped position. In this study, manipulation of posture only had a significant effect on pride if it occurred simultaneously with performance feedback. An explanation may be found in Helson's (1964) suggestion that longer maintenance of a posture results in a decrease of intensity of influence. This is in concordance with the physiological principle that neural effects are produced by changes in sensory input rather than by mere state (Deutsch & Deutsch, 1973). From this it can be derived that not merely *being* in a certain posture has the greatest influence on emotional state, but rather a *change* in posture does.
Stepper & Strack's (1993) criticism of the studies of Duclos et al. (1989) and Riskind & Gotay (1982) is that in these studies subjects are explicitly placed in a specific posture or instructed to do so. It is argued that this enhances awareness of body state in the subject, which may trigger interpretation of the body state and thus influence self-perception of emotion. To avoid this, Stepper & Strack (1993) take care to avoid attention being drawn to the changes in posture and thus show that posture can influence emotional state at an implicit level, giving support to the central network model of emotion. This constitutes another important point for the type of emotion induction we want to study; when emotion is physically influenced during a multimodal experience, the attention of the user may not be drawn to this process, because the immersive experience of the user must be uninterrupted, even enhanced. Therefore, emotion elicitation must occur without the user being aware of it.

One possible underlying mechanism for the effect of posture manipulation on emotional feeling state is discussed by Stepper & Strack (1993): *respiration*. They refer to the vascular theory of emotion efference (VTEE), which states that cooling of the brain enhances positive affect and heating of the brain enhances negative affect and that brain temperature is influenced by the inhalation of air through the nose, which in turn is regulated by facial movement. The implications of this theory have been researched by McIntosh et al. (1997). In a first study, results showed a simultaneous occurrence of a decrease in volume of nasal air inhalation, an increase in forehead temperature –serving as a measure of brain temperature– and an increase in negative affect, but they failed to show a clear causal relation between these effects. In a second study, decrease of nasal air volume is associated with an increase in negative affect, but again without an indisputable causal effect and moreover without an increase in forehead temperature. However, a third study does show a significant relation between forehead temperature and nasal air volume, countering the lack of temperature results in the second study. All in all, these studies do not provide VTEE with solid evidence, although the theory does seem plausible. In any case these studies do show that, regardless of VTEE providing the correct explanations or not, affect can be influenced by changes in breathing patterns through changes in facial musculature.

Respiration

Respiration patterns as a possible source of emotional influence were later researched by Philippot, Chapelle & Blairy (2002). Boiten et al. (1994) had already found objective respiratory patterns that could be associated with specific emotions and Philippot et al. (2002) showed that people can produce quite specific emotions through self-regulation of breathing patterns. These patterns were subjective, but specific, showed a clear differentiation among emotions and were consistent with the objective patterns that were found by Boiten et al. (1994). The subjective breathing patterns found in the first study were used in a second study to induce emotions in subjects who were unaware of the goal of the study and simply followed breathing instructions. The results support the central network model of emotion, but Stepper & Strack's (1993) earlier criticism that awareness of body changes may trigger interpretation thereof in emotional terms, applies to this study as well.

The studies of Philippot et al. (2002) show that specific subjective feeling states can be induced through specific breathing patterns. Such patterns were found for joy, sadness and anger, but fear yielded mixed results and could not be differentiated from anger. However, the different breathing patterns used for anger and fear differ only slightly in amplitude, which may provide sufficient explanation for the fact that the two emotions could not be clearly distinguished. The question remains if the patterns found and used are accurate and that the small difference is due to actual physical resemblance in emotion or if the patterns themselves were inaccurate, a possibility which cannot be ruled out considering the small amount of 23 participants used in the first study. The results found by Boiten et al. (1994) show the same difference between respiratory patterns for fear and anger, only in a more pronounced manner. On the other hand, the relative success with finding breathing patterns for the other emotions in Philippot et al.'s (2002) studies may indicate that the small difference in anger and fear breathing patterns is accurate. More extensive research into this matter could help clarify the issue.

Temperature

As said earlier, McIntosh et al. (1997) focussed on the vascular theory of emotional efference (VTEE) as a description of the physiological mechanisms involved in the elicitation of affect. Breathing patterns and temperature play major roles in this theory, and at least breathing patterns are shown to be capable of inducing affect (Philippot et al., 2002). So how about temperature?

VTEE states that brain temperature influences affect, where cooling enhances positive, and heating enhances negative affect. Beside brain temperature, it has been shown that temperatures of other parts of the body vary in association with emotions (Mittelmann & Wolff, 1939, Briese, 1994, McFarland, 1985). McFarland has shown a relation between skin temperature changes and affect in music. His study tested whether an ongoing increase or decrease in skin temperature could be perpetuated, stopped or reversed with music that was subjectively categorized by subjects as calm and evoking positive affect or arousing and evoking negative affect. His conclusions are that skin temperature decreases are terminated and increases perpetuated by positive music, while the opposite goes for negative music. The causal relationship in this case is inferred in the direction of emotion towards physical response. A reversed causal effect where skin temperature changes can cause changes in affect would be of great interest for the purposes of implicit emotion elicitation.

Such a relation has been investigated, but most investigations on this subject focus on the relation between temperature and aggression (for a review, see Anderson, 1989). The basic hypothesis concerning this relation is that uncomfortably hot temperatures increase aggressive tendencies. Although findings are not fully consistent across various studies, especially not for those performed in a laboratory setting, results do clearly support the temperature-aggression hypothesis. In a more recent research, Anderson, Anderson & Deuser (1996) investigated amongst other things the relation of temperature not only to aggression, but also to general negative affect. This research showed an increase in negative affect as a result of hot as well as cold temperatures, but this increase was considerably less pronounced than the effect of temperature on hostility.

Haptic and Tactile Feedback

In the search for further possibilities to physically and implicitly elicit emotions, one can think of haptics. Thus far, haptic and tactile feedback is used to communicate information. One may think of interfaces in a car allowing you to feel the switch of the windshield wipers without having to look or vibrating mobile phones alerting you to a call or a message. In the context of video games, haptic feedback is implemented through vibrating controllers, often mimicking sound effects or other events seen on screen. A more advanced use of tactile feedback can be found in wearable tactile displays (Tan & Pentland, 1997). One such display makes use of a physiological effect called sensory saltation, to convey directional information through vibration patterns. None of the mentioned interfaces however, is used for the elicitation of emotion. Some interesting experiments have been performed that use haptic feedback in the communication of emotion between humans, but they are concerned with active cognitive interpretation of a communicated emotional state (Brave & Dahley, 1997, Mathew, 2005, Rovers & Van Essen, 2004).

More interestingly, a product called the *Hapticat* was developed to study the relationship between touch and affect (Yohanan, Chan, Hopkins, Sun & MacLean, 2005). The product can best be described as a fuzzy football with ears and a tail and is capable of showing emotion through various behaviours, such as purring, breathing and changing temperature. A sample of emotional responses was selected and implemented in ways that were seen fit to represent these emotions, which were then tested on subjects. The results show that people were able do discern distinct emotions in the responses of the Hapticat and interaction with the device changed affect in the subjects as well. In the context of non-cognitive emotion elicitation this has great potential, as an emotional device may, through empathy, elicit similar emotions in the user. There are some problems that should be noted here however, which need to be addressed before such a device is implemented in the suggested manner. First of all, the Hapticat experiment used implementations of emotional responses based on the intuition of the researchers. The implementations do not seem to be supported by any research and in this way they obscure the results of the experiment. Given a certain range of responses to assign a certain range of emotions to, the mapping may be quite accurate. If the subject would not be aware of any range of possibilities however, the results may prove to be quite different. Of course, if a similar device was implemented to elicit emotions in a non-cognitive manner, the subject should not be aware of or limited to any number of choices. This leads us to the second problem: user awareness of an emotional charge. In the Hapticat experiment, users are presented with various emotions to assign to the responses of the device, alerting them to emotional effects. This would of course be quite contradictory to the goal of *implicit* emotional elicitation. Thirdly and finally, the Hapticat experiment investigated if subjects responded emotionally to the device, but the experiment did not seem to be aimed at reproducing the perceived emotional response of the device in the subjects. Emotional subject responses did occur, but more as positive surprise and elation at the fact that the device responded at all than as a replication of the devices affective reactions.

Concluding that the Hapticat, or a similar device, may not be a good option at this point, should we drop haptics altogether as a means for physical emotion elicitation? We believe not. Let us look again at the sensory saltation effect and the way in which interfaces may use it. In such an interface, a series of pulses applied in sequence by a small array of vibration modules may yield the sensation of a line being drawn over the skin. Even though no previous research shows how this could induce emotions, in the light of our hypothesis it may prove to be a useful tool.

As the *central network model* of emotion states, specific emotions can be elicited by inducing their corresponding bodily changes. As we have seen so far, this has indeed proven to be possible.

As Tarja Laine (2006) and others before her noted, we experience film not only in an audiovisual way, but with our entire body. We relate emotions to touch, as can be seen in various expressions such as “it makes my skin crawl”. The sensory saltation effect, then, can be used to our advantage and send an actual shiver up a person’s spine, stimulating the emotion of fear or disgust. We might even create a tingling sensation over the length of the entire body, causing shivers or goose bumps.

Haptics may further be employed to induce emotion through general vibration. We can feel the vibration of low frequency sound, which may help us to immerse in the experience of a movie, experiencing the sound with our entire body, rather than with just our ears. We can use this in a more specifically emotion inductive manner, namely to influence heart rate. Research indicates that false feedback of heart rate has the potential to alter our emotional response (Decaria et al., 1974, Larkin et al., 1990, Liebhart, 1977), even when the feedback signal is ignored (Parkinson & Colgan, 1988). Although most researches do not show that false feedback of heart rate influences actual heart rate, they do show that emotional interpretation itself can change as a result of false feedback. Whether it works through a process of attribution or through a more direct and purely physical process is beyond the scope of this research to answer. What is important here is the effect, which has been shown to exist.

Palmar sweat

Skin is important in emotion in another respect: sweating. It has been shown that skin conductance changes in response to emotion (Collett et al., 1997, Critchley et al., 2000, Critchley, 2002, Hubert & De Jong-Meyer, 1990, Khalfa et al., 2002, Pecchinenda & Smith, 1996). Anxiety or emotional arousal affects the resistance and conductance of the skin: the higher the level of arousal, the higher the electrical conductance and the lower the resistance of the skin. The activity of the sweat glands has been associated with this effect, and is generally accepted as an index for the level of arousal (Ferreira & Winter, 1963, Mittelmann & Wollf, 1939). Of course in this research, it is not measurement of anxiety that is of importance, but rather the induction of it. And even though no research to date has investigated emotional responses as a result rather than a cause of palmar sweat, such an implementation deserves attention. As the central network model of emotion predicts the possibility to elicit emotional responses by inducing their accompanying physical states, a hypothesis that we have seen can rely on a great deal of supporting evidence, the physical act of sweating may prove to be a potent emotion elicitor as well. One practical advantage here is that Allen et al. (1973) have shown that emotional sweating is not restricted to palms, but occurs on other parts of the body as well, the amount of sweat being roughly proportional to the amount of sweat glands present in a given region. In a practical, emotion inductive setup, this gives us room to work around the problem of getting one's hands to start sweating and allows us to target other regions.

Scent

Finally, let's look at what the sense of smell has to offer in terms of emotion.

First of all, it has been shown that odours can have a strong influence on emotion and mood. In fact, this influence can be stronger than that of any other sense, due to a more direct linkage of the olfactory sense with the part in our brain that is "critical for emotional memory" (Epple & Herz, 1999, Herz et al., 2004). The result is that odours can get certain meanings and evoke emotional associations, influencing our mood, emotion and performance. Epple & Herz (1999) have shown this to be true for children who had learned to associate a certain smell with failure and Rétiveau, Chambers IV and Milliken (2004) showed an effect of fine fragrances on the mood of women. The keenness of our sense of smell has been further demonstrated by Haviland-Jones and McGuire (1999), who showed that humans can in fact discern the emotions of fear and happiness from body odour.

Odours, then, provide a rich source of possibilities for emotion elicitation in entertainment. Apart from providing olfactory cues fitting the perceived environment in a movie or a video game, with information about implicit influential capacities of odours on emotion, the emotional state of the viewer or player can be directly manipulated through scent.

Many researches on the subject of scent and emotion however, focus on the ability of odours to evoke emotional memories, in which case there is already an existing association with a given odour. For the purposes of this research, odours with a more general influence on emotion are needed. Luckily, such odours do appear to exist. It has been shown that inhalation of Cedrol (a compound of cedar wood oil) has a relaxing effect (Dayawansa et al., 2003), as do the scents of orange and lavender (Lehrner et al., 2005). Vernet-Maury et al. (1999) even tried to link different odours with different specific emotions, with some success: lavender induced mainly happiness, butyric and acetic acid induced anger and disgust, and camphor induced either happiness, surprise or sadness, depending on the subject's history. Again, the link with emotional memory proves strong and effects of odour on emotional response may never be fully separated from previous experiences. However, it seems that at least lavender does have a specific effect which does not vary much between individuals. The same goes for acetic and butyric acid, although the associations with anger and disgust match in intensity. Still, even if limited, this does provide some basis for the use of scent for emotion induction.

Components of Emotion

Let's recapitulate and take a look at what possibilities there are to induce emotion through physical means and on an implicit level.

One approach to answer this question would be to list the specific emotions that have been found to allow for physical elicitation. Such a list would presently consist of fear, anger, sadness and joy. A problem would occur when we try to determine which physical measures can induce which emotions. Whereas posture and respiration could relatively easily provide solutions for each of these four emotional responses, temperature, haptics and palmar sweat have yielded less distinct results. Temperature for example has known effects only on aggression and the dimension of pleasantness of emotions. With haptics we can influence the arousal dimension of emotions through heart rate

simulation, but solutions for specific emotions are not known, save perhaps fear through simulated shivering.
Finally, palmar sweat is only known in relation to anxiety, no specific emotions have been researched in relation to this physical aspect.

Perhaps a better idea would be to approach the various physical measures in the context of the pleasure-activation model of emotion, as used by Russell (2003). In this model, emotions consist of two dimensions: pleasure and arousal. Any emotion can then be described in terms of these two dimensions, distress being high in arousal and low in pleasure and contentment low in arousal and high in pleasantness.
Based on this model, we can try to distil ways to employ our physical measures to influence the emotional state on either the pleasure or arousal axis, or both. This approach has the added advantage that we need not achieve the level of specificity used in some researches to achieve one specific emotion. The goal is to stimulate certain emotional responses to enrich an experience in which emotions are already triggered, such as a movie. In this setting, manipulation along the two proposed axes should be sufficient to enhance the experienced emotions.
The axes of pleasure and arousal are not the only two axes in which we can describe emotion. In fact, Mehrabian (1995, 1996) showed a system of three axes to accurately describe emotion: pleasure, arousal and dominance. With this third dimension of dominance, it is possible to better differentiate between certain emotions that would be cluttered in the two-dimensional space of pleasure and arousal, such as fear and anger. Both of these emotions are specified by low pleasure and high arousal, but when we add the dimension of dominance, we can see that fear is on the low (or negative) side of that dimension and anger on the positive side. In other words, when angry we are dominant and we feel that we can control our environment, but when we are afraid we tend to feel submissive and controlled by our environment. Mehrabian shows in a convincing manner that the pleasure-arousal-dominance system of emotional components provides us with a very helpful and effective model for describing and understanding emotional states.
A possible problem when using this three-dimensional model when physically inducing emotion is that the various inducible body states and their accompanying emotions we have seen thus far do not readily show a change in dominance that can be easily targeted. Or rather, adding some nuance, the relation between body states and high or low dominance is not intuitive.
One would suspect that, for example, low dominance would be typified by a relaxation and high dominance by tension. However, both fear and anger show great tension, but differ greatly in dominance, which counters our prediction. One could argue however that although fear is related to negative and anger to positive dominance, both emotions trigger a fight-or-flight reaction of the body and that it therefore seems that extremes in dominance are accompanied by for example an upright posture. Posture does indeed seem to have some relation to dominance, as an upright posture has also been shown to increase feelings of pride, an emotion that also has a high dominance factor. So, does posture influence arousal or dominance?
Of the bodily states we’ve looked at, posture does indeed provide the strongest link with dominance, but the arguments supporting this point of view are ambiguous. Indeed, fear, anger and pride all have an extreme dominance factor (i.e. very high or very low). We must not forget however that all of these emotions also have a strong arousal component, which is positive for all three. And where posture cannot be unambiguously mapped to dominance (sadness is very low in dominance, but is not accompanied by a fight-or-flight reaction), it can be related to arousal in a much more understandable way: a slumped posture for low arousal and an upright posture for high arousal.
So even though posture may in reality affect dominance, our current knowledge of this interaction is too limited to justify a choice for implementation of the pleasure-arousal-dominance model over the simpler pleasure-arousal model. Therefore, for this research we shall abandon dominance as a target component for physical influence and we will employ the two-dimensional model of pleasure and arousal.

Posture

As far as posture goes, we have a description of postures that elicit fear, anger and sadness. Both fear and anger are very tense postures, while sadness is related to a very relaxed posture. From this it would seem that posture is most effective in targeting the arousal component of emotion, with high arousal requiring a tense, upright, and low arousal requiring a relaxed posture.

Respiration

The indicated respiratory patterns for the emotions of joy, anger and sadness are more specific than those for postures even. The aspects that vary among the patterns are speed, amplitude and tenseness of the ribcage and shoulders. The latter is of course more of a posture manipulation. Looking purely at breathing, speed and amplitude remain as important factors. Where joy is associated with slow, deep breaths, and sadness with normal speed and amplitude, anger and fear both relate to fast and irregular, shallow breathing. Even though by varying speed and amplitude we can influence emotion, it is unclear in which dimension. Fast and shallow breathing appears related to fear/anxiety and anger, while slow and deep breathing resulted in mixed results of positive feelings and sadness. It seems that faster, shallower breaths produce high arousal and low pleasure, affecting both dimensions and that slower and deeper breathing reduces arousal, but does not necessarily increase pleasure.

Temperature
Moving on to temperature, we have seen that aggression can be caused by uncomfortably hot temperatures and negative affect can be induced by hot and cold temperatures alike. Also, the other way around, skin temperature decreases as a result of music with negative affect and increases with positive music. We can conclude, then, that temperature influences the pleasure dimension of emotion when it reaches uncomfortable values, but this may also indicate that comfortable temperatures prevent the occurrence of negative affect and as such, unlike extreme temperatures, may be used in implicit emotion elicitation.

Haptics
For false haptic heart rate feedback, things are somewhat clearer. By influencing heart rate, we influence arousal. However, the proposed simulated shivers would influence the dimension of pleasantness in the negative direction.

Sweat
Then there is palmar sweat, or rather emotional sweat in general. As said, the extent to which the palms of one's hands sweat is an indication for that person's anxiety, which relates to high arousal. Therefore, if sweating can induce an emotional response, it will affect it so that arousal increases.

Scent
Finally, we come to scent, for which the pattern is somewhat more difficult to discern. It has been proposed that pleasant odours evoke positive and unpleasant odours evoke negative emotions. From this it would seem that odours simply act on the pleasure dimension of emotion, but an increase in arousal was also demonstrated in response to unpleasant odours. Furthermore, "happiness" was seen to result from the smell of lavender, but how is this emotion defined in terms of the various emotional dimensions? It is high in pleasure to be sure, but is it high or low in arousal? Does it maybe have a dominance factor? The term "happiness" (the strongest finding in response to lavender scent in the research of Vernet-Maury et al. (1999)) is simply too vague to allow for any solid conclusions about the effect of lavender on the separate emotional dimensions.
The lack of knowledge about the exact effects of scent on emotion that is not related to memory is one reason to abandon scent as a mechanism for

Table 1.

Effect of various physical measures on the pleasure and arousal components of emotion

	Posture	Respiration	Temperature	Haptics	Sweating
Effect on pleasure		Fast & shallow: -	Comfortably warm: + Hot or cold: -	Shivers: -	
Effect on arousal	Upright: + Relaxed: -	Fast & shallow: + Slow & deep: -		Fast HR feedback: + Slow HR feedback: -	Sweat: +

Table 2.

Summary of physical means to influence arousal and pleasure components of emotion

	Increase	Decrease
Arousal	Posture: upright Respiration: fast & shallow Haptic:fast HR feedback Sweat: increase	Posture: relaxed Respiration: slow & deep Haptics: slow HR feedback
Pleasure	Temperature: comfortably warm	Temperature: uncomfortably hot or cold Haptics: shivers

emotion elicitation in this research. Another reason is that as we focus on reproducing physical representations of emotional states to evoke the accompanying emotion, as the central network model of emotion states to be possible, we must conclude that the types of odorants researched are not produced by the human body as a result of an emotion. Such odorants will, then, not be used to elicit emotions in this research. We would like to stress however, that the subject of emotional effects of scent not related to memory deserves more extensive future research, and from the viewpoint of the current research even more so if such research concerns the emotion-inducing potency of the bodily odours that we *do* produce as a result of an emotion.

Practical Implementation

Now that we have an overview of changes in body state that influence emotion (Tables 1 and 2), we must look at how they can be implemented. Because we are looking at ways to influence emotion during a multimodal experience, such as watching a movie or playing a video game, modifying a chair to allow for manipulation of a person's body state seems like a logical choice. We now discuss how such a chair could be adapted to implement different emotion induction techniques.

Posture
First, it is wise to use a chair with an adjustable angle for the back. This can then be fitted with servomotors for example, making the angle of the back and thus the posture of the person in the chair automatically adjustable.

Respiration
As easy as it seems to manipulate a person's posture, so hard is it to manipulate a person's breathing pattern. So far, in studies done on the influence of respiratory patterns on emotion, the subjects were asked to actively adjust these patterns. This is something we can not do in the context of what we're trying to achieve, so another way to influence respiration without the person being cognitively aware of it must be found. For now, we only have solutions (e.g., inflating and deflating the back of the chair, as if the chair itself was breathing) that rely heavily on intuition. In the current experiment, influence of respiration will therefore not be included, but will have to wait until such implementations can be provided with a more solid argumentation.

Temperature
Influence of temperature seems something that should be feasible through an automated system. In a chair, we can think of heating elements and a cooling system integrated into the back and seat of the chair. Another, perhaps more convenient, way may be through the ventilation of air onto one's neck, the air varying in temperature.

Haptics
False heartbeat feedback through haptics is something that may be achieved through attaching a set of vibrating units to the legs of the chair; when the frame of a chair vibrates, this will be felt through the entire chair. By measuring the actual heart rate of the person in the chair and adjusting the feedback to be slightly faster or slower, it should be possible to influence the actual heart rate.
Evoking shivers using the sensory saltation effect would be interesting to see in action, but is based on some speculation. Using the described sensory saltation effect it should be possible to let a person feel a line being drawn along his or her spine, but it remains the question if this will actually induce a shiver. Chances are that users will be too cognitively aware of what is happening to allow them to remain immersed in the multimodal experience. As we aim to enhance this experience rather than disrupt it, inducing a "spine-crawling" shiver in this way may prove to be counter effective.

Sweat
As far as sweat goes, inducing or simulating palmar sweat would be ideal, but considering the fact that each person places his or her hands in different locations and positions, inducing sweatiness on a more 'stable' location of the body is much more convenient. In this case the back is a good candidate, as it is at all times resting against the back of the chair and apart from the palms the back is a place where we readily notice sweatiness in response to anxiety. To recreate the experience of a sweaty back, the back of the chair can be fitted with a type of irrigation system which can be triggered to release small droplets of liquid.

Scent
Finally, we come to scent. As discussed, this modulation will not be used here due to unclear and ambiguous effects. If it were to be used however, we would have two types of odours to use: lavender and acetic acid. These odorants can be diluted in mineral oil and then delivered by flowing air, as described by Vernet-Maury et al. (1999). A facial mask to deliver the odours is too invasive, so a position should be found for the odour evaporating system so that it is not readily noticed by the user.

Summary
Summarized, this gives us the following list of modifications that could be made to the chair:

1. Motors to automatically adjust the back of the chair
2. Ventilation system venting warm or cold air onto the neck of the user and/or heating and cooling elements in the back
3. System for measuring actual heart rate of the user
4. Vibration elements attached to the chair to create heart rate feedback
5. Irrigation system in the back of the chair to moisten the back of the user

Research question

The main question that this research will attempt to answer using this prototype is (1) if physical manipulations can increase the immersiveness of a multimodal experience.

There is much evidence to suggest that physical influence of emotion is possible, supporting the central network model of emotion, and the assumption that more intense emotional reactions to a multimodal experience increase its immersive potential leads to the expectation that the answer to this question will be positive. This leads us to the following hypothesis:
An emotionally charged multimodal experience will be subjectively experienced as being more intense when the physical states related to those emotions are induced than when this is not the case.

To test this hypothesis, we have developed a prototype interactive chair, and tested its effect the experience subjects have while watching movies clips of different emotional content.

Materials and Methods

Overview
To reduce complexity and duration of development, the prototype chair we developed for this research uses four of the five modes of physical manipulation: posture (1), heart rate (3,4) and temperature (2). See Fig. 1 for a view of the chair. On the left the air flow regulation system can be clearly seen, which consists of tubing connected to a fan at the lower end and opening onto the sides of the participant's neck at the front of the chair. This is used to achieve cooling of the participant to a lower, uncomfortable temperature. Heating is achieved through pads integrated in a flat cushion on the back of the chair. Also on the left picture the vibrating motor can be seen which provides heart rate feedback. It is attached to the back so that vibrations can be felt throughout the entire chair. Automated adjustment of the back for posture manipulation was implemented through an integrated motor. An Arduino I/O board connected to a computer system allowed communication between Processing software and the hardware of the chair prototype.

Emotional video footage consisting of eight different scenes was shown to a total of 20 participants. The scenes were selected to fall into one of the four quadrants in the pleasure-arousal domain, each quadrant being represented by two scenes. Every participant viewed four scenes without being influenced by the chair and four while the chair attempted active influence, so that for each pleasure-arousal quadrant every person would see one scene with influence and one without. The order of the scenes, as well as which were shown with and without active influence, was randomized for each participant. Each scene was shown to an equal number of participants with and

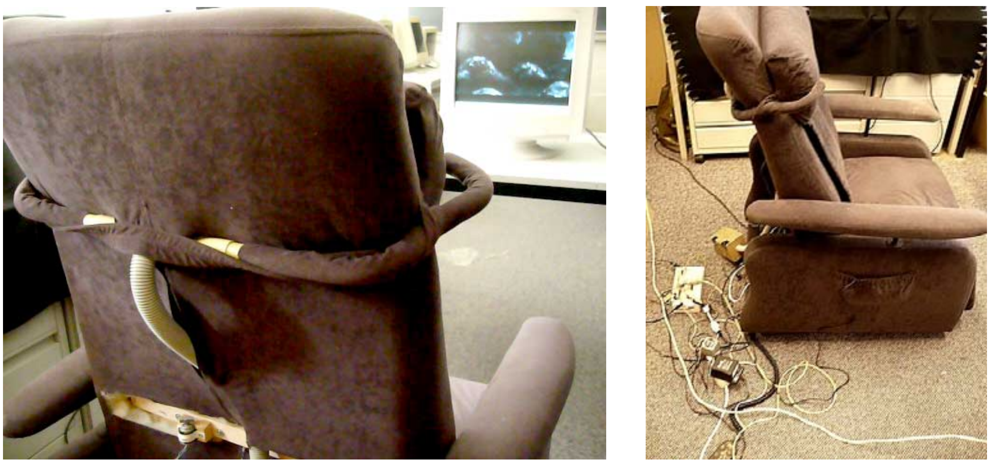

Fig. 1.

Two views of the chair prototype that was developed for this experiment. On the left the air ventilation system as well as a vibration feedback implementation can be seen. The picture on the right shows the back cushion into which heating pads are integrated and the electronics that communicate with the hardware.

without active influence. To account for a possible need of participants to adjust to the chair being active, the scenes were grouped by influence, meaning that all scenes with influence were shown consecutively, as were those without. Half of the participants started with the scenes with influence, the other half started with those without.

Subjects

The subjects were 10 males and 10 females, aged between 15 and 58 years (mean age 27), 13 of which were students at the Media Technology master programme of Leiden University.

Procedure

The participants, one per session, were led to the experimental setup. They were seated in the chair created for this experiment and faced a computer monitor. The experimenter explained the procedure, took place behind a folding screen and when the participant was ready, the first scene was shown on the computer monitor. After viewing the scene, the participant was presented with a questionnaire, based on the Affective Level Questionnaire (McFarland, R.A., 1985). The questions concerning emotions that could be clearly separated into a pleasure and an arousal component were used and intermingled with non-emotional items to obscure the actual goal of the experiment. Two items reflecting the measure of immersion of the participant into the scene were also added. Each question consisted of two terms located at either side of a scale of 1 to 6, 3.5 being the neutral position. A slider could be positioned at 0.1 intervals along the scale to indicate the intensity of the experienced feeling. The questions were slow heartbeat – fast heartbeat, security – anxiety, cold – hot, sadness – joy, contentedness – frustration, distraction – immersion, tired – energetic, boredom – fascination, calmness – tension and unpleasantness – pleasantness. Emotional items were picked to be at opposite sides of the pleasure-arousal domain. One extra question was added: “Try to describe in your own words what emotion(s) you experienced during this scene”.

After the participant had answered the questions, the process was repeated until all eight scenes were shown and questionnaires answered. After this, some more questions followed concerning experience with movies, favourite genres, etc. Then the participants were debriefed about the goal of the experiment and had a chance to ask questions and give comments.

Results

Through the questionnaire, each participant rated the intensity of various experienced emotions for each scene. The intensity score reflected which of each set of items was relevant (smaller or larger than 3.5) and how intense it occurred. These values were corrected to reflect the direction and intensity with a number between -1.0 and 1.0 (subtract 3.5, then divide by 3.5).

To analyze the intensity of emotions experienced with and without influence of the chair, the scores for the items reflecting axes in the pleasure-arousal domain were used. The calmness-tension item reflected purely the arousal axis, the unpleasantness-pleasantness item the pleasure axis, and sadness-joy and contentedness-frustration two pleasure-arousal diagonals. Pleasure and arousal intensity values were extracted from the scored intensities for these items and were used to map the average locations in the pleasure-arousal domain at which the different scenes were rated, with and without chair influence.

Fig. 2 shows how the various scenes were rated in terms of pleasure and arousal, with a distinction between scenes seen with and without chair influence. Scenes 1 and 2 were chosen to represent quadrant 1 (top right), scenes 3 and 4 quadrant 2 (top left), scenes 5 and 6 quadrant 3 (bottom left) and scenes 7 and 8 quadrant 4 (bottom right). The

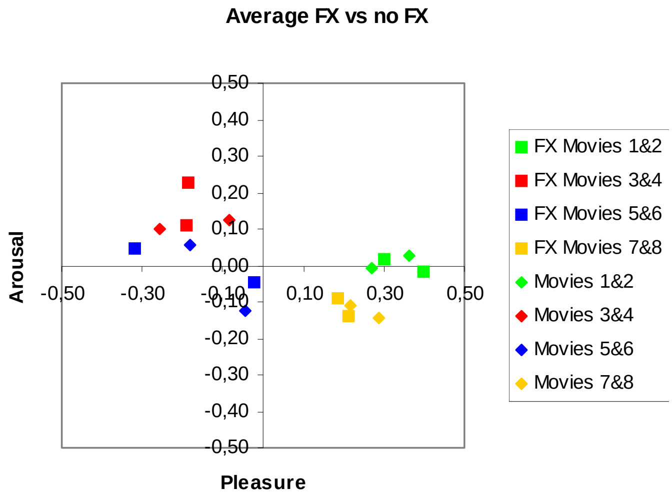

Fig. 2.

Average pleasure-arousal mapping of 8 scenes, with and without chair influence (FX). Similarly colored items represent scenes chosen to fit the same pleasure-arousal quadrant.

graph shows the difference in reported pleasure and arousal intensity between scene presentation with and without chair influence, as well as between the different scenes.

Looking at Table 3 we can see that the effect on reported intensity of pleasure is not significant between pleasure-arousal quadrants 1 and 4 and quadrants 2 and 3, which is to be expected as quadrants 1 and 4 are on the same side of the pleasure axis, as are quadrants 2 and 3. Concerning the effect of the quadrants on arousal intensity, the data in Table 4 shows a similar effect, but between quadrant 1 and quadrant 3. The expected similarity between quadrants 1 and 2 (positive arousal) and quadrants 3 and 4 (negative arousal) does not show.

Analyses of the reported emotion intensities have not shown any significant effect of chair influence on experienced intensity when split either by quadrant or scene or in aggregated tests. Some significant values were found when the separate questionnaire items were considered and analyzed per scene. Table 5 gives an overview of the *p* values that showed significance.

Discussion

Considering the data presented in Table 5 we can conclude that this experiment did not succeed in confirming the hypothesis that an emotionally charged multimodal experience is subjectively experienced as being more intense when the physical states related to those emotions are induced than when this is not the case. Although in some cases intensities significantly differ with influence, there does not seem to be a clear effect. Only scene 1 and 2, which represent the same pleasure-arousal quadrant, show a significant effect on fascination. One might conclude from this that bodily influence did have some effect on scenes high in both pleasure and arousal, but when we look at Fig. 3 we can see that the effect on pleasure is opposite in both scenes, eliminating the possibility to draw such a conclusion.

Fig. 3 and 4 show something else as well, which is the division into pleasure-arousal quadrants of the scenes based on participants' ratings. In Fig. 3 we can see how scenes 1, 2, 7 and 8 are rated as positive in pleasure and scenes 3, 4 and 6 as negative. This corresponds with the aimed effect of the scenes on pleasure, except in the case of scene 5, which participants stated had an ambiguous emotional charge or was not understood at all. For arousal (Fig. 4) a similar division can be discerned, again corresponding with the aimed effect. In this case, scene 6 falls out of line due to the unforeseen combination of anxiety with the intended effect of sadness. The scattering in the pleasure-arousal domain of the scenes representing the third quadrant, which could be seen in Fig. 2, thus is shown here again.

The design of the experiment described here has led to some choices that were based on intuition. When

Table 3. Pairwise comparison of the difference in effect of the four pleasure-arousal quadrants on pleasure intensity

Quadrant	**1**	**2**	**3**	**4**
1	-	0,000	0,000	0,105
2	0,000	-	1,000	0,000
3	0,000	1,000	-	0,000
4	0,105	0,000	0,000	-

Bonferroni adjustment for multiple comparisons was used

Table 4. Pairwise comparison of the difference in effect of the four pleasure-arousal quadrants on arousal intensity

Quadrant	**1**	**2**	**3**	**4**
1	-	0,000	1,000	0,000
2	0,000	-	0,000	0,000
3	1,000	0,000	-	0,003
4	0,000	0,000	0,003	-

Bonferroni adjustment for multiple comparisons was used

Table 5. Overview of p values < 0,05 for the effect of chair influence on the reported intensity for ten questionnaire items, split per scene

Question/Scene	1	2	3	4	5	6	7	8
Slow-fast heartbeat				0,029				
Security-anxiety								
Cold-hot								
Sadness-joy								
Contentedness-frustration						0,038*		
Distraction-immersion					0,038			
Tired-energetic								
Boredom-fascination	0,034*	0,03						
Calmness-tension								
Unpleasantness-pleasantness						0,038*		

* *Mann-Whitney 2-tailed test did not show significance*

scenes were selected to represent each pleasure-arousal quadrant the aim was to find scenes that were pure in the emotional charge they contained and they were selected intuitively (by two independent researchers) to fall into a certain quadrant of Russell's (2003) pleasure-activation model. It is therefore interesting to see that at least to some extent this intuitive mapping corresponded with the emotional rating participants gave to the different scenes, even if not all scenes were equally representative of their quadrant. The data leads one to believe that translation of scenes to pleasure and arousal components is possible to a certain extent. Even if the current research does not show a great effect of bodily influence on emotion, at least this finding is of interest and of possible use in further research. Even though scenes were attributed to the four quadrants based on classification of two independent researchers, it seems that selection of scenes should in future research be even more thoroughly thought through.

Apart from the emotional charge of scenes not being fully unambiguous, there were other, more technical, problems with the experimental setup that may have influenced the outcome. One such problem was poor video quality due to technical limitations, leading to visible compression and jumpy playback during fast paced sequences. As a large number of participants were Media Technology students with an eye for technical shortcomings in the presentation of media, this issue may have had a great influence on the immersion of these participants and thus the outcome of the experiment.

Another problem was the subtlety of influence, or lack thereof. Technical imperfections in the chair hindered implicit bodily influence and made the

Fig. 3. Estimated means of reported pleasure intensity per scene

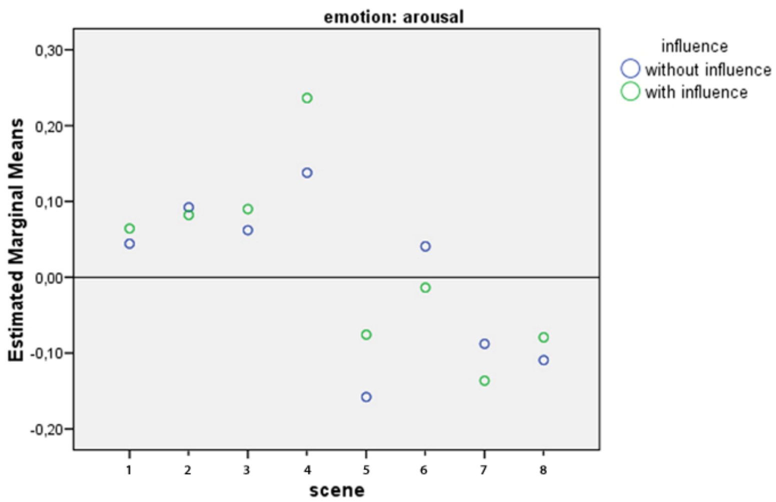

Fig. 3. Estimated means of reported arousal intensity per scene

user more aware of the fact that they were being influenced than should have been the case. A prime example is the movement of the back of the chair from a neutral to a tense or relaxed posture. Due to issues in the development of the chair, this movement could not be slowed down to a speed where the user would hardly be aware of any change, and the experiment had to be executed with the seat moving between neutral and extreme positions in a timespan of five seconds. Such a fast movement may be disruptive of the emotional experience of a movie, although multiple participants claimed to be able to ignore this when they expected it to happen.

Another major issue occurred with the air ventilation system. Cold air was led through tubing by a fan, which was embedded in soundproof casing to prevent noise. To reduce the air stream to a subtle strength however, the fan was slowed down and as a result started producing a high pitched whine. As the tubing ended by the sides of the neck, this high tone was carried close to the ears of the participant and caused reported irritation and confusion in many cases. Any negative influence on pleasure, which was the goal of the ventilation of cold air, could therefore also be caused simply by irritation over the background noise. However, the heating pads did seem to work well as their presence was never noticed but their effect could be clearly felt when aware of their presence. It is therefore unclear if any effect on pleasure that occurred was caused by temperature or irritation.

A third problem concerned heart rate feedback. Again, unforeseen noise production hindered the experience of the participants, as the rotating motor with off-centre weight attached to the back of the chair produced a whizzing noise that confused and even annoyed some participants. Even though the vibration was felt throughout the chair, but not noticed as such by most participants, there was no significant effect on reported heart rate. Whether this was due to the interruption of the experience or if this modality is simply unable to produce the desired effect remains unclear and may be subject for further research.

Finally, a choice in the presentation of the questionnaire led to a possible problem. In stead of asking participants to recall their experienced emotions for all scenes at the end of the experiment, a choice was made to pause between scenes and have them fill out the questionnaire regarding the last viewed scene to prevent difficulties presented by the recollection of emotions. The result was that participants were not only made aware of their bodily state as such, but even of their emotions as the final question was always to describe the emotions they experienced. Even though hardly any of the participants claimed to know the goal of the experiment at the debriefing, some could guess and it is possible that the implicitness of the emotional influence was endangered simply by making users aware of their emotions and their role in the experiment.

Regarding the analysis of the data, a problem was encountered when deriving the pleasure and arousal intensities scored per scene. The questionnaire contained items that scored purely along one single axis, but also items that represented diagonals in the pleasure-arousal domain. In this way, participants were forced to score a scene along a diagonal which may not apply at all to a scene. For example, when faced with a choice between frustration or contentedness for a happy or sad scene, does pleasure or arousal influence the direction in which users will score the scene? As the diagonal enters two quadrants both of which are not applicable to the selected scene, to what extent can the score indicated along this diagonal be regarded as a reliable result? The solution in this case was to consider all scores as vectors in the pleasure-arousal domain and average them. As both axes and both diagonals are represented, the average vector should still occupy the correct quadrant. Still, the effect of using these diagonals is not quite clear and should perhaps be avoided in future research in order to get a clearer image of how participants experience a movie scene.

This experiment encountered many problems that may have influenced the outcome. These problems consisted mainly of technical issues that hindered the immersion of the participants' experience. On top of that, many will agree that it is difficult to gather unambiguous empirical data when working with people and subjectively experienced emotions.

In conclusion we can say that, in spite of the problems encountered, the fact that movie scenes can be considered in terms of pleasure and arousal is in itself interesting. The main hypothesis of this research is not supported by these results though, but by no means does this indicate that it is not possible to enhance an immersive experience through induction of bodily states specific to certain emotional states.

Future Work

More research can provide us with more insight into the possibilities of applying William James' theory of emotion in the entertainment industry.

Some changes should be made to this experiment setup to ensure more reliable and possibly useful data. Such changes would include (1) the use of many more participants, (2) fewer scenes, perhaps only one per quadrant or two per axis, and fewer scenes per subject, (3) blind rating of the emotional charge of selected scenes by a group of independent reviewers prior to experimentation, (4) fewer and clearer questionnaire items in terms of their meaning in pleasure-arousal terms, (5) more subtle influence in terms of noise and speed of position changes.

Regarding the various modalities, some considerations as to the exact implementation should be made as well. In this experiment the chair was fitted with air ventilation to lower the temperature because, among other reasons, it was the quickest and cheapest solution to create. Some people did notice the air flow however and of course the noise from a slow moving fan is an issue. Perhaps a cooling system integrated in the back and seat of the chair would be more functional. Peltier elements may be used for heating as well as cooling if budget allows. In terms of position adjustment, a speed-adjustable, programmable motor with Hall-sensor for position feedback would be the wise choice. As for heart rate feedback, perhaps smaller, silent vibrating elements can be used in the back and seat, although one single vibrating motor on the back was enough to feel a vibration through the entire chair. A silent version of this solution would work well. Finally, other modalities as described earlier can be added as well, although for the purposes of clear and unambiguous results we would advise against an abundance of modalities. Perhaps the various modalities should even be tested separately, in separate experiments, to determine their effectiveness in this field.

Acknowledgements

The author wishes to thank Rob Overkamp and Daniel Attevelt for extensive technical support, Arjen van der Meulen for providing and aiding in the selection of video material, Sofie Brandsteder for her great help with statistical analysis and most of all Joost Broekens for superb all-round assistance and supervision in every phase and facet of this project. Many thanks!

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