EMOTIVe : Emotions, Induction, Measure and Use in Virtual Environments

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ABSTRACT. *During the last two decades, various studies showed the efficacy of Virtual Reality in the treatment of anxiety disorders. The goal of most of these studies was to elicit emotions and reactions in order to modify human cognitions and behaviors. For the moment the studies are based on simulations of the reality in the most accurate way. This paper proposes a brief emotions state of art and it continues with an analysis of emotion exploration. It exposes the battery of procedures which were defined to induce emotional changes at the participants in experiments controlled in laboratory, then it inventories the different tendencies that begin to take place in the field of virtual reality, and finally it exposes our perspective of work.*

RÉSUMÉ. *Pendant les vingt dernières années, de nombreuses études ont montré l'efficacité de la réalité virtuelle dans le traitement des troubles anxieux. L'objectif de la majorité d'entre elles a été d'induire des émotions et des réactions afin de modifier les cognitions et les comportements de l'individu. Pour l'instant les études sont fondées sur des simulations les plus proches possible de la réalité. Cet article propose un bref état de l'art sur les émotions ainsi qu'une analyse de l'exploration des émotions. Il expose un ensemble de procédures qui ont été définies pour induire des changements émotionnels chez des participants à des expérimentations contrôlées en laboratoire, puis il fait un inventaire des diverses tendances qui commencent à prendre place dans le domaine de la réalité virtuelle, et enfin il expose nos perspectives de travail.*

KEYWORDS: *Virtual reality, emotions, human behavior, psychophysiology, human disability, health*

MOTS-CLÉS : *Réalité virtuelle, émotions, comportement humain, psychophysiologie, incapacité, santé.*

1. Introduction

Virtual Reality (VR) is a human-computer interaction paradigm, in which users are no longer mere external observers of images on a computer screen, but active participants in a three-dimensional (3D) virtual world. Virtual reality allows the presentation of virtual objects to all human senses, in a way as close as possible to their natural counterpart. Virtual reality also offers a variety of tools and approaches that can be used to understand human emotional responses.

These capabilities have been exploited in psychotherapy. Experiments have been successfully conducted, especially in the treatment of phobias (Hodges *et al.*, 1995; Rothbaum *et al.*, 2002; Klinger *et al.*, 2003; Riva *et al.*, 2003). The goal of most of these studies was to elicit emotions and reactions in order to modify human cognitions and behaviors.

Our objective is now to go more deeply in the knowledge of emotions and to explore their induction, measure and use in virtual environments.

2. Emotions: State of art

The research literature offers a plethora of definitions of the term “emotion”. Appraisal theory (Scherer, 1986; Frijda, 1988) views emotion as a short term reaction to events evaluated along features such as pleasantness, goal conduciveness, ability to cope, justice ... Emotions differ from mood or personality trait by a short term feature. Emotions are essential for human cognition and play a major role in the life of every human being. They influence different aspects of people's life like: perception (Nasoz *et al.*, 2003); goal generation, evaluation and decision-making (Damasio, 1994); focus and attention (Derryberry *et al.*, 1992). Six basic emotions are considered fundamental (Ekman, 1994): fear, anger, disgust, happiness, sadness and surprise.

Emotion, as the subject of scientific research, has multiple dimensions: behavioral, physiological, subjective, and cognitive. The study of emotions is part of psychology, neuroscience, and more recently, artificial intelligence and virtual reality (Klinger *et al.*, 2004).

2.1. *Emotion theories*

While Averill said that “emotions are many splendored things”, the term “emotion” has no universally accepted definition (Averill, 1994). Psychologists proposed a wide-range of diverse theories to define, to study and to explain emotions (Cornelius, 1996).

Darwin proposed an evolutionary-based theory, in which he claimed that emotions are evolutionary phenomena that play an important role in survival (Darwin, 1872). He described the facial expressions and the corporal movements that accompany emotions. Ekman's work on basic emotions is representative of the Darwinian theory (Ekman, 1994).

William James proposed the first theory based on a physiological approach (James, 1884). According to this theory, emotional stimuli evoke physiological reactions with visceral, postural or facial expression. Sensory feedback from reactions is perceived by the brain to generate feelings.

According to the cognitive perspective, thoughts and emotions are inseparable. Emotions depend on appraisals whose differences explain the differences in emotional reactions (Arnold, 1960). All the situations evoking the same pattern of appraisals evoke the same emotion.

Recently, emotions have been the object of a renewal of attention mainly due to the developments in affective neuroscience (LeDoux, 1996), (Damasio, 1994). In this neurological approach (Plutchik, 1980), neurophysiology and neuroanatomy are used to explain the nature of emotions.

Recent advances have also been made using functional magnetic resonance imagery (fMRI). In particular, (Hoffman *et al.*, 2004) having noticed that virtual reality could reduce pain, investigated the neural correlates of virtual reality analgesia. Using fMRI, pain-related brain activity was measured during virtual reality exposure sessions. Virtual reality reduced pain-related brain activity in five regions of interest; the anterior cingulate cortex, primary and secondary somatosensory cortex, insula, and thalamus. These results suggest that virtual reality has a direct effect on human brain pain responses. Much has to be done in the field, yet. However, such work suggests that virtual reality scenarios are able to trigger complex responses in humans, and that coupling of VR scenarios to advanced imagery techniques may promote significant advances in further understanding of emotion-related brain activity.

Our work on emotion induction will be based on current theories, mainly the cognitive perspective and the affective neuroscience. We retain that emotions are short term states, with an evaluated object. They have expressive and physiological components and they modulate behaviors. The goal of the applications we intend to develop will be to understand better the influence of some emotions, such as fear, joy, disgust, on subjects' behaviors.

2.2. *Emotion taxonomy*

Two different approaches are used in the field of emotions: one may consider that they constitute a discrete, universal set and the other is a multidimensional, continuous approach.

In the first approach, there is no consensus neither on the definition, neither on their identity, nor on the numbers of basic emotions. The number varies from a few emotions to more than one hundred. The continuous approach supposes that emotions result from sub-dimensions and the representation or the model is carried out in a multidimensional space. Three dimensions (Mehrabian, 1980) are defined and only two are commonly used:

– Arousal, or the degree of motivation/activation, represents the level of body excitation ;
– Valence (pleasure/displeasure) allows us to distinguish the positive emotions, pleasant, like the joy, with the negative emotions, unpleasant, like anger ;
– Dominance is a measure of the influence of the situation on the subject's freedom of choice and the pressure of an event. It makes possible to distinguish the emotions leading to approach and fighting reactions (like anger) and those generating avoidance behaviour or an escape (like fear).

3. Emotion exploration

Emotions lead to a certain number of physical, cognitive and behavioural expressions whose interpretation results in a statistically acceptable deduction of their origin (Lang *et al.*, 1993).

3.1. *Self reporting*

The psychic "activity" emotion evaluation is an evaluative method which consists in questionnaires, trying to define the emotive state. Subjective methods of self assessment through questions evaluate emotional states along category judgments (fear, anger, disgust, sadness, joy, surprise, interest) or along dimensions such as positive and negative affect (Feldman, 1995). Valence, arousal and dominance can be assessed, for example, with the Semantic Differential Scale (Mehrabian *et al.*, 1974) which consists in a set of 18 bipolar adjective pairs, or with the Self-Assessment-Manikin (SAM) (Lang, 1980) which uses three sets of graphical manikins. The most frequently used method is SAM.

3.2. *Behavioral activity*

3.2.1. Emotion recognition from facial expression

There are many ways in which humans display their emotions. The most natural way to display emotions is by using facial expressions. In the past, there has been much research on recognizing emotions through facial expressions.

Since the early 1970s, Paul Ekman et al have performed extensive studies of human facial expressions (Ekman *et al.*, 1978). They found evidence supporting the idea of universality in facial expressions. These “universal facial expressions” are those representing happiness, sadness, anger, fear, surprise, and disgust. They developed the Facial Action Coding System (FACS) to code facial expressions where movements on the face are described by a set of action units (AUs). Each AU has some related muscular basis. Each facial expression may be described by a combination of AUs. This process is very time consuming.

In the early 1990s the engineering community started using these results to construct automatic methods for recognizing emotions from facial expressions in images or video (Mase, 1991; Chen, 2000).

(Black *et al.*, 1995) used local parametric models to extract the shape and movements of the mouse, eye and eyebrows. (Tian *et al.*, 2000) attempted to recognize Actions Units (AU), developed by Ekman and Friesen (1978), using permanent and transient facial features such as lip, naso-labial furrow and wrinkles. Geometrical models were used to locate the shapes and appearance of these features. They achieved a 96% level of accuracy.

(Essa *et al.*, 1997) developed a system that quantified facial movements, based on parametric models of independent facial muscle groups. They modelled the face using an optical flow method coupled with geometric, physical and motion-based dynamic models. They generated spatial-temporal templates that were later used for emotion recognition. They achieved a 98% level of accuracy.

(Otsuka *et al.*, 1997) first computed optical flow layout, then computed their 2D Fourier transform coefficients, which were then used as feature vectors for a hidden Markov model (HMM) to classify expressions. The trained system was able to recognize one of the six expressions, close to real-time (about 10 Hz). (Oliver *et al.*, 2000) used lower face tracking to extract mouth shape features and used them as inputs to an HMM based facial expression recognition system (recognizing neutral, happy, sad, and an open mouth).

3.2.2. Emotion recognition by speech

Several approaches to recognize emotions from speech have been reported. Most researchers have used prosodic features as their acoustic cues for emotion recognition, in which utterance-level statistics are calculated. For example, mean, standard deviation, maximum, and minimum of pitch contour and energy in the utterances are widely used features in this regard. (Dellaert *et al.*, 1996) attempted to classify four human emotions by the use of pitch-related features. They used 17 features and compared different classification algorithms and feature selection methods. They achieved 79.5% accuracy.

(Roy *et al.*, 1996) classified emotions using a Fisher linear classifier. Using short-spoken sentences, they recognized two kinds of emotions: approval or disapproval. They conducted several experiments with features extracted from measures of pitch and energy, obtaining an accuracy ranging from 65% to 88%.

3.2.3. Sensori-motor control

Intuitively, it seems reasonable to assume that the more involved a user is going to be in a virtual world, the more his/her overall performance (in terms of goal achievement for instance) will be attuned to the environmental events. However, things are not so straightforward, notably due to external (e.g. interface) or internal (e.g. skills, experience) factors.

“Simple” behaviors may show participants feel as if they are in the virtual environment. (D'Mello *et al.*, 2005) used an instrumented seat allowing the determination of the subject’s posture at the time of an emotional stimulus (posture tracking). (Zimmermann *et al.*, 2003) analysed the use of a keyboard and a mouse: the number of click, pauses, the distance of movements etc..., are reported. Other researchers took account of the viewing time of a stimulus (pictures) (Lang *et al.*, 1997). “Simple” behaviors may include reaching for a virtual object, socially reacting to avatars, turning away or closing the eyes when presented with an approaching object, and startle responses (Held *et al.*, 1992).

These reflex-like responses could provide indicators of emotional response to a VE. For instance, in the "pit room" (Slater, 2002), the fact that users walk carefully when close to the visual cliff seems a reasonable indicator that they feel present in the virtual environment, exhibiting fear of falling. (Prothero *et al.*, 1995) looked for a possible relation between vection and a sensation of presence. Two experiments examined the hypothesis that "presence" is enhanced by manipulations which facilitate interpreting visual scenes as "background.". Along this line, (Freeman *et al.*, 2000) have tried to measure the relationships between presence ratings and motion-induced postural reactions. They measured the degree to which participants swayed back and forth while watching a video shot from the hood of a rally car. They particularly considered situations in which the subjects saw the video either monoscopically or stereoscopically. There was a positive effect of stereoscopic display on the magnitude of postural movement. In the same time, subjective measures of presence were also higher for the stereoscopic presentation.

All these behaviors are however quite simple, reflex-like sensori-motor coupling, which might even not be specific to humans (for example, closing one's eye in an avoiding response to an approaching object). We might nevertheless want to consider more integrated, skilful behaviors. From a more integrated behavioral point of view, we can refer to (Slater, 2002), talking about the "pit room" experiment: "Presence in the virtual room at any moment results in choice of the hypothesis that indeed this is a room with a precipice rather than the physical place of the CAVE. Of course, the participant has abstract knowledge that ‘really’ they are in the CAVE. But visual perception overrides this knowledge and the bodily system reacts as if they were in the pit room - heart rate rises, *locomotion is carefully judged*, the subject reports symptoms of anxiety (italics added)". Two points have to be noted here. First, what does "locomotion is carefully judged" exactly mean. Obviously, a simple rough performance evaluation is not enough here. The analysis of spatio-temporal determinants of locomotion (and in general of the subject activity in the virtual environment) has to be conducted.

3.3. *Physiological activity*

The body has different manners of reacting to an emotional situation, either by a modification of the activity of the autonomous nervous system (ANS) or by a controlled activity. The variation of the ANS activity is measured through many non-controlled physiological parameters : neural imaging can be used to explore brain activity during emotional processing : positron emission tomography (PET) (Lane *et al.*, 1997), functional magnetic resonance imaging (fMRI) (Lang *et al.*, 1998), heart rate, blood pressure, volume of the blood impulse, temperature, quantity of salivation, respiration, dilation of the pupil, skin conductivity, or controlled parameters like the muscular activity evaluated by electromyography (EMG) like corrugators (eyebrows), eye blinking (half controlled), eye sphincter, zygomatics (smiling).

Direct relations exist between emotions and the measured variations of physiological activity. Heart rate increases with anger, decreases with attention and joy, blood pressure increases with joy, sadness, fear, anger, (ascending order), finger temperature increases with anger more than joy or sadness and decreases with fear, surprise and disgust (Ekman *et al.*, 1983). Skin conductivity acts on the arousal whereas facial activity EMG and heart rate act on the valence (Detenber *et al.*, 1998). Pleasant stimuli increase EMG zygomatic activity and accelerate heart rate. Unpleasant stimuli decrease heart rate.

3.4. Emotion classification/data processing

Objective measures are used to determine and classify emotions according to two methods, either by computing arousal, valence and dominance and by reporting values onto a three-dimensional space, or by using a classification method. (Winton *et al.*, 1984) provided some of the first findings showing significant differences in autonomic nervous system signals according to a small number of emotional categories or dimensions, but there was no exploration of automated classification. (Fridlund *et al.*, 1983) appear to have been the first to apply pattern recognition (linear discriminant) to the problem of emotion classification from physiological features, attaining rates between 38 and 51 percent accuracy on subject-dependent classification of four different facial expressions (happy, sad, anger, fear), and given four facial electromyographic signals.

(Picard *et al.*, 2001) propose to identify a set of features on witch the different treatments are based. Six features are used; the mean value, the standard deviation, the mean of the absolute value of the first difference, the mean of the absolute value of the first difference of the normalised signal, the mean of the absolute value of the second difference of the signal, the mean of the absolute value of the second difference of the normalised signal. Emotions are classified and induced with the Clynes procedure (Clynes, 1977). Many classification algorithms may be used SVM, KNN, Fischer projection, Neural Networks … (Herbelin, 2005) used the same feature set but proposed to compute arousal and valence combining them according to a weighted set of pertinent features. Results seem less interesting than the direct classification method.

4. Emotion induction

In the last decades, sets of experimental procedures have been developed to induce emotional changes in participants, thanks to calibrated stimuli.

(Lang *et al.*, 1997) have developed sets of calibrated stimuli to use in the scientific study of emotions. There are the pictures of the International Affective Picture System (IAPS), which includes normative ratings of the pleasure and arousal associated with each picture; the sounds of the International Affective Digitized Sounds (IADS) as well as verbal materials Affective Norms for English Words (ANEW) (Bradley *et al.*, 1999a; Bradley *et al.*, 1999b). Research has demonstrated that these stimuli evoke a broad range of emotional reactions, varying in intensity, and involving both pleasant and unpleasant affect (Lang *et al.*, 1993). The exploration of physiological responses; behaviors, brain activity showed the emotional impact of these stimuli.

Set of procedures, called “Mood Induction Procedures” (MIPs), were developed to induce positive and negative mood states experimentally, mood being considered synonymous with emotion, affective states and related terms. Some meta-analysis proposed a review of the different MIPs characteristics and their effectiveness (Gerrards-Hesse *et al.*, 1994; Westermann *et al.*, 1996; Klinger *et al.*, 2004).

According to these reviews, the efficiency of MIPs was demonstrated and depends on the MIP used. Some of the MIPs have been pointed out: self-statements or Velten procedure, music, hypnotic suggestion, facial expression, game feedback, social feedback, autobiographical recall, social recall, imagery, empathy, experimenter behavior, films, threat, public speaking, drugs, social interaction, combination of MIPs.

These traditional MIPs present some limitations. The effectiveness or success rate of the different mood induction procedures is very variable. Some techniques induce the required mood in more than 75% of cases (Music, Autobiographical Recall, Solitary Recall or Films). Other procedures achieve 50% success (Velten, Social Recall, Facial Expression or Social Feedback). The intensity of the induced moods may be assessed by the time of duration of the induction effects, or by a comparison with people suffering from a mood disorder. The variability in range of the results is large. MIPs may induce depression, happiness, anxiety, anger. They can also place the subject in neutral condition and then induce “no mood”. The range of the induced moods is quite limited.

We believe virtual reality may bring significant advantages by allowing the induction of a range of different emotions, by increasing the length and the level of the induced moods. Generally only the content of the stimulus was manipulated. According to the studies carried out by communication researchers, Virtual Reality offers the possibility of taking into account the form of the stimulus in playing with screen size, viewing distance, color, motion (Simons *et al.*, 1999). Another advantage of virtual reality is the possibility of experiencing the information through several sensorial modalities at the same time.

4. Virtual reality and emotions

At present, a number of studies are carried out to explore emotion induction in virtual environments. We will focus on four of them.

The Engaging Media for Mental Health Applications (EMMA) project (Alcaniz *et al.*, 2003) aimed, in one of its objectives, to develop “mood devices” able to induce mood enhancement on both clinical and non clinical samples.

The Sensory Environments Evaluation (SEE) project (Morie *et al.*, 2002) was investigating the potential of emotionally compelling environments for more effective training. This work was founded on results of research studies showing that emotionally charge situations are remembered longer than emotionally neutral ones

The Exploratorium (Waterworth, 2003) allows the subject to explore places and feelings, and to navigate by means of a Body Joystick, vertically using breath and horizontally using balance.

Finally, the rationale of a method was described for measuring mood with mouse and keyboard (Zimmermann *et al.*, 2003), thanks to the assessment of user affect in parallel with task processing. Film clips were used as affect elicitors. The task was an online-shopping task. Physiological measurements were measured; rating scales (SAM) were filled up. Behaviors were measured thanks to recording mouse and keyboard actions.

To date, the design of virtual environment (VE) focuses on visual realism or physic-based accuracy that yields to the necessity on the one hand of significant processing power, on the other hand of compromises. The idea is to use skillful combinations of sensory inputs designed to trigger emotional responses (posed pictures, moved pictures, sounds, movies, narrative feedback).

4. Perspectives

Our global objective is to contribute to the elaboration of a global framework for controlled emotion induction and evaluation in virtual environments.

Our first goal will be dedicated to the induction of emotions. We intend to design emotional stimuli using VR, in order to induce some of the basic emotions: fear, joy, anger and surprise. Some neutral stimuli leading to no emotional state will also be created. Investigated emotions will be linked with action. Action may be toward the stimulus (approach) or away from the stimulus (avoidance), revealing participant behaviors (Heilman, 1997). We intend to use means like pictures (associated or not with movement), music and sounds, lighting, colors, narrative feedback to design emotional cues. We will combine these cues, in order to design events that will systematically generate the target emotion.

Our second goal will be to measure physiological and behavioral responses to emotion stimuli. We intend to identify and evaluate the emotional impact of the stimuli on the participant. Physiological measures will be performed. We think about the startle blink, which is a robust test of the Central Nervous System (CNS), widely used in psychophysiology, the heart rate, the skin conductance. In a further step we think about some physiological feedback to the VE. Behaviors will be analyzed thanks to all the recorded data (positions of the subject, actions, performance in task, time). Self-report questionnaires will be chosen to obtain a subjective feedback of the participant.

Finally, our purpose is the integration of all these developments into VR-based experiences. The final aim is to build an objective account of emotion induction and evaluation in humans with/without disabilities. The experimental work will consist in complementary approaches, like the evaluation of subject's performance with/without emotional stimuli, the comparison of subjects' behavior according to the nature of the induced emotions, the multi-dimensional analysis of complex behaviors using state-of-the-art assessment tools (from self-reporting to physiological markers), or the comparison of data collected among various populations of emotionally challenged patients. The exploration of the influence of emotions on the cognitive performance in case of disabilities is also one of our fields of interest.

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