The Role of Posture in the Communication of Affect in an Immersive Virtual Environment

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Abstract

This paper presents an experiment that investigates the importance of nonverbal behavioral cues when designing affective virtual characters for an immersive virtual environment (IVE).

Forty-nine participants were each instructed to explore a virtual environment by asking two virtual characters for instructions in a CAVE™-like system. The underlying emotional state of the virtual characters was depicted through the use of nonverbal behavioral cues. We focus on two types of behavioral cues (facial expressions and posture) and two emotional states (Angry and Sad).

The results indicate that posture plays an important role in the communication of affect by virtual characters in the case when the state portrayed is 'anger', but not when it is 'sad'. We conclude by discussing the importance of designing holistically congruent virtual characters especially under immersive settings.

CR Categories: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism – Virtual reality;

Keywords: immersive virtual environments, virtual characters, affect, posture, facial expression, presence, co-presence.

1 Introduction

This paper presents an experiment designed to evaluate the responses of participants to sequences of affective behaviors exhibited by virtual characters in an immersive virtual environment (IVE). In particular we are interested in investigating if responses of participants to the underlying emotion portrayed by a virtual character are in keeping with those observed in the physical world. For instance, if a participant encounters a virtual character exhibiting postures indicative of anger, does the participant respond accordingly and which cues play a more important role in instigating the response?

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There are two main challenges generally encountered in designing plausible affective behaviors for virtual characters. The first revolves around the lack of systematic studies describing a set of behaviors for an emotional state. While research into facial expressions of emotion has been widely researched [Ekman, 1982], other nonverbal behaviors such as posture has been largely neglected. The second issue focuses on investigating the relative importance of designing affective behavioral cues in accordance to the context portrayed in an IVE. In some situations such as entertainment, high-end artist-created behaviors are essential [Thomas et al., 1981]. However in other applications such as virtual therapy, the careful design of specific behavior cues has proved to be highly successful [Pertaub et al., 2002]. Research into nonverbal behavioral cues can offer valuable leads in improving character fidelity [Garau et al., 2003].

In the experiment presented here, we focus on two types of affective behavioral cues: facial expression and posture. We explore the relative importance of posture in comparison with facial expressions in the communication of an underlying emotional state. This work builds on the methodology used in [Vinayagamoorthy et al., 2004] to model behavioral cues based on observations derived from previous work. We integrate results obtained under a non-immersive study, where static postures were categorized based on specific emotion labels [Coulson, 2004], into a model used to control the perceived behavior of a virtual character in an immersive setting. In addition, we investigate an approach to designing expressive characters based on an approach to examine participant responses to virtual sensory data presented in [Sanchez-Vives et al., 2005].

In the following section, we discuss the significance of different forms of behavioral cues in the communication of affect. We then describe the design of our experiment including a model of the behavioral cues used. This section also includes a questionnaire that looks at user responses to the characters as a set of multi-level responses to virtual sensory data as if it were real sensory data. We conclude with findings and suggestions for future directions.

2 Related work on affective behavioral cues and user responses to virtual characters

One of the properties that add richness and versatility to social interaction is affective behavior and emotional feedback [Schroeder, 2002] [Thomas et al., 1981]. Simply increasing the "liveliness" of the character through the addition of movement or random behaviors often serves to highlight flaws due to a number of limitations such as the lack of meaningful expression [Schroeder, 2002] or inconsistencies between appearance and behavior [Garau et al., 2003]. Studies conducted on multiple users interacting in a shared virtual environments suggest that a lack of expressiveness led user to judge a virtual character as 'cold' [Schroeder, 2002]. On the other hand, studies have shown that virtual characters with minimal behavioral fidelity can elicit significant and lifelike responses from participants [Pertaub et al., 2002]. This suggests that one approach to designing effective virtual characters is to compare and contrast responses evoked in participants in virtual environments with those observed in the physical world. If the user responds to the character as if it were real, then the virtual character is effective. These responses could be measured using a variety of tools from objective physiological sensors through to subjective self-reported questionnaires [Sanchez-Vives et al., 2005].

However this approach poses challenges in two distinct areas. Firstly, there is a lack of studies into the role of communicative nonverbal behaviors other than facial expressions. In their efforts to interpret or evaluate other's motives, moods and behavior, individuals look to postural cues as well as facial expression and speech itself, in their attempts to interpret or evaluate other people's motives, moods and behavior. However the study of behavioral cues of affect has been heavily biased towards facial expressions. This is in spite of the likelihood that bodily cues act as valuable indicative tool not only of the intensity of an emotion but in some situations may act as more dominant source of information in the perception of affect [Ekman et al., 1967]. Furthermore an individual may display postural cues without the conscious intention to communicate affect [Bull, 1987]. This is because individuals pay less conscious attention to the control of posture than facial expressions especially in a social context. Postural cues are thought to be of more importance when facial expressions are not visible [Walters et al., 1988]. It has also been argued that even though the face is the most expressive area of the body and the primary carrier of affect, when it is accompanied with congruent bodily cues there is less ambiguity while communicating affect [Argyle, 1998]. This could be an important factor especially in an immersive virtual environment setting in which participants are able to see and interact with full-body characters. Since there are no empirical studies regarding the attributes of posture, this poses a technical challenge in trying to build a model of affective postures.

Silva and colleagues collected motion data containing affective gestures from actors trained to portray an underlying emotion with the intention of measuring the salient features in the data and using it to discriminate between a set of emotions [De Silva et al., 2004]. Their findings highlighted the importance of posture to overall communication of affect, suggesting that postural cues can be used to communicate affect efficiently. However, their model did not discriminate sufficiently between some emotional states due to a lack of sufficient data.

A recent study is of direct relevance to this paper. Coulson designed a set of static postures designed in keeping with previous theoretical work [Coulson, 2004]. The study was limited to examining postures associated with six emotions: anger, disgust, fear, happiness, sadness and surprise. Coulson's findings mirrored those of [De Silva et al., 2004], in that specific postures were attributed to an emotional state especially in the cases of anger, sadness, and happiness. Based on the findings, Coulson reported on the common attributes shared by postures in a given affective group [Coulson, 2004]. Even though the work carried out by Coulson was limited to a small number of emotion labels, the resultant postures gives a starting point with which to create a postural behavior model.

The other difficulty in studying participant responses to virtual characters is the lack of clarity in understanding an individual's response to emotion-eliciting behaviors in the physical world. Responses to some affective stimuli is well documented such as the '*popping out*' effect observed when viewing threatening stimuli such as angry expressions [Hansen et al., 1988] [Green et al., 2003]. However other responses, such as physiological responses to affect and spatial behavior, are still relatively unknown. This adds limitations to how participant responses to virtual characters can be measured in an objective manner.

To date, the existing and limited studies on postures have been conducted in non-immersive settings and in a static form. In addition, the role of posture in a given social context has not been investigated with respect to virtual characters.

3 Experiment goals and hypotheses

Our goal for this experiment was three fold. Firstly we were interested in exploring the relative importance of the roles played by facial and postural cues in the communication of two emotions (anger and sadness) under a specific condition. We investigate the importance of posture in a situation where the affective state is directed at a focus other than the self. Secondly we examine if the angry and sad postures reported in [Coulson, 2004] were effective in communicating the desired affect under an immersive setting. Finally we explore the variations in participant responses to characters perceived to be in a certain emotional state.

Our main hypothesis is that adding affective behavioral cues to virtual characters would enhance the participant's perception of the character and add to the character's perceived realism. We expected participants to recognize the character's underlying emotional state more accurately if the character portrayed congruent facial and postural cues. We also anticipated postural cues to play a significant role in aiding participants recognize the character's emotional state.

4 Experiment design

4.1 The scenario

We were interested in investigating how participants interpreted and responded to a virtual character designed to be in a specific emotional state. A scenario was developed in which participants could observe two characters in discussion. The verbal content of the discussion was designed to be unintelligible. We refer to one character as the *active* character and the other as the *passive* character. The active character displayed an underlying emotional state (anger or sadness) through facial and/or postural cues towards the passive character. The passive character portrayed exactly the same 'neutral' state throughout the experiment by displaying behavioral cues that were designed to be non-affective. The participant was instructed to move towards the characters, and once the participant got close enough to breach the social interpersonal distance as defined in [Hall, 1969], the active character stopped the discussion and adopted a neutral state as well. The two characters then turned towards the participant and interacted with the participant through the use of neutral nonverbal behaviors and verbal content. This meant that the participant played two roles in the experiment; the role of an observer to an emotionally charged discussion between two virtual characters followed by a direct face-to-face neutral interaction with the characters.

This scenario was developed for two reasons. It allowed participants to observe and form impressions about the perceived affect of the characters without being explicitly instructed. Secondly, an individual's response to an emotional event varies depending on their prior emotional state, personality traits and

	Angry Posture	Neutral Posture
Angry Facial Expression	7 males	7 males
Neutral Facial Expression	7 males	7 males

	Sad Posture	Neutral Posture
Sad Facial Expression	7 males	7 males
Neutral Facial Expression	7 males	*Repeated cell*

Table 1. 2x2 Factorial Designs

their perception of factors leading to the stimuli [Böddeker et al., 2000]. The scenario designed for the experiment allowed the participant to observe the affective behavioral cues of a virtual character only when it is being directed towards another character in a bystander-type situation.

4.2 Independent Variables

Two sets of between-groups 2 (*facial expression*) x 2 (*postural cues*) factorial designs was employed in the experiment. One set per emotional state investigated (Angry and Sad). As can be observed from Table 1, the two factors in each set control the manner in which the underlying emotional state of the active character is portrayed. In essence the affective state of the active character towards the passive character was designed to be angry, sad or neutral depending on the behavioral cues used. This created eight conditions however the control condition (*neutral posture with neutral facial expression*) is repeated within the design. This results in three emotional states (*angry*, *sad* or *neutral*) for the active character and just seven distinct conditions.

4.3 Justification of emotion choices

The main emotional state of interest in our research was anger due to its association with threat perception and the varieties of possible responses invoked in individuals witnessing an act of aggression. Anger is seen as a negative emotion therefore there is evidence that others focus a heightened attention on individuals displaying the cues to portray anger [Green et al., 2003].

Sadness was chosen as a second emotion to investigate in order to disambiguate between any possible effects caused by simply having meaningful behavioral cues. Either fear or happiness would have been good choices for the second emotion however they both had to be excluded from the study since results from [Coulson, 2004] suggest that both states could not be portrayed unambiguously using postural cues.

4.4 Apparatus

The participants experienced the immersive virtual environment in a ReaCTor system, which is similar to the CAVE™ system [Cruz-Neira et al., 1993]. The Trimension ReaCTor is an immersive projection technology (IPT) display consisting of three 3m x 2.2m walls and a 3m x 3m floor. The participants wore CrystalEyes stereo glasses and were tracked by an Intersense IS900 system. The system allows the participant to move fully

Figure 1: A participant in the virtual maze in the IPT. Clockwise – the central room (observing the characters), the bedroom, the dining room and the library

immersed in the environment displayed while viewing it in the correct perspective. They held a wireless navigation device with an analogue joystick that is similarly tracked. The joystick was used to move around the virtual environment. Participants were also fitted with Thought Technologies Ltd. ProComp+ electrocardiogram sensors on their torso and galvanic skin response sensors on their non-dominant hand and a respiration sensor around their torso. This was used to record physiological responses during the experiment.

4.5 Software

The software used was implemented on a derivative of DIVE 3.3x which was ported to support spatially immersive systems [Steed et al., 2001]. DIVE (Distributed Interactive Virtual Environment) is an internet-based multi-user virtual reality (VR) system in which participants can navigate in a shared 3D space. A VRPN plugin to DIVE was used to enable the logging of tracking data and events. The behavior of the characters were controlled using interpretative Tcl scripts which called procedures in PIAVCA [Gillies et al., 2005]. The Platform Independent Architecture for Virtual Characters and Avatars (PIAVCA) is a library for controlling virtual characters through the use of motion data. In addition a posture loading module enabled the experimenter to assign a set of emotion-grouped postures to each agent in the scenario.

4.6 Population

In order to eliminate results that were dependent on gender, only male participants were recruited to take part in the experiment. Forty-nine participants were assigned randomly to one of the seven conditions. Most of the participants were in their twenties and more than 85% of the participants had very low experience with virtual reality systems. Participants were recruited from the postgraduate community in the university using poster campaigns and emails. They were paid $10 for an hour and half study.

4.7 Virtual Environment: The Maze

The environment used as a backdrop to the experiment consisted of a training room connected to a centralized virtual maze. The training environment was used to acclimatize participants to viewing and navigating in a virtual environment. The maze was modeled around a central room where participants met the two virtual characters. The central room consisted of eight doors, three of which were connected to three rooms by long inter-connecting corridors; a bedroom, a dining room and a library (Figure 1).

4.8 The Virtual Characters

4.8.1 Visual appearance

Two male virtual characters of the same height (1.7 meters) were used in the experiment (Figure 2). It has been found in previous studies that participants perceive characters to have roles of leadership purely on the basis of their visual appearance or enhanced capabilities [Schroeder, 2002]. For this reason, a deliberate decision was made to use a virtual character in formal dress to be the active one (Figure 2).

4.8.2 Postural animations

Depending on the condition, the active character was assigned a set of thirty-two basic affective postures corresponding to the underlying emotional state using the posture loading module (Figure 2). The postures were adapted from [Coulson, 2004]. Similarly the passive character was assigned a set of thirty-two neutral postures. None of the postures in the Neutral set overlapped with either the Angry or the Sad sets. The posture loading module used a base posture and the set of assigned postures to create a much larger interpolated set of postures using an interpolation algorithm similar to [Johnson, 2003]. Each new posture in the interpolated set was then produced by assigning a random weight from a uniform distribution to some or all of the basic postures and summing the resulting poses. The resulting postures were smoothly blended into an animation at intervals generated using pseudo random observations generated from an exponential distribution with a mean of 1000 milliseconds. Each postural shift was then accompanied with the condition-appropriate facial expression. Additional conversation feedback-type animations were created and assigned to the each virtual character. These feedback animations were only used during face-to-face participant-character interactions.

4.8.3 Facial expressions

The PIAVCA facial animation functionality was used to create gaze behaviors, blinking and facial expressions for both characters. Two angry facial expressions and two sad facial expressions were used to create the condition-dependent emotional facial expression for the active character (Figure 2) [Ekman, 1982]. Random weights were generated and used at run time to interpolate between the facial expressions resulting in affective facial animation. In addition, the subtle but complex behavior of a more realistic gaze model coupled with semi-photorealistic characters, such as those used in this experiment, significantly improved the user's perceived quality of communication [Garau et al., 2003] [Vinayagamoorthy et al., 2004]. Therefore this gaze behavior model was implemented in addition to other conversation feedback-type behaviors such as the raising the eye brows while making a query. Finally, a model to generate blinking behavior and lip synching animations was implemented using appropriate facial mesh deformations.

4.8.4 Behavior generation

There were two sets of behaviors assigned to the virtual characters. The first set was used to control the condition-dependent affective state of the active character towards the passive character, which in turn displayed neutral behavioral cues. This set of behavior was only generated when the participant was purely observing the virtual characters in discussion. Once the participant invaded the social space of the virtual characters, the active character glanced at the participant and turned towards the passive character once more as if to stop the discussion. At this point, the first set of behaviors was brought to an end and the participant becomes the focus of both virtual characters.

Figure 2: Top images – Active character (grey suit) displaying angry & sad postural cues towards the passive neutral character. Bottom – Angry and sad facial cues.

The second set of behaviors was used to enable an experimenter-controlled participant-character verbal interaction. In keeping with the active-passive identities created as part of the scenario, only the active character engaged in conversation with the participant. The passive character remained a listener. For instance when the participant asked a yes/no question, the active character replied vocally and non-verbally by shaking it's head while saying 'no' or nodding it's head while saying 'yes'. The passive character would do similar but more subtle animations as if to re-affirm the active character's response. Forty-two pre-recorded questions and answers were triggered by an experimenter at appropriate times. The range of topics needed for these pre-recorded messages was minimal due to the task given to the participants.

4.9 Task

Each participant was given the task of counting trash bins after finding three rooms to explore in a virtual maze. They were informed that the virtual characters in the central room of the maze would be able guide them to three different rooms one after the other. The participants were asked to come back into the central room after exploring each room to get further instructions from the virtual characters.

4.10 Procedure

The study was approved by the UCL Ethics Committee for Non-Clinical Research. Two experimenters walked each participant through the experiment. On arrival the participants were asked to sign a consent form, given information and asked to complete a number of pre-experiment questionnaires. The participant was then invited to step into the IPT and fitted with the tracking devices, physiology monitoring devices and a microphone. After collecting a baseline for the physiological measures and training the participants in navigating virtual environments, they would spend about ten minutes in the virtual maze carrying out the task.

All participants were directed by the virtual characters to three rooms: the bedroom, the dining room and the library. Each participant interacted with the characters thrice. During each interaction, the participant initially saw the virtual characters having a discussion until the participant got close enough to interrupt the characters and get instructions to the next room.

The participant is videotaped throughout their time in the maze while an experimenter notes down observations of interest. Finally a number of subjective responses are collected using post-experiential questionnaires and a semi-structure debrief interview.

4.11 Response Variables

Our key response variable is the extent to which participants respond to the characters and the virtual sensory data as if it were real sensory data. We follow the methodological standpoint of [Slater, 2004] and note that questionnaires by themselves are not sufficient for the measurement and understanding of these responses, but are a useful adjunct to a range of other tools. In our experiment we are measuring this response at several levels:

- Subjective with post-experiential questionnaires and in-depth semi-structured interviews.
- Physiological (heart rate through electrocardiogram, galvanic skin response and respiration);
- Behavioral by observing participants' responses to the situation they encounter;

The subjective responses collected from the participants can be categorized into four indicators. The first indicator was based on the SUS questionnaire and measured the extent to which participants report a sense of "being there" in the environment. [Slater et al., 2000]. For instance one of the five questions in the SUS questionnaire was "*During the time of the experience, which was strongest on the whole, your sense of being in the maze, or of being in the real world of the laboratory?*". The last two indicators were designed based on the concept of operational presence defined in [Sanchez-Vives et al., 2005]. In this approach, presence is taken as the extent to which participants act and respond to virtual sense data as if it were real, where 'response' is considered at different levels ranging from physiological through to cognitive. Similar to the SUS, the operational presence questionnaire is based on the types of statements that people have made in post-experimental interviews over many years. The following 6 questions were used to construct the second indicator (*operational presence*):

- How much did you behave within the maze as if the situation were real?
- How often did you find yourself automatically behaving within the maze as if it were a real place?
- How much was your emotional response in the maze the same as if it had been real?
- How much were the thoughts you had within the maze the same as if the maze had been a real situation?
- How much were you thinking things like 'I know this isn't real' but then surprisingly finding yourself behaving as if it was real?
- To what extent were your physical responses within the maze (e.g., heart rate, blushing, sweating, etc.) the same as if the maze had been a real situation?

The third indicator (*operational co-presence*) also consisted of six questions and is similar to the operational presence indicator except it measured the extent to which participants reported behaving and responding as if the virtual characters were real. All these three indicators were scored on a 7-point Likert-type scale where 1 corresponded to strong disagreement and 7 was strong agreement. A score of 6 or 7 was counted as a high presence or co-presence response. The final indicator was measured through a modified version of the standard SAD dichotomous scale from [Watson et al., 1969]. The modified SAD indicator took into account that the social context experienced was virtual.

4.12 Explanatory Variables

A number of demographic variables were recorded including: age, computer literacy, experience in programming, virtual reality, and computer game playing experience. In addition there were four standard psychological questionnaires used:-

- *SAD*: This scale provides 28 questions assessing social anxiety in everyday life [Watson et al., 1969].
- *STAI*: A 40-item questionnaire assessing two measures of anxiety: state and trait [Spielberger et al., 1983].
- *APT*: This is a 14-item questionnaire gauging a person's level of emotional perception [Coulson et al., 2002].
- *EC*: This 15-item scale measures susceptibility to catching the emotions of others [Doherty, 1997].

4.13 Method of Analysis

4.13.1 Subjective questionnaire data

Since Likert scales are ordinal, it is not suitable to treat the responses as if they on an interval scale. The same logistic regression method used in [Garau et al., 2003] was applied to our questionnaire responses. The response variables were thought of as counts of "successes" in a number of trials corresponding to the number of questions. All scores above '5' on the 7-point scale were counted as a high response. Under the null hypothesis of no relationship between the explanatory and response variables, the responses would have a binomial distribution as required in logistic regression. Where the right-hand-side of the regression consists of only one factor (for instance a condition) this is equivalent to a one-way ANOVA but using the binomial distribution and logistic link function rather than the Normal distribution with identity link.

In this regression model the *deviance* is the appropriate goodness of fit measure, and has an approximate Chi-squared distribution with degrees of freedom depending on the number of fitted parameters. A rule-of-thumb is that if the deviance is less than twice the degrees of freedom then the model overall is a good fit to the data (at the 5% significance level). More importantly, the change in deviance as variables are deleted from or added to a fitted model is especially useful, since this indicates the significance of that variable in the model. A large change of deviance relative to the Chi-Squared distribution indicates a significant contribution of the variable to the overall fit of the regression model.

4.13.2 Objective physiological data

Prior to analyzing the data, we normalized the physiological signals which are recorded at a sample rate of 32Hz. The extraction of HR from the electrocardiogram data was performed using the g.BSanalyze biosignal software package by Guger Technology at 256Hz [Guger et al., 2004]. The first step in the analysis was to de-trend the GSR signal to take into account the slow recovery times of the sweat glands after stimuli. It is important to note that analysis was conducted on the variation of the signals from the mean of the baseline signal recorded for each participant before the experiment.

The physiological data set from the experiments were categorized in accordance to the condition of the experiment experienced by the participants. Each subset of data was then evaluated in aggregate. The signal was normalized using the mean in the baseline period for each participant, to have only the variation from his own baseline mean, and divided by the absolute value of the mean. In this way, a variation in percentage has been plotted. Then a spatial distribution analysis of the signals was considered by evaluating the average of the signal values of all the participants within a condition.

5 Results

In this paper, we present results from the questionnaires and findings in our preliminary analysis of the physiological data.

5.1 Subjective Responses

There were significant factor-related results in the responses collected through the "being there" and "operational co-presence" indicators in the Angry conditions. In the Sad conditions, the "operational presence", "operational co-presence" and "modified sad" indicators yielded significant results.

In the Angry condition, the neutral postures were associated with less reported presence as measured using the "being there" indicator (χ^2 = 9.11, 1 d.f., P ≈ 0.0025). There was also a significant positive association between the age of the participant and reported presence (χ^2 = 24.39, 1 d.f., P ≈ 7.87e-^{007}). This positive association with reported presence was repeated with the number of times participants played videogames in the past year (χ^2 = 7.31, 1 d.f., P ≈ 0.0069), how computer literate the participant was (χ^2 = 11.60, 1 d.f., P ≈ 6.60e-^{004}) and their knowledge of computer programming (χ^2 = 7.18, 1 d.f., P ≈ 0.0074). There was significant negative association between the level of prior experience participants had in virtual reality systems (VR) and reported presence (χ^2 = 8.55, 1 d.f., P ≈ 0.0034). There was also a negative association between the EC score of the participant and reported presence (χ^2 = 7.03, 1 d.f., P ≈ 0.008). The overall model fitted had a deviance (χ^2) of 42.16 on 20 d.f. Similar analysis on the "being there" presence response variable for the Sad condition revealed no significant factor-related results.

Analysis on the operational presence response variable within the Angry conditions did not yield any significant factor-related results. However in the Sad condition, the neutral postures was associated with an increase in reported presence (χ^2 = 7.15, 1 d.f., P ≈ 0.0075). There was also a positive association between the age of the participant and reported presence (χ^2 = 4.08, 1 d.f., P ≈ 0.0434). Finally there was a significant negative association between the number of times participants played videogames in the past year (Game) and reported presence (χ^2 = 7.02, 1 d.f., P ≈ 0.008). The overall model fitted for the operational presence response variable therefore included Posture, the age of the participant, and the Game variable (χ^2 = 59.27 on 24 d.f.).

The operational co-presence indicator was designed to capture the responses of the participants to the virtual characters (Table 2 and

Variable	Deviance χ^2	d.f.	~P value
Posture	4.689	1	0.0304
Trait Anxiety	8.863	1	0.0029

Table 2. Logistic Regression for the "operational co-presence" indicator in the Angry condition. Overall χ^2 = 66.27 on 25 d.f

Variable	Deviance χ^2	d.f.	~P value
Posture	5.366	1	0.0205
Face	4.221	1	0.0399
VR	8.305	1	0.0040

Table 3. Logistic Regression for the "operational co-presence" indicator in the Sad condition. Overall χ^2 = 32.47 on 24 d.f

Table 3). In both the Angry and the Sad conditions, the neutral postures were associated with an increase in reported co-presence. In the Angry condition, there was a negative association between the trait anxiety of the participant and the reported co-presence. In the Sad condition, the neutral facial cues were associated with higher reported co-presence. The VR variable was also positively associated with reported co-presence.

The final indicator "modified sad" measure evaluates the participants' level of self-reported social anxiety in response to the virtual characters. In the Angry conditions there are no significant factor-related results. In the Sad condition, the neutral postures are associated with increased social anxiety (χ^2 = 7.733, 1 d.f., P ≈ 0.0054) while neutral facial cues are associated with less social anxiety (χ^2 = 20.02, 1 d.f., P ≈ 7.66e-^{006}). Other variables in the Sad condition that were associated with an increase in social anxiety included the age of the participant (χ^2 = 23.85, 1 d.f., P ≈ 1.04e-^{006}), their knowledge of computer programming (χ^2 = 7.448, 1 d.f., P ≈ 0.0064), their level of social anxiety experienced by the participant in the physical world (χ^2 = 5.888, 1 d.f., P ≈ 0.0152), the APT score (χ^2 = 7.827, 1 d.f., P ≈ 0.005), and their trait anxiety level (χ^2 = 9.699, 1 d.f., P ≈ 0.0018). The overall model fitted had a deviance (χ^2) of 45.96 on 20 d.f.

The results indicate that although the individual terms within each fitted model are significant, the overall deviances of the model suggests that there are other explanatory variables responsible for the variations in the reported responses.

5.2 Preliminary Physiological findings

Regardless of condition, participants generally show a very high peak in their physiological signals in the central room, where they meet the virtual characters especially while approaching the characters during the first meeting. This suggests that the presence of the characters and the ensuing interaction with them activates a sympathetic nervous system response. Generally, the Neutral conditions invoke low level of physiological arousal other than the periods during which participants first approach the characters. However the most interesting result is obtained when comparing the Angry and Sad conditions.

Our preliminary analysis suggests that in the Angry conditions with affective postural cues, participants tend to experience much higher physiological arousal than in the Angry conditions with neutral postural cues (Figure 3). There is significantly higher physiological arousal near the virtual characters and throughout

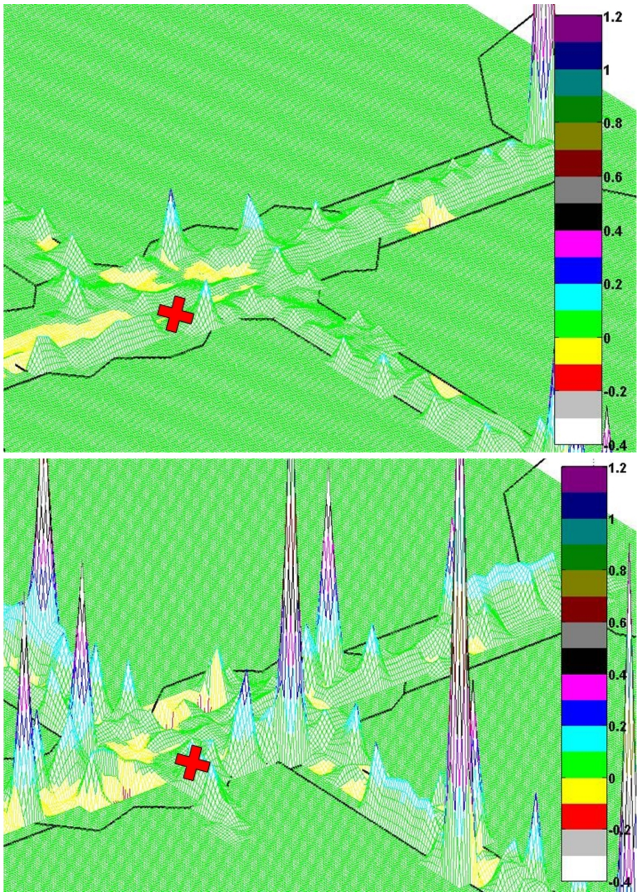

Figure 3: Normalized GSR data average over all participants in the Angry conditions within the central room (Top– condition with neutral postural cues; Bottom – condition with affective postural cues). The red-cross marks the spot where the characters were in the first meeting with the participants.

the experimental period. This effect is repeated in the Sad conditions, but not to the extent observed in the Angry conditions. In the Sad condition, the lower physiological arousal in comparison with the Angry conditions is especially the case after the first participant-character interaction period in the experiment. Overall the physiological findings suggest that the affective postural cues of the active virtual characters have a significant impact on the physiological responses of participants.

6 Conclusion and Future Direction

The study was designed to ascertain the importance of using meaningful postures in virtual characters in addition to investigating the role of posture in the communication of affect. Previous research suggests that the postural cues displayed by individuals in the real world plays an important role in the communication of affect. If the same theory is appropriate in immersive virtual environments then designing high-fidelity postural cues might be a cost-effective approach to designing effective full-body virtual characters for use in collaborative virtual environments. Our analyses indicate that postures play a vital role in the design of virtual characters as indicated through the preliminary findings in participants' physiological responses.

The contrast between the Sad conditions and the Angry conditions was significant in both the subjective responses and the physiological responses. When considering the SUS "being there" indicator in the Angry condition, affective postural cues results in higher reported presence. Yet this result was not mirrored consistently through all the subjective indicators though it is re-enforced by the preliminary results obtained from both the physiological responses of participants (Figure 3) and post-experimental interviews. All the participants in the Angry conditions with postural cues mentioned the body language as a primary indicator of the active character's underlying emotional state. Many participants remarked on the appearance of the virtual characters by referring to the active character as having authority over the passive character. In the Angry conditions with affective postures, the participants continue to infer that the passive character was being chastised due to some blunder on his part. They refer to the body language of the active character as being aggressive and agitated towards the passive character. These participants also refer to the conversation between the virtual characters as an 'argument'.

An additional outcome was that less than 30% of the participants in the Angry conditions with postural cues identified the passive characters as Neutral. The passive character was perceived to be afraid by 50% of the participants in the condition even though the cues portrayed by the character were always neutral. This suggests that participant's perception of the state of the active character was influenced by their perception of whole social relationship between the two characters. In other words since they perceived the situation as an argument, if one character was Angry then the other by implication should have been afraid. In the Neutral and Sad conditions, references to the body language of the characters indicating an argument, is very rarely made. The preliminary results of the physiological analysis might be a reflection on this phenomenon. It suggests that participants get physiologically aroused when seeing the characters in the Angry condition. This is in keeping with the operational approach adapted in this study. It suggests that to some extent participants in immersive virtual environments do respond to virtual characters as if they were real. This is verbalized by a participant in the Angry conditions: "*For me the main thing is that I saw them in a conflict, some type of argument, so I held back interacting with them. Similarly if I saw two people fighting in the real world, I won't approach that person…*". We believe that analysis of virtual environments using the kind of operational approach used in this study can be a powerful tool for understanding appropriateness of design, in this case of character postures.

Affective postural cues in the Sad conditions were negatively associated with reported responses even though they do cause some physiological arousal in participants. A reason for the effects experienced may be in the underlying posture model used in the Sad conditions and its implementation. This is reflected by participant comments: "*I thought they seemed to be engrossed in some kind of conversation, although the guy kind of looked awkward… He was sort of bent down and … one leg stuck out and was bobbling about*". Further analysis of the collected objective and interview data is needed to prove this hypothesis. In addition, the relatively poor performance of the bodily cues in the Sad condition suggest that behavior model for Sad postures did not capture the qualities of bodily movement associated with the emotional states studied especially Sad. In addition to further analyzing the data obtained from this experiment; we aim to conduct smaller but more in-depth focus experiments on participant responses to affective virtual characters using a modified version of the postural model which includes these qualities.

Finally a number of questions remain unanswered at this point. The analysis of subjective post-experimental questionnaires indicates that postures do have an impact on participant responses however the exact relationship between these responses and the postural cues remains unanswered. An interesting aspect of the results is that although participants respond at the physiological level, for example to the Angry condition with affective postural cues, this is not always reflected in their subjective responses. This is further illustration that it is impossible for questionnaires alone to adequately reflect people's responses.

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