



Sociality of facial expressions in immersive virtual environments: A facial EMG study

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ABSTRACT

Immersive virtual environment technology is increasingly used by psychologists as a tool for researching social influence in realistic, yet experimentally controllable, settings. The present study demonstrates the validity and reliability of facial electromyography as a marker of affect in immersive virtual environments and further shows that the mere presence of virtual humans is enough to elicit sociality effects on facial expressiveness. Participants viewed pleasant and unpleasant images in a virtual room either alone or with two virtual humans present. The patterns of smiling and frowning activity elicited by positive and negative stimuli in the virtual environment were the same as those found in laboratory settings. Moreover, when viewing positive stimuli, smiling activity was greater when two agents were present than in the alone condition. The results provide new psychophysiological evidence for the potency of social agents in immersive virtual environments.

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1. Introduction

Immersive virtual environment (IVE) technology is increasingly used by psychologists as a tool for understanding human behavior in realistic, yet experimentally controllable, settings (see Fox et al., 2009; McCall and Blascovich, 2009, for reviews of IVE use in behavioral research). The immersive visual experience is often conveyed to participants through a head-mounted display (HMD) that uses head movements to adjust the visual display of the environment in real-time, permitting visual and physical exploration of a three-dimensional, computer-simulated environment as though it were real. The immersive world instills a sense of presence in the user – a feeling that the user exists in the virtual environment (rather than merely watching it); the IVE is capable of portraying psychologically realistic scenarios (e.g., Kotlyar et al., 2008) and socially potent computer-controlled virtual humans (i.e., *agents*; Bailenson et al., 2001). The present study extends what is known about the social potency of agents by testing the effects of the apparent “company” of virtual others on facial expressiveness through electromyography (EMG).

The social potency of IVEs has been demonstrated with a variety of methodologies. For example, the amount of interpersonal space an immersed participant grants to an agent can be augmented by having the agent engage in eye contact (Bailenson et al.,

2003) or by altering the ethnic appearance of the agent (Dotsch and Wigboldus, 2008; McCall et al., 2009). On the basis of such findings, Blascovich et al. (2002) proposed a threshold model of social influence with IVEs. Whether an agent will influence the participant's behavior depends on four variables: *behavioral realism* (the extent to which the agent behaves like its real-world counterpart), *social presence* (the degree to which the participant believes the agent is under the control of an actual human), *self-relevance* (the extent to which the interaction has value or meaning to the participant), and *the target response system* (the level of the behavioral response – automatic and low-level vs. more controlled and high-level). According to the model, virtual humans are more likely to have an impact on the participant's behavior as each of these variables increases. For example, when a participant believes the agent is controlled by another person, and the agent's behavior and appearance closely approximates real human behavior, the participant should interact with the agent much like he or she would in the real world.

An aim of the present study was to examine the extent to which such agents in an IVE can influence a low-level behavior: spontaneous facial expressions. Facial expressions can serve as automatic markers of an affective state. Consistent with this interpretation, pleasant stimuli reliably potentiate smiling (i.e., zygomaticus major activity) and inhibit frowning (i.e., corrugator supercilii activity) expressions (see Tassinari et al., 2007, for a review). Yet, the correspondence between affective states and facial muscle activity varies considerably across individuals (Larsen et al., 2003) and social contexts. For instance, the perceived presence of

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other humans intensifies smiling toward pleasant stimuli (i.e., the “sociality effect;” Fridlund, 1991). This sociality effect on smiling is strongest when a social other is physically present, yet the implied presence of social others, such as knowing that a friend is viewing the same material in another room, is sufficient to elicit exaggerated expressions to positive stimuli (Fridlund, 1991; Hess et al., 1995). It is unclear, however, whether agents can also elicit the sociality effect, particularly when social presence and self-relevance are low.

Prior research has demonstrated that depictions of virtual humans can influence facial muscle movements, even when participants are not immersed in an IVE. Consistent with the Blascovich et al. (2002) threshold model of social influence, simply viewing the facial expression of a dynamic avatar¹ (i.e., one with higher behavioral realism) on a computer screen elicits more mimicry than a static avatar (i.e., one with low behavioral realism) as measured by facial EMG (Weyers et al., 2006). In addition, when self-relevance is increased by nonconsciously priming social competition, facial mimicry when viewing happy and sad avatar faces while playing a live online game becomes counter-empathic (Weyers et al., 2009). Such unconscious nonverbal behaviors suggest that agents trigger automatic, reactive goals within us (Bargh and Chartrand, 1999). To date, however, no study has examined the sociality effect in a virtual environment.

Building on this prior research, the present study examined the effects of agents in an IVE on two distinct automatic functions of facial expressions within a virtual environment: expressions as affective markers and expressions as social signals. A fuller understanding of such effects would help establish the pervasiveness of the sociality effect – that is, perhaps we are so used to modifying our facial expressions in the presence of other humans, we automatically do so at the slightest suggestion in a virtual environment. In addition, because facial EMG has been a useful measure of affect in other contexts, demonstrating that it is a valid marker of affect in response to variables manipulated in an IVE would mean that researchers would have another noninvasive measure to add to their methodological armamentarium.

Participants wore a stereoscopic HMD while facial EMG was recorded from the brow and cheek regions. First, we examined whether facial expressiveness in an IVE is affected by affective visual stimuli in the same manner as in previous laboratory settings. We hypothesized that pleasant and unpleasant visual stimuli would elicit greater zygomaticus and corrugator activity, respectively. Second, we tested whether the mere presence of social agents in an immersive virtual environment is sufficient to elicit exaggerated facial expressions when viewing pleasant stimuli. We provided no information about the agents. That is, social presence was low, as participants did not believe the agents were controlled by actual humans, and self-relevance was also low because the agents had no ostensible connection to the participant. Given the low-level response of facial activity, however, we hypothesized that zygomaticus activity would be potentiated for positive stimuli when these nominally social agents were present in the virtual environment, similar to when a friend was present in the earlier studies of sociality effects (Fridlund, 1991; Hess et al., 1995). In addition, we examined whether sociality effects would occur for unpleasant stimuli and whether corrugator activity was similarly affected by social cues, as such sociality effects have not been previously demonstrated for negative stimuli.

¹ Although the stimuli in these studies better conformed to Blascovich et al.’s (2002) definition of agents (i.e., computer-controlled virtual humans) rather than avatar (i.e., a virtual human controlled by real human), we use the term avatar to be consistent with the respective studies’ terminology.

2. Method

2.1. Participants

Forty-nine university students (23 women, 26 men) were recruited from an introductory psychology course in the United States and received course credit for participation. Participants were between the ages of 18 and 30 years ($M = 21.5$; $SD = 2.4$).

2.2. Stimuli

Forty stimulus pictures were chosen from the International Affective Picture System (IAPS; Lang et al., 1999) according to normalized valence ratings provided with the set. One half of the pictures (the “positive” stimuli) were selected for their high pleasantness ratings² ($M = 8.04$, $SD = 0.17$) and the remaining pictures (the “negative” stimuli) were selected for their low pleasantness ratings³ ($M = 2.25$, $SD = 0.17$), $t(38) = 109.85$, $p < .001$. Positive and negative pictures were matched for arousal based on the ratings that accompany the IAPS set. Pictures depicting gore, mutilations, and nudity were not included.

Each session used one of two pseudo-randomized orders to present the stimuli. Each order was randomized and then adjusted to minimize consecutive presentations of stimuli from the same valence set to a maximum of two.

2.3. Procedure

Participants were seated in a comfortable chair. Bipolar EMG was recorded over the right eyebrow and cheek regions, targeting the corrugator supercillii and the zygomaticus major muscles, respectively (Fridlund and Cacioppo, 1986). A ground electrode was attached over the left forehead. The participant was then equipped with a stereoscopic head-mounted display (HMD; see Fig. 1a), which could be adjusted for comfort. The corrugator EMG electrodes were thus completely covered by the HMD device, and their wires ran under the cushion of the HMD. The Virtual Research V8 HMD uses dual 1.3 “diagonal active matrix liquid crystal displays to project a 640×480 resolution display to each eye giving the participant a 60° field of view in 3D vision. The HMD rendered a virtual room in which participants perceived themselves as seated.

Participants were instructed to look around the virtual room from their seated position before the study began. In front of the participant a movie screen hung in front of a white wall. When participants looked around the room, those in the co-viewing condition ($n = 23$) could see two human-looking agents in brown chairs seated slightly forward and to either side of their own position; the agents remained seated throughout the task (see Fig. 1b). For participants in the alone condition ($n = 26$) the two brown chairs were empty.

Participants were told that they would watch a slide show on the screen in front of them and rate each slide (i.e., IAPS image) after it was displayed. Before each picture, a fixation point was displayed in the center of the screen for 5 s. A 2-D picture was then displayed on the virtual screen for 5 s, which was then followed by a rating screen. The rating screen showed a scale with ratings 1 (*Bad*) to 5 (*Good*). Participants rated the affective valence of each slide using this scale. After participants viewed and rated all 40 pictures, the experimenter removed the HMD and the electrodes before debriefing and dismissing the participant.

2.4. Data reduction

A Biopac amplifier (Biopac Systems, Inc., Santa Barbara, CA) amplified signals from the EMG electrodes by a factor of 5000 and applied an online filter (0.1–500 Hz). EMG from both regions was recorded at 200 Hz⁴ and stored for later scoring. Corrugator data for four participants (two from each condition) were not reduced further due to recording malfunctions; all zygomaticus data were retained.

Offline, data were filtered (band-pass 10–100 Hz, 60 Hz notch), digitally rectified, integrated with a constant of 50 samples. EMG data for each trial were segmented into a 1-s pre-stimulus epoch and a 4-s post-stimulus epoch. Magnitude change scores were calculated by dividing each 4-s epoch by the 1-s pre-stimulus epoch (van Boxtel, 2010). Due to positive skewness, the magnitude scores were then logarithmically transformed. An outlier analysis of mean baseline activity for each muscle revealed three participants with excessive zygomaticus baselines and two participants with excessive corrugator baselines. Those respective EMG channels were removed from further analyses for those participants.

² Pleasant IAPS images were 1440, 1460, 1610, 1710, 1750, 1920, 2040, 2050, 2057, 2070, 2080, 2150, 2260, 2340, 2530, 2570, 5830, 5910, 8190 and 8501.

³ Unpleasant IAPS images were 2053, 2900, 3230, 3500, 6212, 6243, 6360, 6821, 7380, 9050, 9220, 9340, 9421, 9520, 9560, 9800, 9810, 9910, 9911, and 9921.

⁴ The sampling rate was unusually low due to a software error. A small-scale replication of this study using a higher sampling rate (1000 Hz) found nearly the same pattern of results. Data from this small-scale replication was not included in this study because the replication was conducted in a different laboratory with a different HMD.

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