Exploring Influence of Social Anxiety on Embodied Face Perception during Affective Social Interactions in VR

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Figure 1: Virtual Agent Social Interaction Framework.

ABSTRACT

Our research studies early face-body perception of socially anxious individuals during social interaction with a virtual agent (VA) in VR using EEG. VAs' expressiveness is manipulated during social interactions through their facial animations portraying realistic positive/negative/neutral expressions. Facial expressions of the VAs are recorded using real-time facial animation performance capture and pre-validated. Wearing an HMD, tactile-based VR controllers and a mobile EEG system, participants will interact with individual VAs in a virtual office setting (an employee meeting their employer with a handshake), a scenario known to generate anxiety. Behavioural, physiological, and EEG data will be analysed to reveal the effect of emotional valence on early face-body perception during social interactions. This study provides a framework for synchronised multimodal data recording and analysis.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

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1 INTRODUCTION

Virtual reality (VR) is an effective medium enhancing ecological validity by presenting controlled and dynamic perceptual stimuli within an immersive VR environment simulating real-world experiences to examine the affective responses of users. VR is a cutting-edge technology in the field of psychology for studying behaviour and improving the assessment and treatment of mental health disorders such as social anxiety disorder (SAD).

VR is being used in various ways to modulate the emotional states of users. This includes eliciting subjective levels of social distress to individuals by exposing them to fearful or avoided stimuli, and improving their emotional well-being through therapeutic interventions, mindfulness, and stress management exercises [23, 49]. Cognitive Behavioural Therapy (CBT) is the most empirically suggested psychological intervention for SAD [17]. Exposure therapy is a component of CBT that systematically confronts individuals with situations they feared or avoided without using safety behaviours to help participants reduce fear and avoidance. In VR exposure therapy (VRET), individuals are gradually exposed to the feared or avoided social situations in a VR environment which mimics social situations [15]. For instance, individuals with SAD, who fear and avoid social interactions due to fear of negative evaluation, are gradually exposed to anxiety-provoking scenarios within a VR environment. Studies have already examined the effect of immersive natural elements in terms of restorative benefits and reducing stress, resulting in improvement in participants' moods and physiological measures [26, 36]. Meta-analyses and systematic reviews suggest that VRET is an effective tool for the treatment of social anxiety symptoms and it is effective as in-vivo exposure therapy [9, 23, 37, 40].

Social interaction studies examining VRET treatment in SAD include situations such as presentations or interviews where inclusion of virtual agents (VA) is essential. Studies have examined the effect of realistic VAs by displaying users' facial expressions during social interaction [42, 46]. Having natural and believable VAs is significant for realistic social interaction which improves both the sense of presence and the feeling that VAs are socially present, and it develops real-life-like affective responses from participants [3, 12, 30]. The emotions expressed by VAs affect the behavioural response, attitudes, and perception of individuals [5].

Wearable biosensors are increasingly integrated with VR in psychological research. The most widely used ones are heart rate (HR), electroencephalogram (EEG), electrodermal activity (EDA), and respiration [11, 19, 25, 48]. This novel approach can provide valuable information about SAD because it can reveal neural correlates of SAD in situations representative of real-life experience of SAD patients. However, past EEG research on SAD only showed face images on screens. They found the N170 component of event-related potentials (ERPs) being sensitive to emotional facial expressions, but showed conflicting results on whether N170 differs between SAD and healthy participants [20, 27–29, 38]. The lack of believable social situations/interactions could be the issue. In a recent VR study [33], social threat perception is examined with EEG and HR when participants saw a VA (angry or neutral) approaching them. The results showed stronger N170 and higher HR responding to angry VAs (although, the research did not study SAD). Despite using a chin rest to restrain head movements (lacking ecological validity), this immersive approach is beneficial to SAD research.

The current study will fill this research gap by creating realistic, immersive, and affective (positive, negative, or neutral) social interactions within a VR environment between a socially anxious individual and a VA, with the aim of establishing biomarkers of social anxiety utilising multiple data streams (neural, physiological, and behavioural) during these social interactions. Specifically, neural activities related to early face and body perception will be measured through EEG in VR. The N170 component of ERPs indexes perception of faces and facial expressions and has been suggested to be a good candidate of SAD biomarker [1]. This will be the main focus of the current study, along with several other measures including P1 (representing vigilance and attention processes [22, 24, 27]), P2 and P3 (late emotion-related processes [39, 44]), and frontal alpha asymmetry (the approach/withdrawal attitude [13]). Physiological (HR, EDA) and self-reported behavioural data will respectively measure the objective and subjective experience of social anxiety. By examining the relationships between these measures, we will be able to pinpoint the biomarkers of SAD.

2 SYSTEM DEVELOPMENT

2.1 Virtual Scene

The Unreal game engine (v5.3) is used to create a VR scenario resembling a typical individual office environment that may evoke anxiety among participants during social interactions. Interacting with authority figures is one of the most provoking anxiety scenario for women with SAD, who tend to display heightened fear in these situations [47]. In an office environment, there is a desk equipped with typical office supplies such as a computer with peripherals, folders and other essentials. Behind the desk, there is a chair for the employer, and in front of the desk, a chair for the visitor. The office also includes a cabinet behind the chair, a plant, a neutral picture frame and a coat stand. The floor of the environment will be in the same colour as the experimental space‘s floor to create a smooth transition between the real world and the VR environment. To avoid distraction, there will be no background noise.

2.2 Virtual Agents

Metahuman Creator (Epic Games) is used to create human-like VAs as it allows the creation of photorealistic characters with a high degree of detail and realism. High-fidelity facial animations are captured through Live Link Face app and transferred to Metahuman. As a feature of the Unreal Engine, Live Link enables live facial animation capture, motion capture and other dynamic data inputs to be directly applied to a VA to enhance realism and expressiveness.

34 static VAs are created, all of which are young to middle-aged male and showing a neutral expression. These VAs undergo a validation process created in PsychoPy and running on Pavlovia. 16 volunteers recruited with the same criteria as those of the main study are asked to rate VAs with a 5-point Likert scale on perceived trustworthiness, attractiveness, approachability, human likeness, and dominance.

24 VAs with the highest ratings in dominance, attractiveness, human likeness, and lowest ratings in trustworthiness and approachability are selected to maximise the social anxiety experience [8, 10, 18, 21, 41, 50]. The corresponding dynamic VAs are then generated with positive, negative, and neutral facial expressions. To achieve believability and improve realism, the VAs will maintain eye contact with the participants and blink naturally. A participant will also see partial VR representation of their own body in the first-person perspective (including hands, feet, arms, legs, and part of torso if they look down). To realise this, the participants' hand and arm movements will be replicated in VR with inverse kinematics. To heighten the sense of spatial presence and embodiment in the VR environment [16], body movements of the participant and their virtual counterpart will be synchronised to accurately reflect the participant's upper body and leg movements.

To further strengthen the realism, the participant will have a handshake with each VA.The VA's handshake behaviour is triggered when the participant is within a close distance of the VA and starts moving their arm. The VA's hand responds to the hand movement 10ms later to reach out towards the participant's hand for the handshake. When the handshake takes place, a vibration feedback will be provided by *etee* VR controllers (TG0), along with a "hi" greeting from the VA (the participants will know in advance that VAs are not conversational agents), achieving ecological validity and maintaining the maximal level of control. For the greeting, each VA has a unique voice. Lip-synching will be used to match lip movements and spoken words.

2.3 System Architecture

Figure 1 shows the setup in the main study. An HTC Vive VR HMD displays the VR environment real-time generated by the Unreal Engine from a PC via a wired cable. The HMD also records eye movement data with the built-in eye tracking feature. The lightweight etee VR controllers slide and clip onto hands and allow a more natural handshake with an open hand position. They will track finger position, orientation and movements with pressure sensors [32, 45] and provide tactile feedback for handshakes to greatly enhance immersion [7]. With a 32-channel mobile EEG system (ANT Neuro eegosports), EEG data will be sampled via an EEG cap and amplifiers, then recorded by a USB-connected tablet while being monitored via PC remote control through the local Wi-Fi network. EmotiBit will record HR and EDA data.

To mark scene onsets in the EEG data and to precisely synchronise multiple data streams, markers are sent from the Unreal Engine with a Lab Streaming Layer (LSL) plugin through the local Wi-Fi network. Additionally, multiple streams of real-time data are also sent by various devices to LSL for recording purposes. These include 1) finger pressure data from the etee controllers (also used for controlling VAs' handshake behaviour), 2) HMD position and orientation, and eye movement data (also used for maintaining VAs' eye contact [6]), 3) physiological data (HR and EDA) from EmotiBit. All data streams will be managed and synchronized via LSL.

3 DATA COLLECTION AND ANALYSIS

3.1 Design

The study employs a within-subjects design with one factor (Avatar Valence: positive, negative, neutral). Analyses of covariance (ANCOVAs) will be conducted on the ERP components of interest to assess the neural correlates of embodied perception of social interactions in face and body perception while controlling for the influence of physiological responses (as covariates). Correlations will be employed to pinpoint the biomarkers by examining the relationships between ERPs/EDA/HR and questionnaire scores.

3.2 Participants

Sixty participants will be recruited from amongst university students. The sample size was determined to establish reliable correlation measures. Inclusion criteria include 1) self-identify as women, 2) within the age range of 18 to 50, 3) have normal or corrected-to-normal vision, and 4) without a SAD diagnosis. Only women will be tested because, compared to men, they typically score higher on social anxiety scales [47] and display more serious SAD symptoms (e.g., increased HR, lower HR variability, greater fear and avoidance of social interaction), especially towards men [2, 4]. It is more plausible to identify SAD biomarkers in women than men. People with SAD diagnoses will be excluded to protect their wellbeing.

3.3 Procedure

Before the main study, self-reported Liebowitz Social Anxiety Scale [31] and Social Interaction Anxiety Scale [35] will be used to assess fear and avoidance towards social interactions. To allow a wide range of SAD scores for correlational analysis, no cut-off score will be applied.

In the main study, each participant will first get familiarised with the VR environment without VAs being present. There are several skin tone options for the participant to choose for their own VA. Both right and left hand options are also available for the handshake. The preferred hand will be determined by each participant at this stage and remain consistent throughout. Afterwards, the EEG system, HMD and EmotiBit will be set up.

There are three blocks corresponding to the three valence conditions (positive, negative, neutral), presented in an order counterbalanced across participants. To reduce the carryover effect, immediately before each valence block, participants will watch a 5-minute neutral video in VR, allowing them to return to the emotional baseline. HR and EDA data will be recorded continuously by EmotiBit to assess (post-experiment) participants' emotional baseline before each valence block. Each block has 80 trials, in which 8 random VAs will be used 10 times each, and will not be used in other blocks to avoid emotion memory.

Each trial starts in darkness with an "X" symbol located between a VA's eyes, and an "O" symbol showing where the participant's head is pointing towards. The participant will adjust the head orientation to align the two symbols. This alignment will ensure that the participant will see the VA's face when light turns on. Once aligned, after a random interval of 500-1,500 ms in darkness, the light will be turned on to evoke strong ERP responses to scene onsets (see [14] for this method). From the "light on" moment, the participant will see a VA standing 2 metres away and facing the participant, showing a positive, negative, or neutral facial expression and body posture. The participant will withhold any movement until a "go" sound is played 1,000 ms after the light-on moment, then approach the VA and shake hands before return to the starting location. The handshake will be initiated and ended by the participant.

After each valence block, the participant will evaluate the facial expressions and body postures of the VAs by reporting the perceived valence overall (positive, negative, and neutral) of the VAs. After the main study, Multimodal Presence Scale will be employed to measure physical, social, and self-presence in VR [34]; Virtual Embodiment Questionnaire will be employed to assess body ownership, body agency and perceived change in body scheme [43].

4 CONCLUSION

In this paper, we presented the overall framework for our VR study to investigate social anxiety in human participants through the use of compelling expressive interactive VAs and the analysis of ERP components along with behavioural and physiological data to reveal the influence of emotional valence on early face and body perception during social interactions.

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