Investigating the Effects of Embodiment on Presence in Stressful Immersive Virtual Environments using Physiological Monitoring

Cassandra Ichniowski, Victoria Interrante, and Brian Ries
CRA-W Distributed Mentoring Program
University of Minnesota, Twin Cities
Department of Computer Science

Abstract

This paper presents an experiment using physiological monitoring of heart rate and galvanic skin response to investigate the effects of a fully tracked human avatar representation on presence in immersive virtual environments (IVEs). The experiments will compare participants' physiological reactions in a high fidelity virtual replica of the room occupied and their reactions to a stressful model of the room with the floor removed except for a narrow bridge.

1 Introduction and Previous Work

Virtual reality promises to be a useful tool in 3D design, particularly in the field of architecture. However, research indicates a compression of spatial perception in IVEs [1,9,11]. Recent work by Interrante et al. has investigated contributing factors [2,4], including experiments that imply that a lack of 'presence' may be a factor contributing to the widely acknowledged distance compression that occurs in IVEs [3]. According to Sanchez-Vives and Slater, "'presence research' studies the phenomenon of acting and feeling that we are in the world created by computer displays" [8].

Several studies have investigated physiological reactions to stressful virtual environments, generally as a method for treating phobias, PTSD, and similar conditions, using biofeedback as an objective tool [5,12], occasionally relating the results to 'presence' [10]. Most notably, Meehan et al. presented four studies supporting the reliability, validity, sensitivity, and objectivity of heart rate and, to a lesser extent, galvanic skin response as an objective measure of presence in IVEs. Furthermore, they also found that presence measures decrease over multiple exposures to the same IVE, though not to zero, and that passive haptics cues increase presence significantly [6]. Both of these findings contributed to decisions made in planning our experiment.

Few studies, however, have examined the effect of a fully tracked avatar on presence and veridical perception in IVEs. Ries et al. did a recent study showing the effects of embodiment on ego-centric distance perception in IVEs and discovered that participants equipped with a fully tracked avatar performed significantly better at estimating distances in blind walking [7]. This study does not illuminate what about embodiment affects veridical perception. Hence, the following experiment uses biofeedback as an objective measure to detect the effects of embodiment on presence in IVEs. It further aims to promote presence as a potential factor contributing to ego-centric distance perception compression.

2 Experiment

Due to time constraints, no experiments have been completed, however they are designed as follows. Participants will be equipped with an electrode placed on the chest for heart rate (HR) monitoring and two finger sensors for galvanic skin response (GSR) monitoring. The participants will then be outfitted with a body suit with retro-reflective markers and a head mounted display. Half of the participants will then be equipped with a virtual avatar whose location and motion is fully tracked using the retro-reflective marker. They will then be presented with a high fidelity model of the laboratory. They will be asked to complete a task of walking across the room between two pieces of masking tape to retrieve a small red block. They will then walk to the center of the room, stand on top of two tiles, read the number on a target near the center of the room, and drop the block onto the target. They will then return to the starting position and asked to complete the task again. However, when they turn around, the floor of the model will be moved to 20 feet below except for the narrow bridge between the pieces of masking tape.

Because users will acclimate to the stressful virtual environment, participants will only be tested under one condition of embodiment: with an avatar or without. Therefore, physiological reactions to the stressful environment will be compared between the two groups of participants.

Fig 1: *Laboratory set-up with vertigo-bridge marked out in masking tape and tiles for haptic feedback. Two of the twelve Vicon cameras are visible at the top of the image.*

2.1 Apparatus

All human subject experiments will take place in a large open laboratory on campus. The walkway in the second version of the model is marked out with masking tape in both the actual room and the virtual room.

The model of the virtual room will be presented using a head mounted display (HMD) by nVis, providing 1280x1024 resolution images to each eye with a 60 diagonal monocular field of view (for an effective resolution of about 2.2 arc minutes of visual angle per pixel) and 100% stereo overlap. A 15' cable connects the HMD to a video control box on a wheeled cart, allowing for ample movement.

A Vicon optical tracker will be used to track position and motion of each participant as well as the HMD. Roughly fifty retro-reflective markers are attached to a black two-piece micra suit. These markers denote the joints and limbs of the user's body and allow the system to create a unique skeleton hierarchy for each user.

The ProComp2 by Thought Technology Ltd will be used for encoding physiological monitoring and transferring the data to the computer and software. This device will be worn on the collar of the motion capture suit. Similar to the HMD, a 15' cable will connect this device to the wheeled cart. A UniGel electrode will be used for monitoring heart rate, and a skin conductance sensor with two finger bands will be used to monitor galvanic skin response.

Images are rendered to the HMD screens using the OGRE 3D rendering engine, supplemented with code to enable proper stereo rendering. The virtual room model was created in Google SketchUp, and used high fidelity photographs to texture its surfaces. The virtual avatar was purchased at TurboSquid and was re-skinned to the default Vicon provided skeleton.

Fig 2: *The Vicon system: a user wearing the two-piece suit with retro-reflective 1cm spherical markers. A Vicon camera is in the background at the top of the image.*

2.2 Procedure

Following is a detailed outline of roughly how the experiments will be executed. Participants will be brought into the lab and outfitted with a chest electrode sensor. They will then be instructed on how to put on the motion capture suit and the markers will be adjusted to align properly with that user's joints and limbs. Additional markers will be placed on the hands and feet using toupee tape. It is important here to note that all participants will be fully tracked, as it is relevant for the task, however only half of the participants will have a visible avatar in the virtual space. They will then be equipped with two finger sensors on their left hand and both the HR electrode and the GSR sensors will be wired to the ProComp2, which will then be clipped to the collar of the suit. They will then be brought to the center of the room to perform a range of motion by mirroring an experimenter. An experimenter then aids calibration of a skeleton to the user's proportions by labeling markers in the recorded data. Meanwhile, the user will read and fill out a consent form and receive instructions on their task, which they will perform twice. The participant will be lead to the side of the room pictured in Figure 1 and instructed to stand in a tape square, which is featured in both the real and virtual rooms. Finally, they will be aided in putting on the HMD and fitting it comfortably to their head and given a wireless handheld mouse to hold in their right hand for the task.

Figure 3: *The virtual model with the floor removed. Participants retrieve the block from the chair and drop it from the tiles in the middle of the room.*

Participants will be instructed to walk across the room between the pieces of tape to retrieve a red block sitting on a chair across the room, which can be seen in Figure 3. To pick up the block, they need only hold down the button on the underside of the mouse then click the left button of the mouse. However, their right hand must be within a reasonable range of the block. The block is now bound to the user's fully-tracked hand. The participant will then walk back across the room to two tiles arranged in the center like a diving board (refer to Figure 3 for clarity). They will then look down at the floor and read a number off a target, then drop the block onto the target, as described before. They will then return to the "home base" tape square and stay facing the wall until instructed to turn around and complete the task a second time. However, when they turn around, the floor will be removed except for the narrow bridge as pictured in Figure 3.

The first walk allows them to acclimate to the VR to provide a solid baseline of HR and GSR with which to compare the second trial of the task.

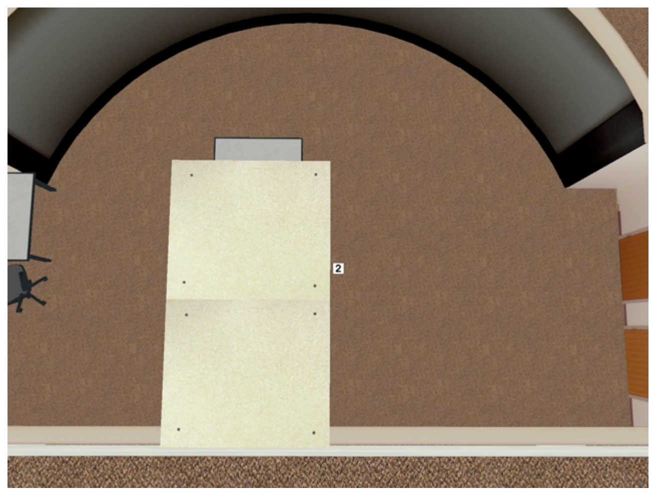

Figure 4: *The virtual room with floor removed. Participants are required to read the number off the target below (here, '2') and drop the red block onto the target.*

3 Results

Due to repairs on the HMD, delayed acquisition of physiological monitoring devices, and complications in IRB approval for human subject experiments, no experiments were carried out during the run of the internship. However, we hypothesize that subjects with a fully tracked avatar will yield higher and sustain higher physiological responses to the stressful IVE compared to their baseline in the non-stressful IVE, suggesting greater 'presence' for embodied users.

4 Discussion

If the experiment yields sufficient data to support the hypothesis, this result implies not only greater presence but also increased veridical spatial awareness from embodiment. Future work may want to investigate the effects of having an untracked avatar (i.e. rigid feet with only location tracked) compared to fully-tracked and the effects of foot size relative to the users, as well as other limitations that can be placed on the avatar to elucidate what about the avatar is significant for presence.

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