Investigating the Physiological Effects of Self-Embodiment in Stressful Virtual Environments

Brian Ries*
University of Minnesota

Victoria Interrante†
University of Minnesota

Cassandra Ichniowski
University of Pennsylvania

Michael Kaeding
University of Minnesota

1 Abstract

In this paper we explore the benefits that self-embodied virtual avatars provide to a user's sense of presence while wearing a head-mounted display in a immersive virtual environment (IVE). Recent work has shown that providing a user with a virtual avatar can increase their performance when completing tasks such as ego-centric distance judgment [5]. The results of this research imply that a heightened sense of presence is responsible for the improvement. However, there is an ambiguity in interpreting the results. Are users merely gaining additional scaling information of their environment by using the representation of their body as a metric, or is the virtual avatar heightening their sense of presence and increasing their accuracy? To investigate this question, we conducted a between-subjects design experiment to analyze any physiological differences between users given virtual avatars versus ones that were not. If the virtual avatars are increasing a user's sense of presence, their physiological data should indicate a higher level of stress when presented with a stressful environment.

2 Introduction

Virtual reality promises to be a useful tool in 3D design, particularly in the field of architecture. It allows its users to experience and explore a modeled environment at correct scale and with proper depth cues. However, research has indicated a noticeable compression in egocentric distance perception in virtual environments while wearing an head-mounted display (HMD). Many possible factors have been explored such as graphics fidelity and HMD ergonomics, but nothing has accounted for the full discrepancy [6, 8]. Recent research by Interrante et al. suggests that a lack of presence may be the cause of this problem [1]. This hypothesis was explored further in additional work by including virtual avatars in the perception tasks, and the results showed a significant improvement [5]. The question arises, are the fully-tracked virtual avatars enhancing presence and can we design an experiment to test this?

Several studies have investigated the physiological reactions to stressful virtual environments, generally as a method for treating phobias, post-traumatic stress syndrome, and similar conditions using biofeedback as an objective tool [3, 9]. 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 [4]. 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. While this research did not include the use of a fully-tracked avatar, its findings suggest the importance of including passive haptics and a limited number of exposures when designing an experiment to assess presence.

*e-mail: riesbr@cs.umn.edu
†e-mail: interran@cs.umn.edu

Additional research has investigated some of the possible benefits of avatars in virtual environments. One of these benefits is an increase in task performance. Lok et al. compared time to complete a task between a purely virtual environment and two different hybrid approaches [2]. The pure virtual environment involved manipulating blocks with a pinch-glove and a modeled avatar representation, while the hybrid conditions consisted of mapping real-time video from an HMD-mounted camera to grant a view of the users hands. Their study found that users performed the task better in the conditions where the users manipulated real objects, and found only a small effect of the accuracy of the avatar representation to the user. This encourages us to design a manipulation task that is natural to perform in the virtual world, and ensure a reasonable amount of faithfulness in our avatars.

3 Experiment

To investigate the feeling of presence granted by virtual self embodiment, we conducted an experiment with a between-subjects design. Physiological differences were compared between two different conditions; receiving a virtual avatar and not. Each subject encountered two exposures, the first being a high fidelity replica of the room they occupied. The second exposure altered the room to create a stressful environment, in this case, a twenty foot drop surrounding the viable tape-marked walkway. Each subject was equipped with a PromComp2 physiological monitoring device made by Thought Technology Ltd. This equipment monitored their heart beat (EKG) and galvanic skin response during the trial.

Figure 1: External view of the first exposure virtual environment.

The physiological data was statistically analyzed to measure the difference in response between the two exposures for each individual participant. This difference was then compared between-subjects to see if there was a significant effect of granting one group a virtual avatar. The physiological analysis was also supplemented with a subjective presence questionnaire based on the Slater-Usoh-

Steed questionnaire [7]. The participants filled out the questionnaire following the experiment, which inquired them to rate their sense of presence in both conditions. Our hypothesis is that providing users with virtual avatars will show a significant difference in subjective and physiological measurements that is correlated to a heightened sense of presence.

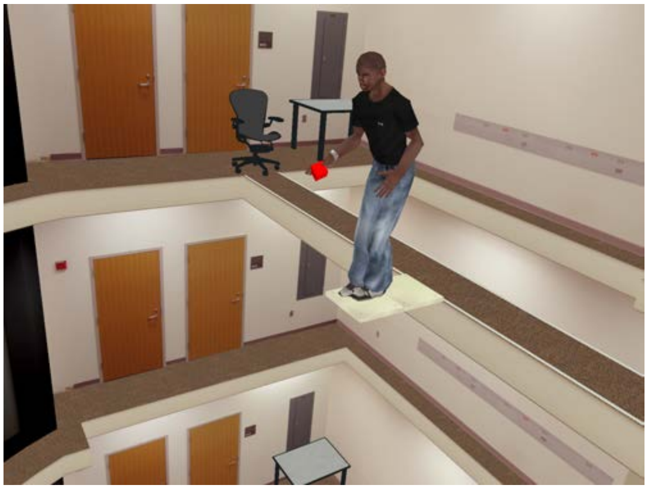

Figure 2: External view of a participant with a virtual avatar in the 'stressful' environment

3.1 Apparatus

Testing took place in the Digital Design Consortium laboratory on the first floor in Walter library on the University of Minnesota campus. The trackable space for the experiment consisted of a 25' by 10' area with a walkway marked with masking tape on the floor to accommodate the space needed for the virtual experiment. In addition, physical wooden tiles and a chair were spatially registered and placed alongside the marked walkway in the real world to provide passive haptic feedback to the user in the virtual environment.

The virtual environment was displayed to the users with the nVisor head-mounted display(HMD) made by nVis. This HMD provides 1280x1024 resolution to each eye with 100% stereo overlap. The screens grant a 60 degree monocular diagonal field of view. The HMD was tethered with a 15' long cable to a controller box mounted on a wheeled cart. This cart is connected to the rendering computer with another 15' feet of cable, allowing the user access to the full laboratory space. The rendering software was run on a desktop computer using a Xeon 2.83GHz processor with an nVidia Quadro 4500 video card and 2.0GB of RAM. The software developed used the OGRE 3D rendering engine and incorporated a human avatar that was purchased from TurboSquid.

Tracking for the experiment was provided by a Vicon optical tracker. This system consisted of 12 cameras spaced equally around the room that provided ample coverage of the area the users were working in. Each participant wore a two-piece black micra body suit with roughly 45 markers attached for body tracking. The Vicon IQ software was used to animate the user's virtual body within the rendering engine, using an avatar re-skinned to fit a default Vicon skeleton.

3.2 Participants

We recruited 20 participants for this experiment, with 10 in each of the two conditions (avatar vs. no avatar). Using a sign advertising our experiment and its corresponding $5 dollar gift card, we were able to recruit our subjects from the sidewalk in front of our building. This gave us access to a pool of naive subjects on demand, which decreased the downtime compared to experiment scheduling. The experiment took approximately 20-30 minutes per individual.

3.3 Procedure

On entry to the lab, each subject was given the two piece body suit to put on over their clothing. Retro-reflective markers were properly placed on their body and the subjects were instructed to begin a capture of their range of motion. This capture involves moving each limb of the body through a scripted series of movements to aid in the automatic calibration that Vicon uses to construct a unique skeleton for the user. Once this range of motion was complete, the subjects read and signed the consent forms for the experiment while the manual phase of the Vicon calibration was conducted. After signing the consent form, the subjects were instructed to put on the heart rate monitor. This involved attaching three electrodes to their chest, and wearing the galvanic skin receptors on two fingers of their left hand. Once the subject was done suiting up for the experiment, the Vicon calibration process was typically finished and the experiment could begin.

Following calibration, the participants were guided to the starting point of the experiment which consisted of marked square in masking tape on the floor. The HMD was placed on their head while the experimenter adjusted its binding to fit comfortably. The virtual environment presented to the user was a replica of the laboratory they occupied with a chair supporting a small virtual block across the room. The virtual floor was marked off with masking tape showing a path from the user's starting position to the chair. Roughly halfway to the chair was the set of two wooden tiles that stuck out from the path.

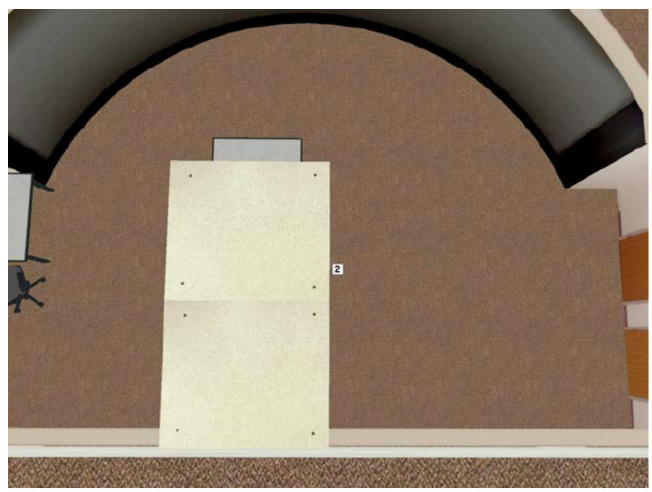

Figure 3: View through the HMD of the 'stressful' virtual environment without an avatar before walking onto the wooden tiles.

The users were instructed to walk down the path to the chair and pick up the virtual block. When the user reached out their right hand in close proximity to the block, an experimenter hit a key to make the block stick to their hand. Then the users turned around and carried it halfway down the path to the wooden tiles. They stepped onto the tiles and walked out until their toes hung slightly over the edge. This provided the user with haptic feedback of their current position and generated a physical disconnect from the carpeted laboratory floor. From the edge of the tile, they were instructed to look down at the numbered target on the floor and report verbally the number they saw (which was randomized each trial). This gave us confirmation that each user performed the task of looking down with their eyes open. The users then extended and shook their hand with the goal of releasing the block having it land on top of the target. This dropping action was also externally controlled by an experimenter to ensure that each user got similar feedback.

This experimental procedure was repeated in a second exposure, where the virtual floor was lowered twenty feet to create a stressful environment. These two trials were conducted identically for the group of participants not receiving an avatar. Because of the lack of visual feedback, the carried block floated in space relative to where the participant's hand was located, and they could not see their feet when stepping onto the wooden tiles (though passive haptic feedback still aided in their positioning). Following the experiment, the users filled out a presence questionnaire and were given a gift card for participation.

4 Results

At this time, the results for this experiment are not yet compiled and are withheld from this position paper.

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