Audio Feedback and Illusion of Virtual Body Ownership in Mixed Reality

Jean-Luc Lugrin* David Obremski† Daniel Roth‡ Marc Erich Latoschik§
HCI Group, University of Würzburg

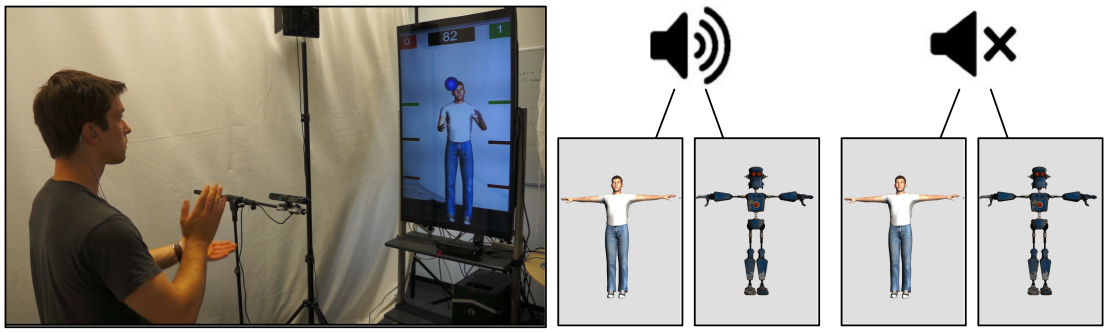

Figure 1: ***Experiment Condition and Task****: Participants saw their avatars body from a third person perspective mirroring their movements and facial expression. Each participant experienced both an avatar with a Human body (either an adult female or male) and one with Non-Human body (a robot). Participants had to clap their hands to destroy falling spheres when they reach a certain level in front of the avatar (indicated by green bars). Only half of the participants received audio feedback in response to their virtual body interactions*

Abstract

This paper presents an exploratory experiment measuring the role of audio feedback on the illusion of virtual body ownership (IVBO) under non-immersive mixed reality (MR) settings with *Human* and *Non-Human* avatars. Our preliminary results revealed that all avatars elicited a similar level of IVBO, despite the addition of audio feedback.

Keywords: Avatar Embodiment, Mixed Reality, Realism, Audio

Concepts: •**Human-centered computing** → **Virtual reality;**

1 Introduction

Avatar Embodiment is the physical process that employs the VR hardware and software to substitute a persons body with a virtual one [Spanlang et al. 2014]. The visualisation of an avatar replicating your movement in a first-person perspective in VR has strong physico-psychological effects. For instance, it can create the Illusion of Virtual Body Ownership (IVBO), when a person perceives a virtual body to be its own body [Lugrin et al. 2015]. The factors and effects of avatar embodiment in fully immersive VR systems, such as the IVBO, are well-known, and have been well-studied [Spanlang et al. 2014]. Meanwhile, despite interesting benefits, the research on IVBO in MR environments is practically non-existent.

This research describes a preliminary experiment exploring the effects of audio cues for avatar embodiment in a*mixed-reality mirror* paradigm. The experimental setup is a replication of the system proposed in [Lugrin et al. 2016], where participants are facing a *fake* mirror. Participants can see their real body as well as their virtual one reflected in a large display screen. The participant's body size, position, movement, as well as facial expression were faithfully reproduced by the avatar.

MR-based avatar embodiment systems, such as our *fake* mirror, possess certain advantages compared to fully visually immersive ones. They are low intrusive (i.e. no special equipment to wear) and enable a full body representation including facial expressions, which is not possible to experience in a first person view virtual environment. Furthermore, the cybersickness is less likely in mixed reality systems which increases the potential target group. In addition, such virtual mirror installations can be useful in various scenarios. They could be used to treat mental disorders like depression by providing an altered self-image of the patient. Moreover, they could be used to control the rehabilitation process of injured limbs by giving feedback about healthy and unhealthy movements. In addition such systems also have a high potential in the field of entertainment. To acquire optimal results in the above mentioned fields, further research on IVBO in MR is necessary. Therefore, our main goal is to provide a first investigation of a potentially important factor: virtual body sound cues.

2 Previous work

One of the few works in the field of sound and IVBO has been done by [Sikström et al. 2014]. They developed a virtual reality game where a player had to fly around obstacles using virtual wings. Their experiment had four different conditions: *i)* no sound at all, *ii)* just sound feedback from avatar's body, *iii)* sound feedback from the body and the virtual wings or *iv)* sound feedback from the body with asynchronous sound feedback from the wings. They found little to no differences in the perceived level of ownership of the wings between the four categories. However, in a non-immersive MR context with the constant awareness of our real body appearance, the presence virtual body sound cues could potentially be more important to elicit a sense of virtual body ownership.

*e-mail:jean-luc.lugrin@uni-wuerzburg.de
†e-mail:david.obremski@stud-mail.uni-wuerzburg.de
‡e-mail:daniel.roth@uni-wuerzburg.de
§e-mail:marc.latoschik@uni-wuerzburg.de

VRST '16, November 02-04, 2016, Garching bei München,Germany
ISBN: 978-1-4503-4491-3/16/11
DOI: http://dx.doi.org/10.1145/2993369.2996319

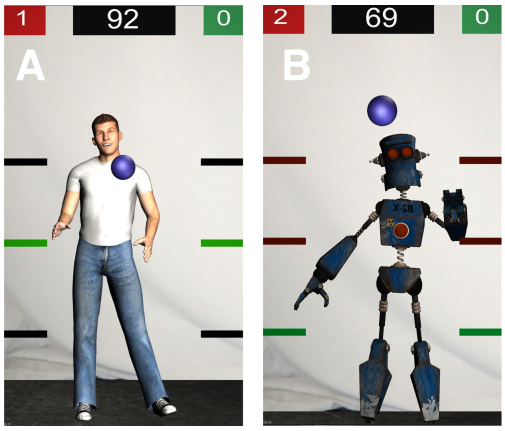

Figure 2: *Left: Human condition with a generic human male avatar; Right: Non-Human condition with a robot avatar (In red: spheres missed; In green: spheres destroyed; In black: time left).*

3 Experiment

We designed a mixed-reality game for IVBO induction, and evaluated the participants' experience with the absence or presence of sound and different type of avatars. We adopted a *mixed* design where:

- **The between-subjects factor** was composed of two conditions represented by the absence or presence of audio feedback (Figure 1). In the latter condition, different *clap* sound cues were played: a metallic sound for the *Robot*; and a real human clap for the *Human* avatar.

- **The within-factor** had two conditions: *Human* or *Non-Human* Avatar. As illustrated in Figure 2, each participant experienced two avatars: *i)* a humanoid robot, *ii)* and a realistic male or female human adult(depending on the participant's gender). We assumed that uncanny valley effects could eventually happen and bias our study when using generic human avatars as suggested by [Lugrin et al. 2015]. Thus, we also used *Non-Human* avatars.

The experimental task consisted of a simple game of destroying targets (here represented by large blue spheres). One game session lasted 100 seconds. Participants had to clap their hands to destroy falling spheres, when they were reaching a certain level indicated by a green bars (see Figure 2). However, only half of the participant received audio feedback using in-ear noise-isolating headphones. To avoid an excessive end-to-end latency, a microphone was used to detect the participant's clap, instead of the body tracking system.

3.1 Measurements

The following measures were collected in this study:

1. **IVBO Questionnaire** [Lugrin et al. 2015]: Measuring different aspects of avatar embodiment using 15-item divided into five main categories: *Body Ownership, Agency, Alter effect, Enjoyment, Threat effect and Anthropomorphism.*

2. **Bias Control**: questionnaire comparing avatar rating and preferences, answered after experiencing all avatars.

3.2 Results

40 participants were involved in the experiment (19 female and 21 male with M_{age} = 22.5, SD_{age} = 2.81, 20 subjects in each group). To get a reliable score for the experienced IVBO, the items that concentrate on the perceived amount of illusion have been isolated. The remaining 12 items were analyzed by calculating the Cronbach's Alpha. The high value (α = 0.87) shows a high correlation between these items from which a mean IVBO value that was computed for each participant. As shown in Figure 3 for both avatars, the mean IVBO rate was higher with sound than without. However, there were no significant differences between *Human* with or without sound (p = 0.054) as well as for the *Non-Human* with or without sound (p = 0.254). Non significant differences in terms of game performances were found either, despite 72% of the participants stated that they preferred the *Non-Human* to the *Human* avatar.

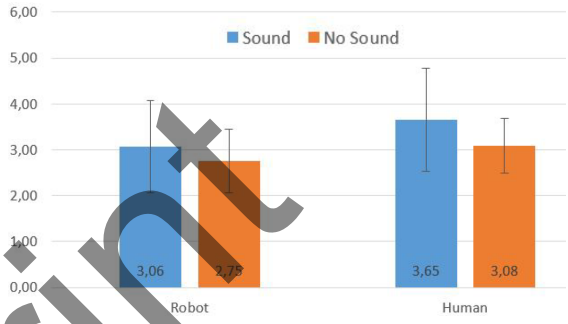

Figure 3: *IVBO scores results (means and standard deviations)*

4 Conclusion

We observed that all avatars elicited a similar level of body ownerships despite their *Human* or *Non-Human* aspect. The addition of audio feedback appeared to not affect the illusion. As suggested by previous results in immersive virtual environments, virtual body sound cues seem to not be a important bottom-up factor of the IVBO in non-immersive mixed reality. Our future work is to continue our investigation by replicating this experiment with additional avatar-object interactions sound cues, as well measuring sound latency impact.

References

LUGRIN, J.-L., LATT, J., AND LATOSCHIK, M. E. 2015. Anthropomorphism and illusion of virtual body ownership. In *International Conference on Artificial Reality and Telexistence Eurographics Symposium on Virtual Environments*.

LUGRIN, J.-L., ZILCH, D., ROTH, D., BENTE, G., AND LATOSCHIK, M. E. 2016. Facebo: Real-time face and body tracking for faithful avatar synthesis. In *2016 IEEE Virtual Reality (VR)*, IEEE, 225–226.

SIKSTRÖM, E., DE GÖTZEN, A., AND SERAFIN, S. 2014. The role of sound in the sensation of ownership of a pair of virtual wings in immersive vr. In *Proceedings of the 9th Audio Mostly: A Conference on Interaction With Sound*, ACM, 24.

SPANLANG, B., NORMAND, J.-M., BORLAND, D., KILTENI, K., GIANNOPOULOS, E., POMÉS, A., GONZÁLEZ-FRANCO, M., PEREZ-MARCOS, D., ARROYO-PALACIOS, J., MUNCUNILL, X. N., ET AL. 2014. How to build an embodiment lab: achieving body representation illusions in virtual reality. *Frontiers in Robotics and AI 1*, 9.