Mediated Physicality: Inducing Illusory Physicality of a Virtual Human via Environmental Objects

Myungho Lee*
University of Central Florida

ABSTRACT

A physical embodiment of a virtual human has shown benefits in applications that involve social interaction with virtual humans. However, it often incorporates cumbersome haptic devices or robotic bodies. In this position paper, we first discuss our motivation of utilizing a surrounding environment in human-virtual human interaction and present our preliminary studies and results. Considering the previous studies and related literature, we define the concept of *Mediated Physicality* for virtual humans, which utilizes environmental objects to increase perceived physicality of the virtual humans, and discuss fundamental aspects of the *Mediated Physicality* as well as future research plans.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, Augmented, and Virtual Realities; J.4 [Computer Applications]: Social and Behavioral Sciences—Psychology

1 INTRODUCTION

Virtual huamns (VHs) can sometimes assume roles of humans for purposes such as medical, military, or teacher training. They can appear in a virtual environment or can share physical space with real human (RH) trainees during training. In general, people treat VHs in a similar way to they do to RHs when they have higher social/co-presence with VHs, and such realistic response to VHs are desired in most cases. For that, most research on social/co-presence with VHs has focused primarily on the VH, e.g., its appearance, intelligence, and verbal and nonverbal behavior.

However, we often perceive the presence of the other person via objects in the shared space. For example, if another person is touching the object at the same time, the movement can transfer through the object and be experienced by the other person. Similarly, if a person heard approaching footstep sounds, he/she can notice the other person's presence. Despite the frequency of such mediated/indirect perception of the other person in everyday interactions, few have examined how these affect human-virtual human (VH) interaction.

2 PREVIOUS STUDIES AND RESULTS

We conducted our preliminary studies to explorer the effects of mediated/indirect interaction via an object in a shared space in human-virtual human interaction.

2.1 Visually synchronized movements of a shared table in MR

The purpose of this experiment was to assess how presence and social presence are affected when a person experiences subtle incidental movement through a shared real-virtual object during a conversational task (a game of *Twenty Questions*). We constructed a projection-based mixed environment with a table that spanned the boundary between the real and virtual environments (see Figure 1 left). During the game, participants in the **Wobbly** group experienced subtle incidental movements of the real-virtual table: the entire real-virtual table tilted slightly away/toward the participant when the VH or participant leaned on it. The **Control** group also played the same game, except the table did not wobble. Results indicate that the **Wobbly** group had higher presence, co-presence, and attentional allocation. This work was presented in IEEE VR 2016 [5].

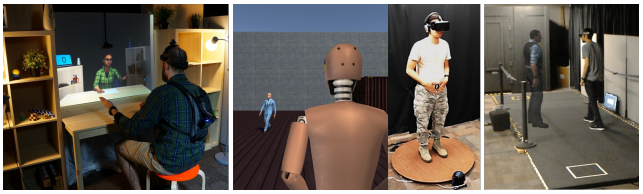

Figure 1: Previous user studies. Each image shows our experimental setups for a projection-based MR (left), IVR (center), and AR (right).

2.2 Vibrotactile feedback via a shared floor in VR

In this experiment, we eliminated the visual movement and the bidirectionality from the previous study. Participants in this study observed a VH walking toward the participants and pacing back and forth within their social space in an immersive VR. We used a between-subjects design with three groups: participants in the **Sound** group heard the footsteps of the VH; participants in the **Vibration** group experienced the vibration of the footsteps along with the sounds; while participants in the **Mute** group were not exposed to sound nor vibrotactile feedback. Results indicate that participants in the **Vibration** group felt a higher social presence with the VH compared to those who did not feel the vibration and exhibited more realistic behavior when the VH invaded their personal space. This work was presented in IEEE VR 2017 [4].

2.3 Vibrotactile feedback via a shared floor in AR

Current-state optical see-through AR HMDs have a unique issue that may affect a users' perception of a VH and the resulting actions and reactions, namely the mismatch between a small augmented visual field and a large unaugmented periphery. This issue can produce unnatural cropping of a VH when a user gets close to the VH. In this study, we applied the footstep vibrations used in the previous study to compensate for the limited augmented visual field and compared the effects of the footstep vibrations between restricted view—we blocked the unaugmented periphery—and unresticted view conditions. We measured participants' locomotion behavior, social/co-presence as well as perceived physicality of the VH. Similar to the previous study, the footstep vibrations increased social/co-presence, perceived physicality, but the effects on the locomotion behavior were less visible.

3 MEDIATED PHYSICALITY

The concept of *Mediated Physicality* aims to induce an illusion from users to regard a VH being able to affect them physically,

*e-mail: mlee@cs.ucf.edu

therefore causing more realistic behaviors, but without direct interaction. For that we propose to make a use of the surrounding environment where the primary interaction takes place and the interaction between the surrounding environment with the VH. In other words, instead directly perceiving the VH's physicality, users will perceive outcomes of the VH's actions on the environment, i.e., the outcomes are mediated. Subtle movements of the real-virtual table, footstep vibrations via the shared floor are the examples of the mediated outcomes.

In such mediation, we believe that the *synchronization* between the actions and outcomes and the *physicality of the mediator* are important factors for the *mediated physicality*. Our assumption is that when people perceive the mediated outcomes synchronized with a VH's actions, then they would naturally attribute perceived outcomes to the VH's actions—as similar to sensorimotor integration could induce the illusion of body ownership [3]—, finally physicality of the mediator would be transferred—to some degree, if not all—to the VH.

3.1 Factors in *Mediated Physicality*

Latency: *Body ownership* research have reported tolerable latencies between sensations, if not satisfied, would there not be such illusion (see [3]). Blanke et al. [1] showed that the sensorimotor conflict in connection with spatial incompatibility of self-touch induced the feeling of the other person's presence, while the sensorimotor integration induced the out-of-body experience. Similarly, latency over a threshold would break the causality between VH's actions and outcomes, cutting off the physicality back-propagation path (see Figure 2).

Physicality of mediator: Jeon and Choi [2] extended the *Reality-Virtual continuum* to a two-dimensional continuum of vision and haptic. Similarly, we consider *Physicality* to be a multi-dimensional concept; each dimension (relating to each sense) would be some degree correlated, forming expectancy in other dimensions in connection with prior knowledge. In an immersive virtual environment, the surrounding environment and objects are all *virtual* in visual perception, therefore, the mediated outcomes should be perceived in other senses, e.g., auditory or haptic, as only reliable *physical* reference is the user himself/herself. However, in a mixed/augmented environment, the mediator object can be a real object and people would consider it as *physical* as they are—from visual perception and prior knowledge. In such situation, a VH's actions and mediated outcomes perceived only visually might be enough for physicality propagation. For example, people would feel a VH more physical if the VH moved a real cup on a table.

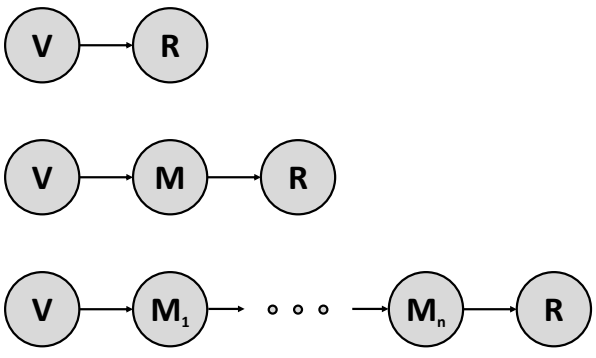

Figure 2: Concept diagram of *Mediated Physicality*. First row represents direct perception; second row represents 1st order mediated perception; third row represents n-th order mediated perception. (V: virtual human, M: mediator object, R: real human)

Order of mediation: In our previous studies (see 2), we only examined the first-order mediation. A VH's actions caused the subtle movements of the real-virtual table or vibrations on the floor, and participants perceived the mediated outcomes on those first-order mediator. We believe that the involvement of second or third object in the chain of physicality propagation will be possible. However, the transferred physicality would be restricted by the physicality of the mediator object, and the mediated physicality will be gradually decreased each time it is transfered.

Slater [6] introduced *Place Illusion (PI)* and *Plausibility Illusion (Psi)* to explain realistic responses people exhibit in an immersive virtual environment. *Mediated Physicality* is similar to the *Psi*—that is difficult to recover once it breaks—in that both rely on certain events that are not caused by a user and the correlations between the events and the sensations. In that respect, 'breaks in mediated physicality' is also a factor, along with the factors discussed above, that needs further investigation for overall user experience.

4 Future Work

As we are currently in the process of defining the concept and finding factors, we will iteratively design our future studies. Our immediate plan for the next study involves a VH manipulating a physical object in augmented reality. Participants will perform a conversational task with a VH. For a half of the participants (treatment group), the VH will move props on a table; for the other half (control group), the VH will not move the props. To consider the effects of physicality of mediator, real props and virtual props will be used for each half of the treatment group respectively.

5 Conclusion

The expected contributions include more articulated definition of *Mediated Physicality*, the factors associated with it, and guidelines for utilizing mediated physicality in virtual/augmented reality simulators. We look forward to the use of *Internet of Things* devices as a means of connecting virtual and physical worlds, in that respect, the concept of mediated physicality is promising.

Acknowledgements

The work presented in this publication was supported in part by the Office of Naval Research (ONR) Code 30 under Dr. Peter Squire, Program Officer (ONR awards N00014-14-1-0248 and N00014-12-1-1003).

References

[1] O. Blanke, P. Pozeg, M. Hara, L. Heydrich, A. Serino, A. Yamamoto, T. Higuchi, R. Salomon, M. Seeck, T. Landis, S. Arzy, B. Herbelin, H. Bleuler, and G. Rognini. Neurological and robot-controlled induction of an apparition. *Current Biology*, 24(22):2681–2686, 2014.

[2] S. Jeon and S. Choi. Haptic Augmented Reality: Taxonomy and an Example of Stiffness Modulation. *Presence: Teleoperators and Virtual Environments*, 18(5):387–408, 2009.

[3] K. Kilteni, A. Maselli, K. P. Kording, and M. Slater. Over my fake body: body ownership illusions for studying the multisensory basis of own-body perception. *Frontiers in Human Neuroscience*, 9:141, 3 2015.

[4] M. Lee, G. Bruder, and G. F. Welch. Exploring the effect of vibrotactile feedback through the floor on social presence in an immersive virtual environment. In *2017 IEEE Virtual Reality (VR)*, pages 105–111. IEEE, 2017.

[5] M. Lee, K. Kim, S. Daher, A. Raij, R. Schubert, J. Bailenson, and G. Welch. The Wobbly Table: Increased Social Presence via Subtle Incidental Movement of a Real-Virtual Table. In *Proceedings - IEEE Virtual Reality*, volume 2016-July, pages 11–17, 2016.

[6] M. Slater. Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 364(1535):3549–57, 12 2009.