The Impact of Avatar-Owner Visual Similarity on Body Ownership in Immersive Virtual Reality

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ABSTRACT

In this paper we report on an investigation of the effects of a self-avatar's visual similarity to a user's actual appearance, on their perceptions of the avatar in an immersive virtual reality (IVR) experience. We conducted a user study to examine the participant's sense of body ownership, presence and visual realism under three levels of avatar-owner visual similarity: (L1) an avatar reconstructed from real imagery of the participant's appearance, (L2) a cartoon-like virtual avatar created by a 3D artist for each participant, where the avatar shoes and clothing mimic that of the participant, but using a low-fidelity model, and (L3) a cartoon-like virtual avatar with a pre-defined appearance for the shoes and clothing. Surprisingly, the results indicate that the participants generally exhibited the highest sense of body ownership and presence when inhabiting the cartoon-like virtual avatar mimicking the outfit of the participant (L2), despite the relatively low participant similarity. We present our experiment and main findings, also, discuss the potential impact of a self-avatar's visual differences on human perceptions in IVR.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; • **Computing methodologies** → Virtual reality ;

KEYWORDS

Virtual reality, self-avatar, presence, body ownership, HMD

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Figure 1: Three levels of self-avatar similarity to its human owner in IVR. (Left) L1-High: a realistically reconstructed avatar from real imagery of the owner. (Middle) L2-Medium: a cartoon-like virtual character wearing the same colored outfit as the owner. (Right) L3-Low: a cartoon-like virtual character with the pre-determined default outfit.

1 INTRODUCTION

In immersive virtual reality (IVR), a self-avatar representing the owner (human user) has shown to have positive effects in his/her sense of presence and the quality of interaction [Steed et al. 2016]. While self-avatars are typically generated using a pre-determined form with developed by 3D artists, it has become more practical to create a self-avatar model precisely and instantly via an automatic 3D reconstruction process, thanks to technical innovations in simultaneous depth sensing and human motion tracking [Feng et al. 2017]. In other words, it has gotten easier to create a self-avatar that looks the same as its owner in IVR via a head-mounted display (HMD), e.g., an avatar with the same colors and materials as the owner's outfit.

Many researchers have studied the effects of an avatar's characteristics on human perceptions of the avatar, such as a visual quality of the avatar [Wu et al. 2014]. Although some have studied the effects of appearance between avatar and its owner [Jo et al. 2017], more comprehensive studies looking into influence (e.g. to sense of ownership and presence) of variety of aspects including the avatar-owner are needed. Therefore, we experimentally investigate how a self-avatar's visual similarity to its owner, particularly in the appearance of clothes and shoes, can influence the perceptions with respect to the avatar. In our experiment, we examine each

participant's sense of body ownership, presence, and avatar realism in an IVR environment via a head-mounted display (HMD), under three different levels of avatar-owner visual similarity as shown in Fig. 1 below and described next.

2 EXPERIMENT

We designed a single-factor (i.e., levels of avatar-owner similarity) within-subjects experiment. The three test conditions by the similarity are: (L1) an avatar comprising a 3D mesh model reconstructed from real imagery of the participant, whose raw point cloud data was captured by a depth sensor, (L2) a cartoon-like virtual character-based avatar created by a 3D artist using colors/patterns that match the participant's real outfit, (L3) a cartoon-like virtual character wearing a pre-determined outfit. See the examples in Fig. 1. We initially hypothesized that participant's (or owner's) perceptions in terms of the avatar's visual similarity would be the highest in L1 and the lowest in L3.

For the experiment, the participant wore an HMD (Oculus Rift) to experience an IVR version of a large virtual cave, with a life-sized self-avatar seen from a first-person viewpoint. During the experiment, each of the 12 participants were asked to perform one condition per day in a random order to eliminate bias, and follow the avatar's body postures operated by an experimenter behind the curtain (Wizard-of-Oz) to help see the participant's body in detail. Then, they were also asked to observe a red sphere that randomly appeared on the body of the avatar, in an attempt to make them aware of the avatar's visual appearance, and hence the similarity to their real appearance.

To assess participant's sense of body ownership, presence, and avatar realism among the different conditions, we used a subjective survey instrument comprising 7-point Likert scale questions. Examples of the survey questions include "I felt like the body I saw in the virtual world was my body," for the sense of body ownership from [Lugrin et al. 2015] to evaluate visual resemblance such as a robot-typed avatar, and "How strong was your sense of 'being there' in the virtual environment?" for the sense of presence from [Dinh et al. 1999] . For the overall avatar realism, we simply asked whether they felt the avatar was realistic or not (1: very unrealistic to 7: very realistic).

3 RESULTS AND DISCUSSION

Prior to the experiment, we expected that L1 (a reconstructed avatar) would induce the highest sense of presence, realism and thus body ownership. First, a one-way ANOVA analysis for the three conditions revealed significant main effects of all factors on all dependent variables, such as body ownership ($F(2,33) = 39.41$, $p<0.05$), presence ($F(2,33) = 13.49$, $p<0.05$), and Overall visual realism ($F(2,33) = 11.68$, $p<0.05$). Surprisingly, the results showed that L2, with relatively lower similarity compared to L1, induced a higher sense of ownership and presence among the three tested conditions. See Fig. 2. Most of the participants noticed gaps in the point cloud comprising the reconstructed L1 model, and stated that they felt the avatar was rather heterogeneous or inharmonious to the surrounding virtual environment, seeming to indicate an effect related to the Uncanny Valley [Mori 1970]. These results could indicate that it is sufficient to establish body ownership by just capturing a set of essential

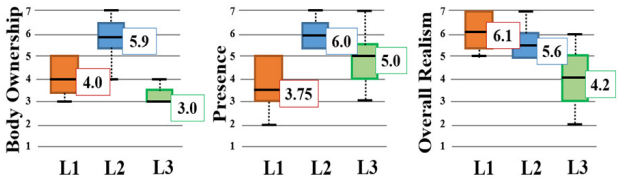

Figure 2: Survey results on the sense of (a) body ownership, (b) presence, and (c) overall visual realism.

salient qualities/features for the user (e.g. clothing, main facial features, body size), and taking into consideration the plausibility of the avatar appearance in the context of the virtual environment.

4 CONCLUSIONS

In this paper, we experimentally investigated the effects of a self-avatar's visual similarity (in three levels) to the sense of body ownership, presence, and overall visual realism. Our study showed that participants generally exhibited a relatively high sense of body ownership and presence in condition (L2) where the self-avatar was modeled in a cartoon-like fashion, when other physical features were preserved, such as the features of the participant's outfit. The results could indicate a counterintuitive effect where, like the Uncanny Valley, the most realistic appearance does not always provide the highest sense of presence, and how one should consider the plausibility of the avatar appearance in the context of the virtual environment.

In the near future, we will continue to explore the effects of other related factors with the significant number of users, such as avatar-owner motion similarity and realistic behavioral qualities (visual-motor synchrony). We will also explore more quantitative and objective measures, e.g., physiological signals.

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