Embodying an Extra Virtual Body in Augmented Reality

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Abstract

Presence and the sense of embodiment are essential concepts for the experience of our self and virtual bodies, but there is little quantitative evidence for a relation between these, and this relation becomes more complicated when there are real *and* virtual bodies in augmented reality (AR). We investigate the experience of body ownership, agency, self-location and self-presence in AR where users can see their real body and a virtual body from behind. Active arm movement congruency and virtual anthropomorphism are varied. We found significant effects of movement congruency but not anthropomorphism, a strong correlation between self-presence and body ownership, and a moderate correlation between self-presence and agency and self-location.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed/augmented reality; Human-centered computing—Human computer interaction (HCI)—Empirical studies in HCI

1 Introduction and Related Work

When using a humanoid virtual avatar, it is important to understand how a user experiences it and the environment in which it acts through concepts like presence and the sense of embodiment (SoE). Presence, the SoE, and relevant subconcepts can be defined as:

presence a psychological state in which virtual objects are experienced as actual objects in either sensory or nonsensory ways [6]

self-presence: mental model of a virtual body in a virtual world

proto self-presence: integration of objects into the body schema

SoE: the sense that emerges when [the body's] properties are processed as if they were the properties of one's own biological body [5]

body ownership: self-attribution of a virtual body (part)

agency: sense of being the author of your actions

self-location: sense of feeling located inside a body

A relation between presence and SoE has been suggested through body ownership and self-presence [5,9] (see Fig. 3), but there is little quantitative evidence to support this. Since studies with a virtual body (rather than only the real body) remain rare in augmented reality (AR), it remains unclear whether the visual presence of the real body in the real environment influences the experience. Note that this differs from VR CAVE studies, where even though the real body is visible, the environment is virtual and unknown to the user. In this study, we investigate self-presence, body ownership, agency and self-location over a disconnected virtual body in AR while the real body is simultaneously visually present, and provide quantitative support for a relation between the SoE and self-presence.

Jin and Park showed that self-presence can be experienced for a disconnected avatar displayed on a screen using congruent body movements while the real body is also visible [3]. Similarly, Lugrin et al. showed that, using a disconnected mirrored virtual avatar shown on a large screen, participants experienced body ownership over this avatar when using direct congruent body movement [7]. It is often mentioned that self-presence is a higher level concept than body ownership [5,9], which is reflected in owning a body (body ownership) versus an object (proto self-presence). There are admittedly studies on body ownership over non-corporeal objects [8], however many of these studies show very low degrees of ownership, bearing the question of whether participants were indeed experiencing ownership, or possibly a related concept. We thus argue that varying anthropomorphism of a virtual body should modulate the strength of body ownership. We hypothesize that an SoE can be induced over a disconnected virtual body in an AR environment while the real body is visible using congruent movements and an anthropomorphic body, and similarly proto self-presence, but the latter regardless of the anthropomorphism. Moreover, we hypothesize that body ownership is a special instance of proto self-presence.

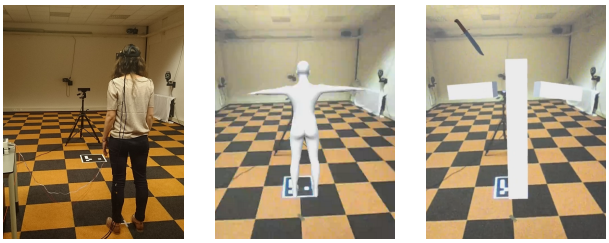

Figure 1: Views of the embodiment experiment. The virtual body appeared on a marker placed 2m in front of participant.

2 Method

Design. A single-blind 2x2 within-subjects design was used with factors *active movement congruency* of the virtual body's and the participant's arms (congruent, incongruent), and *virtual anthropomorphism* of the virtual body (anthropomorphic, non-anthropomorphic), see Fig. 1. A threatening virtual knife was used to induce a physiological ownership reaction [8]. The experimenters made sure that the participant's real arms were not always out of view by following what the participant saw on a separate screen; when facing forward, the arms were in view when held up in front of the participant.

Participants. 34 participants performed the experiment, age range 21-29 (mean 23.9, sd 1.64). 26 participants were male, 8 female; 5 left-handed, 27 right-handed, 2 had no hand preference. Most had little/no previous experience with AR, and none had experience with video see-through head-mounted displays (HMDs). One participant did not finish due to technical issues; this data was excluded from further analysis. The medical ethical committee of the local university hospital had no objections to the execution of this study.

Equipment. The AR environment was displayed in video see-through style through an Oculus Rift CV1 VR HMD (1200x1080 per eye resolution, 90Hz refresh rate, 110°nominal FOV) with two mounted Genius WideCam F100 Full HD cameras (640x480 resolution, 30Hz, 120°wide angle lenses). A Microsoft Kinect v2 captured the participants movements. The total system delay of approximately 80ms should be low enough to produce no unwanted effects [5]. For the skin conductance responses (SCRs) the Biosemi

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ActiveTwo acquisition system was used with electrodes on the left hand. The experiment was created in Unity 5.3.4, using the Kinect for Windows SDK and the Kinect v2 for MS-SDK Examples asset. The environment featured virtual objects displayed over the camera video feed. A 25-item questionnaire was used to measure body ownership (8), proto self-presence (4), agency (5), and self-location (8) (using e.g. [2, 4, 10]) on a 7-point Likert scale. The SCRs were preprocessed using a low-pass filter to remove noise, and then calculated by deducting the 10s pre-knife baseline from the highest peak found in the 10s post-knife window. One zero-responder (values $<0.03\mu$Siemens in $\geq$75% cases) was excluded from further analysis. Finally, the filtered SCRs were transformed with log(value+1).

Procedure. Participants stood on a cross 2m from a marker and 3m from the Kinect. For each condition, the participant was instructed to start in a T-pose, face forward, and after a verbal countdown to start moving their outstretched arms for 3min while remaining face forward. A life-sized virtual body appeared on the marker in front of them, and this body's arms moved using either the participant's own movements or prerecorded movements. After 3min a virtual knife appeared and made stabbing motions. Then the knife disappeared, followed by the virtual body. The participant filled out the condition questionnaire and took a break before starting the next condition. The whole experiment lasted approximately one hour.

3 Results

Questionnaire data (32 participants) were analyzed using two-way repeated measures ordinal regressions in R, the SCRs using a two-way repeated measures ANOVA in SPSS, both with within-subjects factors *active movement congruency* and *virtual anthropomorphism*. 23 models were statistically significant ($p<0.05$), in which cases the movement congruency factor was significant ($p<0.05$). The SCR ANOVA also revealed a significant main effect over movement congruency ($F(1,31)=1.294$, $p<0.0034$). See Fig. 2 for the responses to four questions and the SCRs. Although the subjective body ownership results were low, there was a clear difference caused by the movement congruence, with the SCRs showing similar effects, but we did not find the expected difference over anthropomorphism. A possible reason is that the gap between experienced anthropomorphisms may have become smaller as an effect of the added *limited* movements. Agency clearly occurred in the congruent conditions, whereas a shift or an experience of multiple self-locations only occurred for a few participants. Altogether there is evidence that participants experienced an SoE over the virtual body. Proto-self presence, on the other hand, was hardly experienced, despite a significant effect of movement congruence, possibly because participants had no task, making them more aware of the mediation [9]. Mantel Haenszel tests of trend found a strong positive relation between body ownership and proto-self presence, see Fig. 3. This correlation supports the existence of a relationship between body ownership and self-presence. The results also suggest a moderate relationship between self-presence and both agency and self-location, which gives further supports a moderate to strong positive relation between self-presence and the SoE.

4 Conclusion

In this study, we investigated self-presence, body ownership, agency and self-location over a disconnected virtual body in AR while the real body was visually present. We found that body ownership and proto self-presence were modulated by active movement congruency, but not anthropomorphism, possibly due to the combination of the two factors. Moreover, we provided quantitative support for a relation between subconcepts of the SoE and self-presence. An elaborate description of this study can be found in [1].

Acknowledgments

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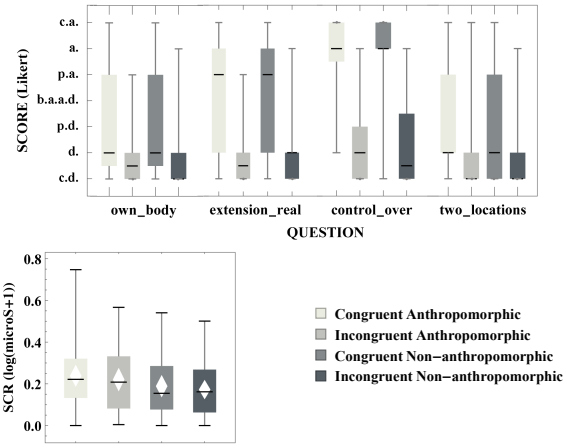

Figure 2: (top) Responses for ownership question *"It felt as if the virtual body was my own body."*, proto self-presence *"...the virtual was an extension of the real body."*, agency *"...I had control over the virtual body."*, self-location *"...my body was at two locations."*. Black lines indicate medians. The Likert ratings are abbreviated: completely disagree, disagree, partially disagree, both agree and disagree, etc. (bottom) SCRs; white diamonds indicate means and their 95% CIs.

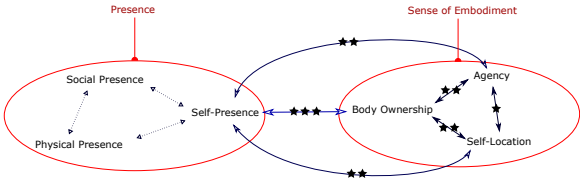

Figure 3: Overview of the relationships between presence and SoE. Solid arrows denote relationships identified in our study (dotted arrows were not), stars denote weak/moderate/strong Mantel Haenszel test results ($\star$: Pearson correlation coefficient <0.3; $\star\star$ 0.3-0.5; $\star\star\star$ >0.5).

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