Avatar Anthropomorphism and Illusion of Body Ownership in VR

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ABSTRACT

In this paper we present a novel experiment to explore the impact of avatar realism on the illusion of virtual body ownership (IVBO) in immersive virtual environments, with full-body avatar embodiment and freedom of movement. We evaluated four distinct avatars (a humanoid robot, a block-man, and both male and female human adult) presenting an increasing level of anthropomorphism in their detailed compositions Our results revealed that each avatar elicited a relatively high level of illusion. However both machine-like and cartoon-like avatars elicited an equivalent IVBO, slightly superior to the human-ones. A realistic human appearance is therefore not a critical top-down factor of IVBO, and could lead to an *Uncanney Valley* effect.

Index Terms: H.5.1 [Information Systems]: Artificial—Augmentedand Virtual Realities

1 INTRODUCTION

The Illusion of *Virtual* Body Ownership (IVBO) builds upon the effect that users feel artificial body parts to be their own. A first-person perspective of the user in an immersive VR setting triggers strong IVBO effects [7], even though the virtual body differs considerably from the real person's body. One's bodily self-perception can be temporarily shifted towards the virtual body of an avatar with a different gender [7], age [1], race [6], body shape [5], longer limbs [4], and even having a different posture [2].

Previous research suggests that such an illusion is the result of an interaction of both bottom-up (synchronous visual, motor and tactile sensory inputs) and top-down (preexisting visual and proprioceptive body representations) factors [9]. However, the influence of one important top-down factor, the virtual body realism in terms of visual human resemblance (or anthropomorphism) has barely been researched. Moreover, previous studies typically presented avatars with strong human appearances, limited freedom of movement (reproducing a certain pattern), and often only partial body tracking. Hence, this research investigates to what degree visual anthropomorphism (visually perceived human resemblance or characteristics) of a virtual body representation is necessary to induce, strengthen or weaken the IVBO.

2 EXPERIMENT

Participants were immersed in a virtual reality game-like scenario, where they were provided with a virtual body, seen in a first-person perspective via a head-mounted display (HMD). The participant's body motion and movement were replicated in real-time to their virtual body, which was co-located and aligned with their real body. The task consisted of a simple game of finding and touching targets (here represented by large spheres) randomly appearing at different places in an exotic forest-like environment (Figure 1). The overall game area represented a volume of 18 m^3 (3 length x 3 width x 2 height meters). During one game round, participants had 2.5 minutes to touch a maximum number of spheres using their virtual body hands or feet. We adopted a $3x2x2$ mixed design with the between-subjects factor being the level of anthropomorphism of the virtual body and the within-factors being the level of virtual threat participants experienced. The between-subjects factor was composed of three conditions represented by four distinct avatars presenting an increasing level of anthropomorphism in their detailed compositions (specific bodys parts shape, scale, dimension, surface topology, texture and color). Each participant experienced either a humanoid machine: a robot, a simplified stylized human: a block-man, or a photo-realistic male or female human adult (depending on the participant's gender). Figure 2 illustrates the different conditions as seen from the user's point of view. The first within-factor had two conditions: the presence of a permanent threat (*F*-condition) or its absence (*NF*-condition). The second within-factor was the presence or absence of a sudden threat (*E*-condition and *NE*-condition). The permanent threat was represented by fire torches while the sudden threat was represented by a sudden final explosion. The following measures were collected in this study:

1. **IVBO Questionnaire**: A post-experimental questionnaire was designed to subjectively measure the IVBO based on [8, 7, 4, 5]. It was composed of 12 closed questions and 3 additional open questions.
2. **Simulation Sickness**: The results of the simulator sickness questionnaire (SSQ) [3] were solely used to sort out participants.
3. **Galvanic Skin Response (GSR)**: The participant's level of stress was evaluated using skin conductance measurements. A higher IVBO should be reflected by a higher level of stress when facing the threats.
4. **Task Performance**: The performance was measured through the number of spheres touched in 2.5 minutes.

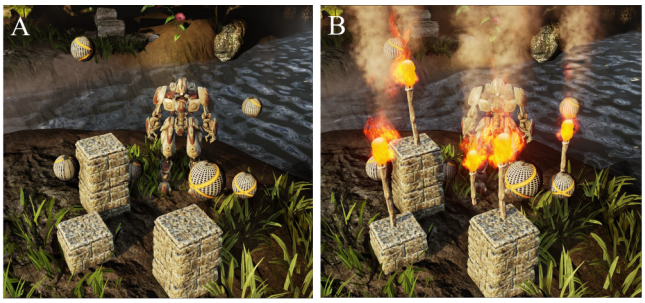

Figure 1: **Task-area with Fire and No-Fire Conditions**. Picture (A) shows the area participants could move in in the *NF*-condition with all possible sphere positions. Picture (B) shows the same area in the *F*- condition

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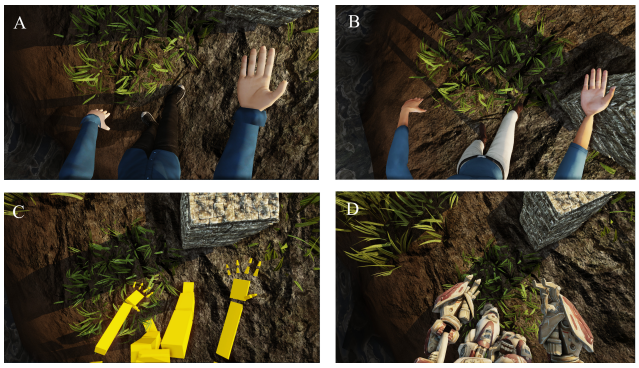

Figure 2: **Avatars from first-person perspective.** Participants saw the virtual avatars from a first person perspective and synchronized with their real body movement in space and time. Each participant experienced either a realistic human body (male (A) or female (B)), or an unrealistic one such as a body made of simple blocks (C), or one made of metal like a robot (D)

Table 1: **Results of the Confidence Interval Equivalence Testing.** Table showing the standard errors of the differences of the means (SE_d) of the three relevant IVBO-questions and the lower (CI_l) and upper (CI_u) bounds of the 90%-confidence intervals for the difference of means for each possible pairing of avatars. *CI*-values that exceed a value of ± 1 (i.e., the maximum difference between means which will be considered as equivalent) are marked with a $*$) where H=Human, R=Robot, B=Block-Man

	myBody			*twoBodies*			*myBodyIntensity*		
	SE_d	CI_l	CI_u	SE_d	CI_l	CI_u	SE_d	CI_l	CI_u
H-R	.204	-.754	-.046	.252	1.26*	2.13*	.230	-.899	-.101
H-B	.158	-.974	-.426	.242	1.58*	2.42*	.253	-.939	-.090
B-R	.206	-.657	.057	.139	.059	.541	.236	-.910	-.090

3 Results & Discussion

A total of 30 participants was involved in this experiment (22 males / 8 females), with an average age of M = 21.60, SD = 2.43. For the reported subjective IVBO, there were no significant differences between all avatars. In fact, the main results presented in table 1 reveal a strong equivalence for the three relevant IVBO-question. However, the *twoBodies*-item is only equivalent for the non-human avatars, with a value significantly lower for the human avatars. In addition, no significant difference in terms of task performance, or skin conductance (stress) was found. Consequently, the avatars seem to have elicited a very similar response in terms of IVBO, independently of their non-human or human appearance. However, the participants with the human-avatar had a significantly stronger feeling of having two bodies during the experiment than participants who had one of the non-human avatars. A strong IVBO would normally mean a weak feeling of having two bodies and vice versa. An *Uncanny Valley*-like effect could explain such higher scores on the *twoBodies*-item for the human avatar. The evaluation of the answers to the open questions provides indications. Participants in the *H*-condition seemed to look a lot more at details of the virtual body such as exact proportions or clothing (*'I felt like the length of my arms was not represented correctly'*). Several participants in the *H*-condition (5 out of 10) pointed out that the avatar had a different hair colour, clothing, was thinner than they actually were or seemed to have longer arms which diminished the illusion for them (*'The body did not bear any resemblance to me (physique, hair colour etc.)'*). For the other two avatars such detailed differences were never reported.

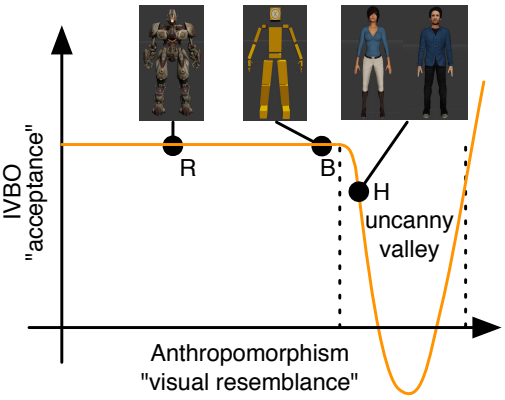

Figure 3: **Results**. The strength of the IVBO in relation to the degree of anthropomorphism of the avatars

4 Conclusion

As illustrated by figure 3, we observed that all avatars elicited a high IVBO with a slight decrease of acceptance towards an avatar with a higher human resemblance possibly indicating an uncanny valley effect with first-person avatars. The elicitation of a sense of embodiment with clearly non-human avatars has both fundamental and practical interests. First it appears possible to convincingly experience alternative body forms in future generations of games. But, more importantly, it also opens novel perspectives to further study the perceptual, psychological and cognitive processes underlying our own sense of body ownership.

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