Toward Understanding the Impact of a Biomimetic Virtual Hand on Behavior and Embodiment in Virtual Reality

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Abstract

Embodied representations are known to impact user behavior in Virtual Reality (VR) through stereotypes associated with their appearance, a phenomenon known as the Proteus effect, or through perceived affordances. This latter concept refers to the interaction possibilities suggested by the environment, as perceived from the capabilities of the user's avatar. VR offers the unique potential of allowing non-anthropomorphic embodiment, enabling new interaction modalities. In this context, we propose to explore the possibilities offered by wildlife inspired avatars. We designed a chimeric avatar providing new interaction possibilities and developed an experiment to assess the effect of embodying a giant crab claw compared to a regular hand on participants' sense of embodiment and behavior when interacting in the virtual environment. This study is a work in progress and will inform designers about the potential of biomimetic avatars to shape user behaviors while supporting embodiment in VR.

1 Introduction and Related Work

Immersive Virtual Environments (IVEs) offer users the possibility to embody a variety of virtual representations also referred to as *avatars*. However, the available choices tend to be oftentimes restricted to anthropomorphic appearances despite social VR application designers and researchers try to investigate new avatar typologies [2]. Previous studies have explored the impact of such virtual representations on user behavior, especially when induced by stereotypes associated with the appearance of embodied avatars, a phenomenon known as the Proteus effect ([6], [15]). Alternatively, avatars may trigger the perception of interaction possibilities allowed by their morphology. This concept was firstly theorized by Gibson [4] as "affordances" and later introduced to the domain of Human-Computer Interactions (HCIs) by Norman [10]. Affordances set a relationship between the perceived properties of the environment and the conscious capabilities of the perceiver, namely the user immersed thanks to Virtual Reality (VR) technologies in our context. As VR theoretically offers an infinity of virtual representations, the potential inherent to bio-inspired avatars provides a way of investigating new affordances. Bio-inspired avatars could indeed suggest new possibilities for interactions to users. However, reshaping users' body may come with impacts on the subjective experience of embodiment. Indeed, VR may induce the emergence of a Sense of Embodiment (SoE), meaning that avatars' properties are "processed as if they were properties of one's own biological body" [7]. The SoE can be broken down into three sub components: the spatial experience of being in the body or *self-location*, the sense of control over the avatar or *agency*, and the self-attribution of the virtual body known as *body ownership*. In such context, altering traditional body schemes could affect the experience of embodiment as anthropomorphism was demonstrated to be a contributor to experiencing body ownership toward the avatar [8]. Conversely, such SoE can still emerge from less anthropomorphic virtual appearances ([1], [3], [13]). It would therefore be interesting to assess the impact of embodying a chimeric avatar with regard to the benefits it could bring to the perception of interaction possibilities [11]. Focusing our approach on the representation of virtual "hands" as the main interaction instrument between users and virtual environment, we aim at answering the following questions: can a

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Fig. 1. Anthropomorphic avatar (left) and biomimetic avatar (right) in the wrecked ship.

biomimetic avatar hand suggest different interaction possibilities from those suggested by an anthropomorphic one? Does an avatar adopting properties from a wildlife animal impact users' embodiment experience?

In this context, we designed a virtual reality experiment aiming at investigating the potential effect of embodying a biomimetic body with a chimeric limb on participants' behavior and sense of embodiment. In this paper, we first present the preliminary online survey we conducted to select the most affordant biomimetic features. We then present the designed experiment aiming at answering the aforementioned research questions and hypotheses. Finally, we conclude on the current progress of this reasearch project.

2 Experiment

2.1 Preliminary Assessment

Our investigation would focus on a well-known wildlife inspired limb and how it could suggest new affordances. We therefore thoroughly compared twelve animal limbs through an online questionnaire based on the interaction they would suggest to users. Participants had to reassociate tools and biomimetic limbs with the features they felt the most relevant, like a saw and a mantis claw or a woodpeaker beak and a wood drill. We then selected the tool and the biomimetic limb that had the most convergent responses, as it indicated strong cultural affordances associated to it. The crab claw was perceived as the most suggestive concerning pinching and punching interactions. We therefore designed a chimeric virtual limb based on the outcomes of the preliminary online assessment (Figure 1).

2.2 Experimental Study

An experimental study was designed to explore the impact of a biomimetic avatar on participants' behavior and sense of embodiment. With this study, we are aiming at manipulating the avatar appearance in order to suggest new affordances. To this end, we will conduct a within-subjects design experiment successively offering participants two different virtual hand representations controlled thanks to the Meta Quest 3 hand tracking capabilities: a gloved human hand and a coconut crab claw (Figure 1). Participants are engaged in an object research task in a wrecked ship taking inspirations from classical fictional stories to fit the participants' potential coherence expectations for both virtual hand representations. Participants are placed in front of several containers set up in a circular shape so that they are equidistant from the room center and reachable. These objects are dived into four categories (Figure 2): fragile amphorae, medium wood box and regular chest and solid metal chest. Participants have to find the key of the ship hull hidden in one of the containers, to do so they are able to either opening the objects by grabbing their handles or breaking the containers by pinching or punching them (Figure 2).

The searched key spawns only after the inspection of ten containers. This particular task enables various interaction possibilities (manipulation or destruction of objects) and navigation in the virtual environment. Participants strategy (opening or breaking containers) will be assessed as an objective measure, as well as the task completion time, participants punching strength (based on engine's physics) and the objects they choose to open or break depending on their perceived solidity. These measures will allow us to investigate any behavioral modifications induced by the avatar independent variable.

In order to assess presence in the virtual space, participants will fill the IGroup Presence Questionnaire (IPQ) [16]. The SoE will be measured through the Virtual Embodiment Questionnaire (VEQ) [12]. Perceived

Fig. 2. Four types of containers from the more fragile (left) to the more robust (right) on the left hand side picture. The right hand side picture displays a broken chest.

plausibility of the avatar will also be assessed using the Virtual Human Plausibility (VHP) Scale [9]. Finally, participants will have to complete questionnaires assessing their perceived task workload (NASA TLX) [5] and system usability (SUS) [14]. All questionnaires will be completed after each counterbalanced exposure, while objectives measures are directly recorded and stored in a local database.

We hypothesize that using of a biomimetic limb crab claw, potentially perceived tougher than the gloved control condition, will originate in a perceived affordance of punching and pinching ability. We also expect that participants with a crab claw will mostly break objects instead of opening them, while demonstrating an equivalent sense of spatial presence.

3 Conclusion

The proposed study aims at investigating the influence of embodying a biomimetic avatar, represented by a crab claw, in an immersive virtual environment to drive users' behavior and perception of interaction possibilities, namely affordances. A preliminary assessment successfully informed the selection of a promising biomimetic limb in the form of a coconut crab claw. The experimental material and protocol have been thoroughly prepared and tested to tackle our research questions. We intend to contribute to the growing body of knowledge regarding the way in which avatar-related affordances can be operationalized through biomimetic limbs while still fostering embodiment and ultimately leverage VR unique capabilities to reshape traditional anthropomorphic representations.

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