Studying "Avatar Transitions" in Augmented Reality: Influence on Sense of Embodiment and Physiological Activity

Riku Otono* NAIST, Japan
Adélaïde Genay† Inria, Bordeaux, France
Monica Perusquía-Hernández‡ NAIST, Japan
Naoya Isoyama§ NAIST, Japan
Hideaki Uchiyama¶ NAIST, Japan
Martin Hachet‖ Inria, Bordeaux, France
Anatole Lécuyer** Inria, Rennes, France
Kiyoshi Kiyokawa†† NAIST, Japan

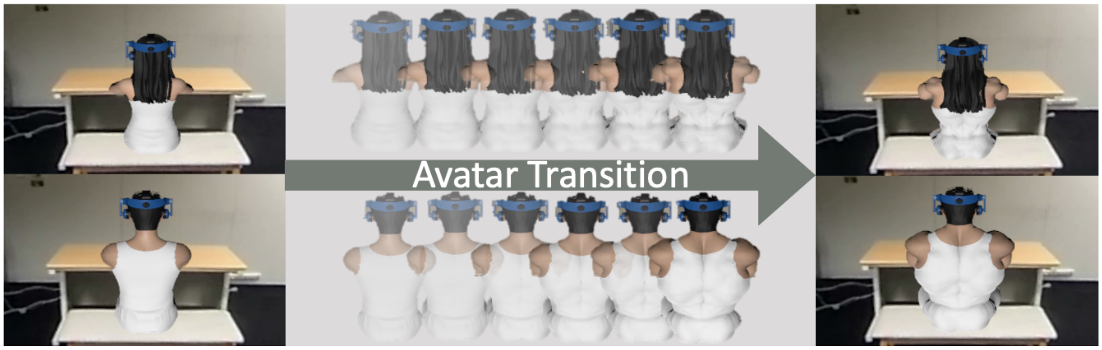

Figure 1: We explored the effects of graphical transitions to embody an avatar. From the upper left to the upper right: female normal body avatar, avatar transition, and muscular body avatar. From the bottom left to the bottom right: a male version of upper avatars.

Abstract

The impact of avatar transitions, in which an avatar's appearance is changed, has been little studied. We implemented an avatar transition system that is decomposed into two parts: an active one and a passive one. In the active transition, the avatar's appearance is transformed according to the user's physical action. In the passive transition, users automatically experience the same transition without physical action. The influence of transitions on the user's physical performance and the sense of embodiment was explored. Our results show that active transitions increase the sense of agency and magnitude of surface electromyography (sEMG) compared to passive transitions, and both transitions increase the sEMG magnitude following the virtual Reality embodiment.

Index Terms: Human-centered computing—Visualization—Visualization techniques—Treemaps; Human-centered computing—Visualization—Visualization design and evaluation methods

1 Introduction

Transition scenes are often used in video games to show the transformation of an avatar's appearance. However, few studies have investigated such transformations in Virtual Reality (VR) or Augmented Reality (AR) where a user embodies the avatar. Therefore, the effect of avatar transitions on the user's sense of embodiment (SoE) is not well known. Only one VR paper has studied transitions between being in one's body and being in one's avatar [2]. They found that such transitions can have positive effects on body ownership illusions. We propose to continue exploring such transitions, but this time to change the appearance of one's avatar while embodying it. We call these transitions "avatar transitions."

To investigate the effects of avatar transitions, we implemented an AR embodiment system letting users transition from a normal avatar to a muscular avatar representing them in a third-person perspective (3PP), (see Fig. 1). We compared two types of avatar transitions by measuring the user's SoE and surface electromyography (sEMG) magnitude using a self-report questionnaire and sEMG sensors. We measured sEMG to see if the change in representation caused an increase in a physiological activity.

The two transition types we tested were: 1) an active transition where the user had to perform an action to trigger a visual transition scene, and 2) a passive transition where this scene was automatically triggered. Our results showed that **1) The active transitions had a positive impact on the sense of agency and the physiological activity when embodied in a muscular avatar**, and **2) Both transitions positively influenced the physiological activity after embodiment**.

2 Methodology

In the active transition, the users were asked to firmly squeeze a pair of dumbbells and then to relax while still holding it repeatedly. While doing this the user's avatar appeared to become more muscular every time they squeezed the dumbbells, (referred to as "visual feedback"). The avatar's muscularity morphed to increase by 20% when the sEMG values exceeded the users' average values, which were measured beforehand. After the users flexed their muscles up to five times, the avatar's body will reach its maximum muscle mass.

In the passive transition, the users could see their avatar's body becoming more muscular without any action on their part: their avatar gained 20% of muscle mass every five seconds and reached its maximum muscle mass after 25 seconds.

Users experience these transitions wearing a head-mounted display (VIVE Pro Eye), in which the AR view is rendered in Unity 2019.3.11f running on Windows 10. A 360 camera (Ricoh Theta V) was used to capture real-time 360 images.

*e-mail: otono.riku.ot6@is.naist.jp
†e-mail: adelaide.genay@inria.fr
‡e-mail: m.perusquia@is.naist.jp
§e-mail: isoyama@is.naist.jp
¶e-mail: hideaki.uchiyama@is.naist.jp
‖e-mail: martin.hachet@inria.fr
**e-mail: Anatole.Lecuyer@inria.fr
††e-mail: kiyo@is.naist.jp

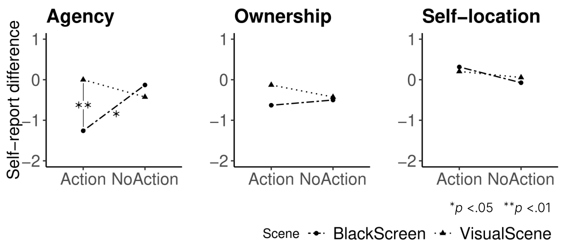

Figure 2: From left to right, the results of the difference of agency, ownership, and self-location between the normal and muscular avatars.

3 Evaluation

27 volunteers (11 females) were recruited (age: M=25.33, SD=3.54). We conducted a within-subjects design (with/without action × with/without visual feedback) and measured the difference between the SoE scores and sEMG from the following conditions.

- **Condition VA**: visual feedback and action. Users observed their avatar's appearance progressively become muscular through their actions.
- **Condition VN**: visual feedback and no action. Users see their avatar's appearance automatically become progressively muscular.
- **Condition BA**: no visual feedback and action. Users try to make their avatar more muscular, but a black screen was displayed until the end of the transformation.
- **Condition BN**: no visual feedback and no action. Users see a black screen without any action until a muscular avatar appears at the end of the transformation.

The order of the conditions was counterbalanced with a Latin-squares design. We evaluated the SoE through six questions on a 7-point Likert scale related to its sub-components (agency, ownership, and self-location) [1]. In each condition, participants answered these questions twice: while embodied in the normal body avatar, and when embodied in the muscular body avatar. We computed scores for the SoE and then obtained the difference between the normal and muscular avatars by averaging the score difference.

To measure sEMG, EMG electrodes were attached on the *extensor carpi ulnaris (ECU)* muscle and on the *Biceps*. The average RMS was calculated as sEMG values per epoch. The sEMG values were measured in each condition (during embodiment in a normal, muscular avatar, and after embodiment). The muscular sEMG values ratio ($EVR_{muscular}$) was calculated by dividing muscular sEMG by normal sEMG. The post-hoc sEMG values ratio (EVR_{post_hoc}) was calculated by dividing the "after" sEMG by the "normal" sEMG.

4 Results

We performed a three-way ANOVA (gender: female vs. male; scene: visual feedback vs. black screen; and action: with action vs. without action) followed by a post-hoc analysis with the Holm-Bonferroni correction for all results. In terms of sense of agency, we observed the interaction effect of the scene and the action ($F(1, 22) = 5.75$, $p < .05$. See Fig. 2). The post-hoc analysis showed a significant difference between VA and BA ($F(1, 23) = 12.34$, $p < .01$) and BA and BN ($F(1, 23) = 7.16$, $p < .05$). This result implies that the active transition improved the sense of agency. We could not find significant differences between the active or passive transitions in terms of ownership and self-location.

The three-way ANOVA also revealed the interaction effect of the scene and the action on the left bicep EVR ($F(1, 22) = 5.77$, $p < .05$. See Fig. 3). Post-hoc analysis showed a significant difference between VA and BA ($F(1, 23) = 8.48$, $p < .01$) and VA and VN ($F(1, 23) = 9.81$, $p < .01$). Regarding the right bicep EVR, the interaction

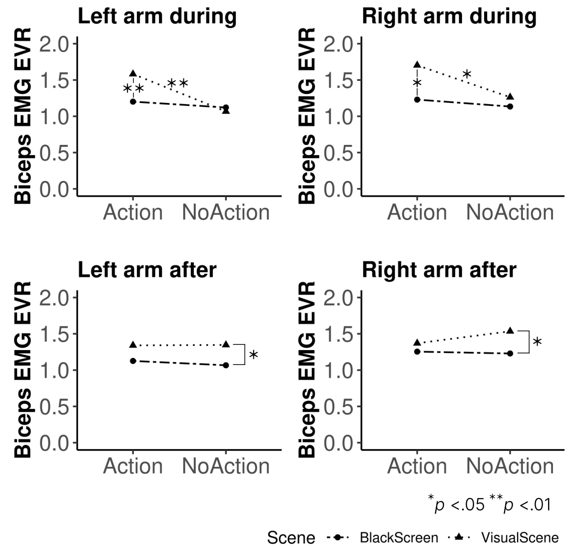

Figure 3: The upper plots depict the $EVR_{muscular}$, showing the active transitions improve the muscular activity during embodiment. The lower plots depict the EVR_{post_hoc}, indicating the visual feedback improves the muscular activity after embodiment.

effect of the scene and the action ($F(1, 22) = 4.70$, $p < .05$). Post-hoc analysis found a significant difference between VA and BA ($F(1, 23) = 7.29$, $p < .05$) and VA and VN ($F(1, 23) = 5.62$, $p < .05$). Therefore, these findings show that active transitions amplify the physiological activity during embodiment in a muscular avatar.

For both the left and right bicep's post-hoc EVR, a significant main effect of the scene was revealed (left bicep: $F(1, 22) = 4.52$, $p < .05$, right bicep: $F(1, 22) = 6.64$, $p < .05$). These results show that the visual feedback (instead of a seeing black screen) improves the physiological activity after embodiment in a muscular avatar even when physical action is not performed while transformation.

5 Conclusions and Future Work

In this research, the impact of avatar transitions in AR was investigated. The implementation includes visual feedback of the changes in the avatar's appearance and triggering this change based on the user's physical activity. Using this system, we found that active transitions positively impacted the sense of agency and the physiological activity during embodiment. Furthermore, both transitions improved the physiological activity after embodiment. Our findings imply that the active transitions help users feel that they are in control of their avatars and feel empowered by the avatar's appearance. In addition, both transitions amplify the Proteus effect of a transformed avatar. This phenomenon could be applied to AR applications such as sports training using a muscular avatar. In the future, we will study avatar transitions using a different appearance avatar.

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