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Strengthening Avatar Embodiment in Virtual Reality: A Pre-Exposure Mental Preparation Approach

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概要: We aim to help users build a stronger sense of embodiment (SoE) toward their virtual reality (VR) avatars. To do so, we designed a mental preparation protocol that involves guided imagery and acting exercises to help participants imagine that they are their avatars before seeing themselves in its body. This article introduces a pilot study that tests our approach with an avatar representing the Hulk, from the Marvel franchise. We hypothesize that this preparation process will help users build a stronger SoE and enhance Proteus Effects. As the pilot study is still underway, the results will be presented and discussed at the conference.

キーワード： Sense of embodiment, Proteus effect, priming effect

1. Introduction

The Proteus Effect is a psychological phenomenon where individuals' behavior and self-perception are altered by the characteristics of their virtual avatars [1]. This effect usually occurs when users experience a sense of embodiment (SoE) toward their avatars and may be exploited to improve their performance in specific tasks. However, there are some situations where avatars are being rejected by their users, even with state-of-the-art Virtual Reality (VR) technology. This difficulty is often explained by the existence of subjective factors, such as personality traits [2]. Depending on the user, they can lead to a propensity to body ownership illusions (BOIs) or to a reluctance to feel embodiment. Therefore, an embodiment system cannot be guaranteed to generate the same experience and effects across users.

While removing subjective factors is impossible, strategies can be elaborated to reduce the variability they cause. We previously explored one of these strategies, using graphical transitions [3]. We found that smoothing the experience of the switch between the real and virtual bodies by applying visual effects improved the SoE.

This article explores another way to enhance the SoE in VR by mentally preparing users ahead of the embodiment. We designed a protocol that involves guided imagery exercise and acting to help participants imagine that they have become their avatar before seeing themselves in its body. We decided to test this protocol on an avatar representing the Hulk (Marvel franchise). We hypothesize that this preparation process will help users build a stronger SoE and reduce individual differences. As the pilot study is still underway, the results will be presented and discussed at the conference.

2. Mental Preparation

Embodiment experiences can be divided into three main phases: pre-embodiment, embodiment, and post-embodiment. In most experiments on the SoE, the stimulation to induce the BOI is typically applied after entering the embodiment phase, once the user can already experience their avatarization. Then, the post-embodiment phase is often used to assess the resilient effects of the avatar on the users or collect additional subjective data. The pre-embodiment phase is rarely exploited: during that time, participants are usually told about their tasks and are confronted with their avatars without further ado. Consequently, users must instantly adapt to their new bodies and learn what they can afford.

To make this change less unsettling, we propose to combine guided imagery and acting exercises over a 10-minute protocol before embodying the avatar. This protocol aims to guide users into imagining they have become their avatars and is meant to be used with avatars that represent specific characters bearing a personality

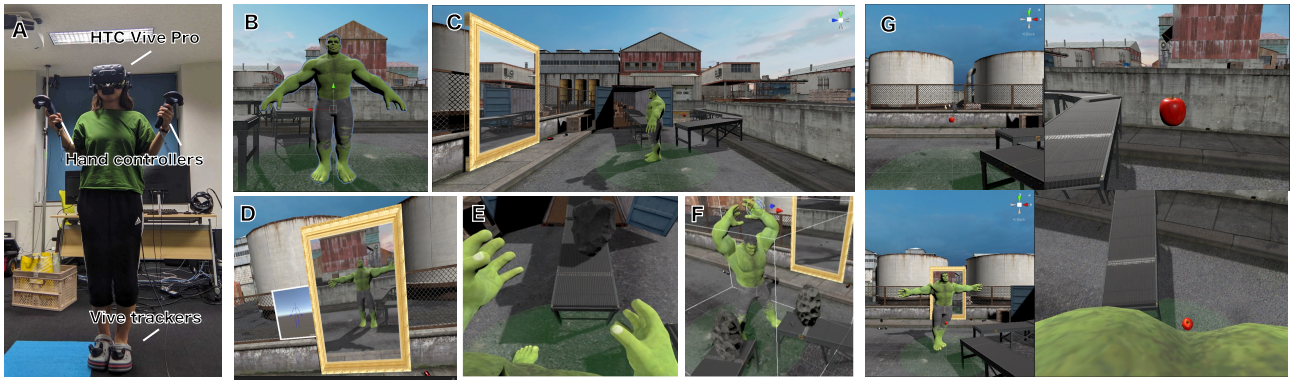

図 1: A) Equipment, B) Hulk avatar, C) VR environment, D) Visuomotor task for SoE induction, E) User perspective, F) Rock crushing task, and G) Apple object used for the grip strength measures. Top and bottom images show the scene and user perspective before and after the embodiment, respectively.

or stereotypes that can be imitated. Therefore, it is not compatible with abstract avatarization forms or with avatars that are not different from the users. Readers should note that the experiment we present does not cover every case but acts as an entry point to investigate how to exploit pre-embodiment time better.

The protocol we propose can be summarized in the following steps:

1. **Explanation**: the user is shown a picture of the avatar and is explained who it is and how it typically behaves. The experimenter checks that the user understood correctly by asking questions, e.g., "How would you describe this character?". Answers are then orally validated or corrected to ensure a baseline knowledge of the avatar's traits.
2. **Guided imagery**: the user actively imagines being the avatar's character. To help them, the experimenter provides instructions on what to imagine visually and emotionally. E.g., "Think of something that made you angry or stressed recently" or "Imagine that your body is growing muscly."
3. **Acting**: the user physically imitates their avatars' character. They also receive instructions to help them perform. For example, "Clench your fists and breath deeply." After going through this step, virtual avatarization is immediately applied.

3. System Overview

We implemented a VR system allowing users to embody the Hulk in the first person to test whether the approach described in Section 2. may effectively reinforce the SoE.

3.1 Apparatus

Figure 1A illustrates the equipment in the experiment. An HTC Vive Pro head-mounted display (HMD) connected to a PC with an NVIDIA GeForce GTX 1060 6GB graphics card, an Intel Core i5-8400 processor, and 32 GB of RAM, is used. The HTC lighthouses are placed in a rectangle-shaped room securing the tracking area of about nine square meters. Participants wear and operate the VR headset, and two hand controllers. Also, two Vive trackers are attached to their feet to perform a 5-point body tracking (see Figure 1A). The experimental software was built on Unity using free assets.

3.2 Avatar

We selected an avatar model representing a character that would not be hard to imitate for non-actors. A character that is familiar to the user and displays a simple behavior would therefore be a plus. Therefore, we used the Hulk from the Marvel franchise (See Figure 1B). The Hulk is characterized by anger and brutality, and the character's image is easily expressed through body language, making it easy to imitate even for those unfamiliar with acting. The model we used was rigged for animation and included detailed body textures. We mapped the action of pressing the hand controllers to animation clips that put the user's fingers into a fist. The rest of the body was entirely animated with body tracking and inverse kinematics (IK).

The calibration of the avatar is done in two stages: (1) adjusting the height of the avatar and the user by the tracking position of the headset; and (2) matching the arm and leg lengths between the avatar and the user using the FinalIK plug-in VRIK calibration scripts. Manual adjustments are quickly made by moving the transforms of the head, hands, and feet target points if they are not perfectly aligned with the user. Lastly, the resulting avatar is scaled back to Hulk's model size (2.5 meters tall).

3.3 Environment

The virtual environment is a realistic industrial area (see Figure 1C). Ambient noise is added to increase im-

mersion (low hum of construction work). To avoid collisions with the real environment, participants can only walk within a restricted area delimited by a green circle on the floor. The environment included life-size objects, such as soda cans, to provide a visual reference for the user to understand their size and the content of the environment. A mirror is placed in front of them to allow them to observe their entire body (see Figure 1D). Two conveyor belts carrying stones for the main task of the experiment are positioned on the right side (see Figures 1E and 1F). When touching or breaking the stones, feedback is incorporated through the sound and vibration of the hand controllers. The intensity of this feedback varies with the intensity of the applied touch.

4. Experiment

This experiment will test the effects of the mental preparation protocol detailed in Section 2. on the BOI of a Hulk avatar and on resulting Proteus Effects. To do so, we compare two conditions in a between-subjects design. These conditions only differ in their pre-embodiment phase as follows:

- **Condition "NO_PREP" (no preparation)** is the control condition. Participants perform dot-connecting tasks on paper for 12 minutes. They are told that their performance is not assessed and that they will embody an avatar representing the Hulk in VR after that (without further details). After completing the task, they embody the Hulk avatar in VR.
- **Condition "PREP"** is the test condition. Instead of the dot-connecting task, participants are explicitly told that their goal is to imagine being Hulk as strongly as possible. They are briefed about the preparation process and the avatar they will embody in VR afterward. Next, they go through the three-step mental preparation process described in Section 2. for about 12 minutes. Finally, the user embodies the Hulk in VR like in condition NO_PREP.

The Hulk embodiment phase in VR that follows each condition is identical and serves to compare the SoE induced by the avatar with and without mental preparation. This phase includes several tasks to stimulate the SoE towards the avatar and allow data collection.

4.1 Measures

To understand the impact of mental preparation during the VR phase, user experience is measured in several ways.

Sense of Embodiment

The SoE towards the avatar is assessed with the revised 16-item questionnaire of Peck and Gonzalez-Franco [4]. The items are adapted to our experiment's context and applied during the VR embodiment.

Proteus Effects

Proteus Effects indicate the success of BOIs. To detect them, we measure the participant's grip strength before and during the embodiment in VR. Stronger grip strengths during the embodiment should indicate the presence of a Proteus Effect. A relative grip strength (RGS) is obtained by measuring the participant's maximum grip strength (MSG) and strength when asked to crush an apple with just enough force. The RGS will be a percentage calculated by dividing the apple-crushing strength by the MGS.

Participants are additionally asked to perform a punching task in VR. Punching speed, hand agitation, and punching posture while crushing rocks are measured by videography and compared across conditions.

Emotional state

Mood may be informative regarding the participant's immersion in the Hulk character, which is expected to be angry and aggressive. Emotional state is measured with the Self-Assessment Manikin (SAM) [5]. This scale evaluates a person's affective state's valence, arousal, and dominance dimensions. We apply it upon the participant's arrival, during the VR embodiment, and after leaving VR.

Simulator sickness

Simulator sickness is controlled as a potential confounding variable by applying the 16-item questionnaire of Kennedy et al. [6].

Post-experiment feedback

Other subjective feedback is obtained through a 7-item custom questionnaire on a 7-point Likert scale. It contains an optional comment box for participants to write open-ended feedback and is applied at the end of each session after VR exposure.

4.2 Procedure

After a brief outline of the experiment's process, participants complete a demographic survey collecting their age, gender, VR experience, weekly video game playing time, participation in acting activities, and understanding of the character image of the Hulk. This information is collected to characterize the tested population and control for potential confounding variables. They are also asked to fill out the SAM scale.

Then, the participant is equipped with the HMD to measure relative grip strength. The participant's maxi-

mum strength is first measured by asking them to grip a dynamometer as firmly as possible. After a one-minute break, participants are shown a virtual apple colocated with the dynamometer, and their strength is measured again while asked to crush the apple with just enough force (see Figure 1G top). Note that they see the virtual environment in life size without any avatar in this phase.

Next, the participant removes the HMD proceeds to the dot-connecting task (NO_PREP) or the mental preparation protocol (PREP), depending on the condition. Once done, the participant wears the trackers and HMD again but are asked to close their eyes while the experimenter launches the software and calibrates their avatars. The VR embodiment phase of the experiment then begins.

Participants are briefly explained how to use their avatar and are asked to face a virtual mirror to perform a visuomotor task, aiming to induce an SoE. This task consists of performing gestures they think the Hulk would do while looking at themselves. We expect that participants who went through the PREP condition will reproduce the gestures from the introductory video they were shown. After accomplishing this, the participant's grip strength is measured again (see Figure 1G bottom) using the same procedure as before the VR embodiment phase. Then, they are asked to face conveyor belts for a punching task: they are asked to destroy 30 rocks by punching at them as they are carried down the conveyor belts, for about 1.5 minutes.

Finally, an interface is displayed within the VR environment, and participants are asked to complete several questionnaires through it (SoE, cybersickness, and SAM) using raycasting. They are then stripped of the VR equipment and complete another SAM and the post-experiment subjective questionnaire.

4.3 Hypotheses

The hypotheses presented in this experiment are:

- **H1** The SoE will be higher in the PREP condition compared to the NO_PREP condition.
- **H2a** MGS will be higher in the PREP condition compared to the NO_PREP condition. We expect it as a result of higher SoE in PREP condition.
- **H2b** RGS will be lower in the PREP condition compared to the NO_PREP condition. We expect it to result from higher SoE in PREP condition so that participants would think a smaller output is enough to crush the apple.
- **H3** Rock crushing performance (e.g., the punching speed) will be higher in the PREP condition compared to the NO_PREP condition.
- **H4** Arousal and valence will be higher in the PREP condition than in the NO_PREP condition.

4.4 Participants

We plan to recruit 40 participants via e-mail on campus. They will be equally divided into two groups corresponding to the two conditions, PREP and NO_PREP. They will be paid 1000 JPY in cash after the experiment. The experiment was approved by a local ethical committee (2022-I-24).

5. Conclusion

In this article, we introduced a pilot study we are conducting to test a mental preparation protocol applied to an avatar representing the Hulk. This protocol aims at reinforcing BOIs of avatars in VR. It involves a guided imagery exercise and an acting activity to help participants imagine that they are their avatars before seeing themselves in its body. We hypothesize that this preparation process will help users to build a stronger SoE, and thereby benefit from more intense Proteus Effects. We hope to present interesting experimental results at the conference and argue future directions.

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