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The Proteus Effect in Augmented Reality: Impact of Avatar Age and User Perspective on Walking Behaviors

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Abstract: The Proteus effect of avatar age in the first-person perspective (FPP) and the third-person perspective (TPP) in augmented reality (AR) was investigated. The Proteus effect is a process that the avatar appearance changes users' attitude and behavior, which has primarily been investigated in virtual reality (VR). We have developed an AR system named Phantact which features a user blurring technique and TPP to induce the Proteus effect in AR. By using Phantact, a user study was conducted with eight participants to validate the hypotheses that 1) intensity of the sense of embodiment in TPP is similar to that in FPP, 2) the Proteus effect is induced in both FPP and TPP, and 3) the Proteus effect is induced longer in TPP than FPP. The experimental results rejected the second and third hypotheses although the first hypothesis was supported. Additionally, it was confirmed that walking smoothness was reduced in TPP compared to FPP.

***Key Words*:** *Embodiment, The Proteus effect, Third-person perspective*

1. Introduction

This paper reports on a user study that investigated the Proteus effect of avatar age for different perspective conditions in augmented reality (AR).

It is known that the appearance of the avatar, usually used in video games and virtual reality (VR), changes user's attitude and behavior. Yee and Bailenson investigated this process and termed it the Proteus effect [1]. They found that changing one's appearance to be more attractive or taller affected how users communicated intimately or confidently with others in VR. In their study, a virtual mirror is presented to enable users to observe their avatar appearance. Since then, the Proteus effect in VR has been intensively studied. On the other hand, the Proteus effect in AR has little been studied due partly to some technical challenges. First, unlike VR, users can see their original body in AR, thus it is difficult for users to feel fully embodied in their avatars. Second, presenting a virtual mirror continuously in AR is disturbing and impractical.

We have implemented an AR system named Phantact [2] to overcome these challenges. In Phantact, a blurring technique is used to obscure the users' original body. Also, in addition to the first-person-perspective (FPP), the third-person-perspective (TPP) can be selected, because TPP is expected to prolong the Proteus effect without a virtual mirror (see Fig.1). Synchronizing avatar motion with the user improves the sense of embodiment in TPP despite that it is not a natural viewing experience [3].

Fig.1: User's view from a third-person perspective in Phantact [2].

Using Phantact, a user study was conducted to validate the following hypotheses:

- Intensity of the sense of embodiment in TPP is

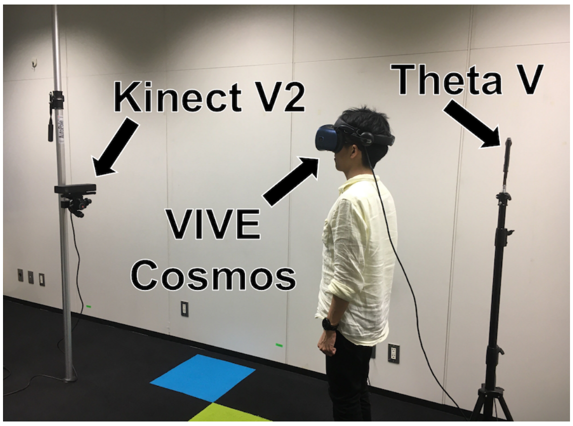

Fig.2: Hardware configurations in the experiment.

similar to that in FPP.

- The Proteus effect is induced in both FPP and TPP.
- The Proteus effect is induced longer in TPP than in FPP.

Corresponding to these hypotheses, the user study compared the sense of embodiment, smoothness of walk-in-place performance, and post-hoc walking time respectively. Through the experiment, it was confirmed that the Proteus effect was not evident, that there is no significant difference between FPP and TPP, and that TPP decreases smoothness of walk-in-place performance compared to FPP.

2. Phantact

2.1 Overview

The prototype system was developed using the Unity game engine (2019.3.11) running on a PC with Windows 10 OS. Both in FPP and TPP, a Ricoh Theta V (1080p) is used to capture a 360 degrees panorama view. The user is equipped with a head mounted display VIVE Cosmos (viewing angle: 110 degrees, refresh rates: 90 Hz, resolution: 2880 × 1700 pixels (1440 × 1700 per eye)). A motion sensor Kinect for Windows v2 is used to capture the user's motion. Also, the user's motion is reflected in the avatar using joint angles obtained by the Kinect. In the following, we explain the details of FPP and TPP in our system.

2.2 First-Person Perspective

The view from FPP is made using a 360 degree panorama image captured by the Ricoh Theta V. The panorama image is taken beforehand from 1.65 meters above the ground at the specified standing position to simulate participants' view. We chose a static image instead of real-time video streaming because it was difficult to overlay an avatar on the user's body precisely.

2.3 Third-Person Perspective

In TPP, we use a real-time video streaming captured by the Richo Theta V. A Camera stand was used to fix the camera while a backpack was used in the original Phantact [2]. Figure 2 illustrates the hardware configurations. The synchronized avatar should be overlaid on the users' body to induce the sense of embodiment in AR from TPP. To realize this, the video is transferred through WebSockets to an additional PC to extract users' body region using BodyPix and bluer the region. Afterwards, the processed video is transferred back to the PC and the synchronized avatar is overlaid on the video background.

3. Experiment

3.1 Hypotheses

In the experiment, we set the following hypotheses, corresponding to the initial hypotheses introduced in Section 1.

H1 There is no significant difference between FPP and TPP conditions in the sense of embodiment measured by the questionnaire.

H2 Smoothness of walking, measured by the jerk cost, is reduced under the elder avatar condition, compared to the young avatar condition.

H3 The walking speed, measured by the walking time, becomes slower after the TPP conditions, compared to FPP conditions.

3.2 Conditions

The experiment followed a 2 × 2 factorial design. The independent variables were the avatar age (young/elder) and the perspectives (FPP/TPP). Therefore, we have the following four conditions:

- A young avatar with FPP
- A young avatar with TPP
- An elder avatar with FPP
- An elder avatar with TPP

All variables were within-subject. 8 participants were recruited (four females, four males) and their age ranged from 22 to 37 (M = 25.75, SD = 4.74). Each participant selected one of the two avatars that were created by using MakeHuman according to their claimed gender (see Fig.3). The participants performed the task under all the conditions in a counterbalanced order based on a Latin-square design.

3.3 Data collection

We measured the sense of embodiment, smoothness of walking, and post-hoc walking time.

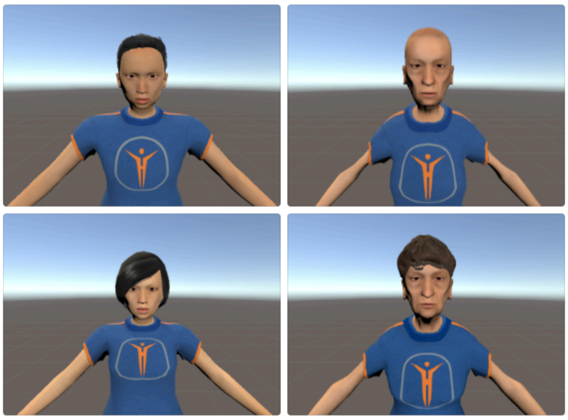

Fig.3: Appearance of the young male avatar (upper left), the elder male avatar (upper right), the young female avatar (lower left) and the elder female avatar (lower right).

Fig.4: Participant's views with the young male avatar in FPP (upper left) and TPP (upper right), and those with the elder male avatar in FPP (lower left) and TPP (lower right).

3.3.1 Sense of embodiment

The questionnaire proposed by [4] was used to measure the sense of embodiment after each condition. This embodiment questionnaire consists of 16 questions with four interrelated sub-scales (Appearance, Response, Ownership, and Multi-Sensory). A 7-point Likert-scale was used in each question and the embodiment score was calculated based on each point of the questions. Although TPP is a different perspective from our natural one, by using the synchronized avatar, the sense of embodiment in TPP was expected to be as high as that in FPP [2].

3.3.2 Smoothness of walking

The jerk cost was calculated to measure the smoothness of walking. The jerk cost refers to the mean square of differentiated values of acceleration, and is used to measure the smoothness of movements (higher jerk cost indicates less smoothness) [5]. In our study, the jerk cost was calculated from the participants' knee positions obtained by the Kinect. Generally, smoothness of walking is reduced for elder people. Accordingly, the jerk cost was expected to be higher with the elder avatar than that with the young avatar.

3.3.3 Post-hoc walking time

In line with the procedure of the experiment in [6], the post-hoc walking time was also measured. The walking distance was set from the task space to the table (five meters) and the walking time was measured using the camera and the background subtraction algorithm. They were not informed that the walking time would be measured to avoid any unwanted bias. Participants could observe their avatar appearance constantly in TPP, therefore, the Proteus effect would be prolonged, in comparison to FPP. As a result, the post-hoc walking time after TPP was expected to be longer than that after FPP.

3.4 Procedure

We first explained our experiment briefly. Next, we guided them to the table where they signed a consent form and filled in a pre-questionnaire about their background (e.g. experience with HMDs). Afterwards, we led them to the task space that is approximately five meters away from the table. The participants put on the HMD and started one of the four conditions in the task space. In each condition, they first watched their self-avatar for one minute reflected in the virtual mirror. Figure 4 illustrates the male version of the participant's views in each condition while seeing the virtual mirror.

Participants could see the moving avatar body synchronized with their own body in either perspective, FPP or TPP. In the second part, we asked them to do walk-in-place for one minute. They took off the HMD after the walking task and went back to the table to fill in the questionnaire.

4. Results

4.1 Sense of embodiment

We treated the resulting scores as non-parametric data and applied the aligned rank transform (ART). We conducted an ANOVA for the transformed data to verify **H1**. The result (see Fig.5(left)) shows, as we expected, there is no significant difference between FPP and TPP ($F(1,28)=0.001$, $p=0.981$). Thus, **H1** is supported.

4.2 Jerk cost

The jerk cost was calculated to test **H2**. The result of a two-way ANOVA (see Fig.5(middle)) shows no significant difference in the jerk cost between young avatars and elder avatars ($F(1,28)=0.606$, $p=0.443$), meaning that the Proteus effect was not evident from this measures. On the other hand, we could confirm a significant difference

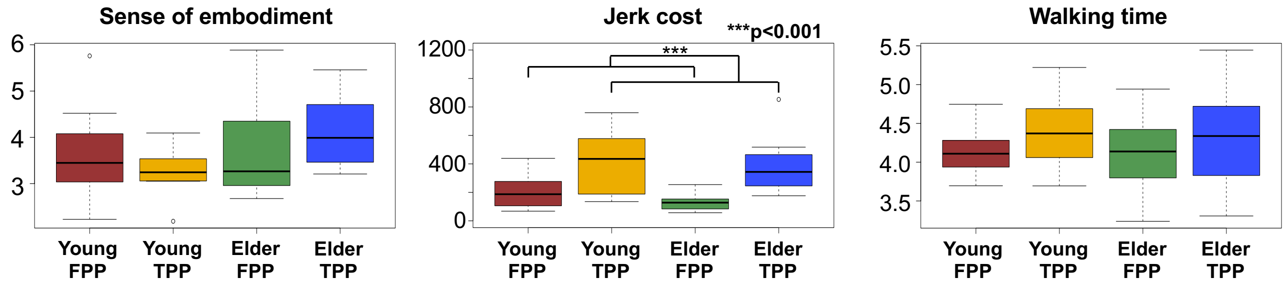

Fig.5: Result of the sense of embodiment (left), jerk cost (middle), and walking time (right).

between perspectives ($F(1,28)=14.606$, $p=0.001$). This result indicates that TPP decreases smoothness of walking. We speculate that the participants were not used to TPP, resulting in lower smoothness of walking. Thus, **H2** is rejected.

4.3 Post-hoc walking time

We used a two-way ANOVA to test H3. Unfortunately, we could not confirm that the Proteus effect remained even after taking off the HMD (see Fig.5). The result shows that the Proteus effect was not confirmed in post-embodiment performance from these measures between avatar age ($F(1,28)=0.080$, $p=0.780$) and perspectives ($F(1,28)=1.569$, $p=0.221$). Thus, **H3** is rejected.

5. Discussion

In the following, we discuss the reasons why **H2** and **H3** were rejected.

5.1 Body tracking

The tracking of some parts of body was not precise, because we only used the Kinect for body tracking. For instance, we got some negative comments related to hand tracking from participants. Consequently, participants might not able to feel enough embodiment to induce the Proteus effect.

5.2 Image processing

Participants could see their blurred own body in TPP. In addition, the motion of the blurred body was slower than that of their avatar, because the communication between two PCs and image processing such as body detection and blurring caused delay. As a result, it is expected that they could not concentrate on their avatar distracted by blurred and delayed their own body.

5.3 Post-hoc walking time

The distance of the post-hoc walking from the task space to the table may have been too short. Due to the limitation of space, we only could set the distance to 5 meters, which is less than the length used by Reinhard et al. [6].

6. Conclusion

In this paper, we investigated the Proteus effect of avatar age for FPP and TPP conditions in AR. We conducted the experiment to verify the hypotheses. The Proteus effect during-embodiment performance and post-embodiment performance was not confirmed from the jerk cost and walking time although it was confirmed that TPP can produce as much sense of embodiment as FPP. We should overcome some technical challenges such as body tracking and image processing to induce the Proteus effect more clearly in AR. Besides, it was confirmed that TPP, compared to FPP, decreases smoothness of walking although the reason is not clear as of this moment. In the future, we would like to conduct follow-up experiments referring to the consideration from this study, and compare FPP and TPP about the persistence of the Proteus effect in more detail.

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