Reducing the Proteus Effect in Virtual Reality: A Mental and Acting Approach*

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Abstract
The Proteus effect in virtual reality (VR) refers to the phenomenon where a user's behavior and perception are influenced by the characteristics of their avatar, often leading to changes aligned with the avatar's stereotypes. While this effect can enhance user experience, it may also result in unintended negative behaviors, such as increased aggression or bias. This study investigates methods to both enhance and mitigate the Proteus effect by introducing a Mental and Acting Protocol prior to avatar embodiment. The protocol consists of three stages: Introduction, Mental Imagery, and Acting. We hypothesized that providing users with information that contradicts the avatar's associated stereotypes would reduce the Proteus effect. A user study with 68 participants tested this hypothesis using avatars of elderly individuals, with walking speed as the primary behavioral measure. Contrary to expectations, the results showed no significant differences in the Proteus effect across the different conditions. These findings contribute to the ongoing discussion on the variability of the Proteus effect in VR and provide guidelines for improving future research on this phenomenon.

Keywords
Virtual Reality, Avatar, Proteus Effect

1. Introduction

Virtual Reality (VR) allows users to immerse themselves in virtual environments and interact through avatars. The Proteus effect is a phenomenon where a user's perception of their avatar influences their behavior and attitudes according to the avatar's associated stereotype, playing an important role in computer-mediated communication [1]. For example, individuals with taller avatars tend to exhibit more assertive negotiation behaviors compared to those with shorter avatars [2].

However, the Proteus effect may lead to unintended behavior. Research suggests that the Proteus effect can reinforce negative stereotypes and biases, leading to more aggressive, racist, or sexist behaviors [3, 4]. Given that the Proteus effect can also have negative consequences, it is crucial to understand how to mitigate these undesired effects. Additionally, instances where the Proteus effect could not be replicated have been reported. For instance, a study on the Proteus effect of game avatar gender on gameplay performance found no significant differences in game performance [5], and experiments on the Proteus effect of muscular avatars showed no significant differences in attitudes [6]. Therefore, we aim to investigate cases when the Proteus effect is enhanced or mitigated and explore methods to address replication concerns.

Previous protocols to enhance the Proteus effect involved Mental and Acting activities that provided prior knowledge about avatars [7]. The Mental and Acting Protocol consists of three stages: introduction, mental imagery, and acting out the avatar. However, this protocol was effective only for those familiar with the avatar before the experiment. As an improvement, we applied a similar protocol to an elder avatar to test its impact on the Proteus effect. Given that most people have some familiarity with elderly individuals, we expected the protocol to be more effective in eliciting the Proteus effect. Furthermore, using avatars of elderly people in VR has been shown to decrease walking speed compared to avatars of younger individuals [8, 9].

We investigate the influence of providing prior information about the avatar on the strength of the Proteus effect to control the extent to which the Proteus effect appears. We propose the following hypotheses:

H0. Users embodied with an elder avatar will walk slower than those embodied in a young avatar. This aligns with common stereotypes and expectations that young avatars would likely be associated with quicker movement than elder avatars, reflecting societal percep-

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tions of age and physical capability.

H1. The stereotype-contradicting (opposite) Mental and Acting Protocol mitigates the Proteus effect of slower walking that appears when using elder avatars. Priming users with a protocol that contradicts age-related stereotypes can mitigate the typical Proteus effect seen with elder avatars, leading to faster walking speeds than young avatars.

H2. The stereotype-consistent Mental and Acting Protocol enhances the Proteus effect. Directly reinforcing stereotypes associated with aging (such as decreased mobility) might amplify the manifestation of those stereotypes, resulting in slower walking speeds.

H3. The stereotype-consistent Mental and Acting Protocol increases the Sense of Embodiment (SoE), while the stereotype-contradicting Mental and Acting Protocol mitigates the SoE. Over-preparation or specific stereotype reinforcement might detach the user from a sense of natural avatar embodiment due to cognitive dissonance or overthinking the role.

Our contributions are outlined as follows:

- An experimental protocol to study the impact of the Mental and Acting Protocol on mitigating the Proteus effect.
- A description of the lack of influence of the Mental and Acting Protocol on the Proteus effect. Non-significant differences showed the following effect sizes: Young avatar condition $d = 0.415$, Elder avatar condition $d = 0.0277$, Elder avatar with the stereotype-consistent Mental and Acting Protocol condition $d = 0.549$, and for the Elder avatar with the stereotype-contradicting Mental and Acting Protocol condition $d = 0.776$.
- Recommendations for conducting user studies on the effect of the Mental and Acting Protocol on the Proteus effect.

2. Related Work

2.1. Proteus Effect

Avatars can impact user behavior and perception through what is termed the Proteus effect, where users align their identity and behavior with the stereotypes linked to their avatars' appearance [2]. A meta-analysis identified replications of the Proteus effect using various avatars and contexts [10]. These studies categorized avatars into two main groups: 1) bodily features, which encompass traits such as gender, race, or attractiveness, and 2) characters, which include the reference or use of famous individuals, uniforms, or even non-human figures Table 1.

These experiments have shown that the Proteus effect may influence psychological aspects such as users' cognitive abilities, emotional states, motor behavior, physiological responses, self-concept, and creativity [10]. Other factors, such as self-esteem and the illusion of embodiment, can modulate the Proteus effect in exergames featuring celebrity avatars [11]. An experiment using the avatar of the famous celebrity Kim Kardashian, known for her narcissistic behavior and materialistic purchases, showed that individuals might only adopt the desirable aspects of the avatars they embody while distancing themselves from the undesirable aspects [12].

It has also been shown that the average effect size of the Proteus effect is small to moderate [13, 14]. In contrast, the Proteus effect of avatars with negative connotations, such as the black cloaks and dressing gowns of Ku Klux Klan (KKK), a secret society of white supremacy in the USA, unconsciously teaches users negative beliefs, leading to antisocial intentions and aggressive thinking [10]. These negative aspects highlight the necessity of finding ways to not only enhance the Proteus effect but also alleviate it.

2.2. Mitigating the Proteus Effect

Mental imagery exercises have been shown to guide imagination, promote perspective-taking abilities, and contribute to empathy-related skills [38]. Engaging in just ten minutes of mindfulness can significantly reduce biases towards different social groups, enhance empathy, and potentially improve SoE [39, 40]. Additionally, acting activities can serve as effective methods for promoting perspective-taking abilities [41]. Role-playing techniques have been found useful in therapy and conflict resolution [42].

A previous study proposed the Mental and Acting Protocol for acting and mental imagery [7]. It was hypothesized that providing prior knowledge about the avatar would improve the SoE and the Proteus effect compared to not providing prior knowledge. This protocol was

Table 1
Summary of the Proteus Effect

Classification	Typical examples of avatar
Bodily Features	Gender[15, 16, 17, 5] Height[2, 18] Attractiveness [19, 20] Age [21] Ethnicity [22] Weight [23, 24, 25] Other [26, 27, 28]
Characters	Famous Individuals [29, 30] Uniforms and Roles [31, 32, 33, 34] Non-Human Figures [35, 36, 37]

tested using the Hulk avatar from the Marvel series. Questionnaires were used to evaluate SoE, and punch speed, emotional state, and grip strength when destroying objects were measured as indicators of the Proteus effect. However, the protocol only enhanced the Proteus effect for participants familiar with the avatar before the experiment.

Given these findings, it is promising that by employing methods such as mental imagery and role-playing, we can effectively negate the stereotypes typically reinforced by the Proteus effect. These approaches are specifically used in our study to counteract the negative stereotypes associated with avatar characteristics, aiming to reduce biases and enhance empathy among users.

3. Methods

3.1. Mental and Acting Protocol

This protocol combines mental imagery and acting for approximately ten minutes, and aids users in immersing themselves in their avatars. We modified the original Mental and Acting Protocol to make it either consistent or contradicting to the stereotype, depending on the desired effect of enhancing or diminishing the Proteus effect.

In the stereotype-consistent version of the protocol, scenarios were created to instruct participants about declining motor abilities. Conversely, scenarios were designed to instruct participants about superior motor abilities in the stereotype-contradicting version of the protocol. In both cases, we used the following three stages:

1. **Introduction**: Participants are introduced to their avatars through detailed images and videos, illustrating their identity and inherent behavioral characteristics. These visual materials include representations of the avatar's physical and behavioral traits, aiming to modify participants' perceptions to either align with or counter the stereotypes typically associated with elderly individuals. For those in the stereotype-consistent protocol, videos showcased characteristics such as difficulty in moving one's body and elderly individuals walking with canes, emphasizing traditional stereotypes of aging, such as slower physical movements and dependence. Conversely, the stereotype-contradicting protocol offered videos featuring top elderly athletes exhibiting powerful, enthusiastic behaviors and exceptional motor skills, representing counter-stereotypical traits such as vitality and active lifestyles. These videos were sourced from free platforms like YouTube [43] and Japan Broadcasting Corporation [44], ensuring a broad representation of the traits described. One is a video of a 102-year-old man participating in track and field events, such as the javelin and shot put, and the other is a video released by the Japan Broadcasting Corporation, a Japanese television station, showing elderly Japanese people.
2. **Mental Imagery**: Participants engage in a guided mental imagery session designed to deepen their connection with their avatars. They are directed through an audio guide to envision themselves embodying the avatar, imagining nine scenarios that depict various aspects of a day in the life of an elderly person, such as "Having breakfast with the help of a caregiver" for those in the stereotype-consistent preparation group, or "Playing soccer with grandchildren, dribbling energetically and scoring goals" for those in the stereotype-contradicting group. Each scenario has an audio description and a 20-second imagination period, repeated twice to reinforce the imagery. Depending on their experimental group, participants either envision themselves with diminished capabilities that align with common age-related stereotypes or with enhanced abilities that challenge these stereotypes.
3. **Acting**: Brief audio instructions lead participants to perform five actions. For those in the stereotype-consistent group, these actions might include scenarios like "Climbing stairs, expressing the struggle but eventually reaching the top," which simulate the challenges of aging, such as moving slowly or with difficulty. Conversely, for participants in the stereotype-contradicting group, the actions involve vigorous activities like "Engaging in exercise with energy and vigor," representing tasks not typically associated with elderly avatars, such as jogging or dancing. Each action is accompanied by a 30-second acting period to deepen the embodiment experience, reinforcing the intended perception of the avatar's capabilities or limitations.

3.2. System

An HTC Vive Pro connected to a high-performance PC configuration was employed for our setup. This PC featured an NVIDIA GeForce RTX 2080 Ti graphics card, an Intel Core i9-9900K processor, and 32 GB of RAM. We positioned HTC lighthouses within a room (Room B in Figure 1) measuring approximately two square meters at opposing corners to facilitate tracking and immersion.

Participants were outfitted with the VR headset, two hand controllers, and two Vive trackers attached to their feet, enabling 5-point body tracking. The experimen-

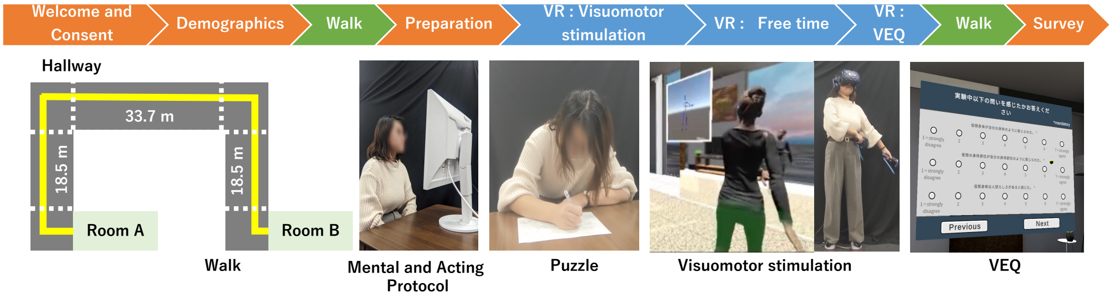


Figure 1: The experimental procedure outlines key steps, including participant preparation, VR immersion, and data collection for walking speed and Sense of Embodiment (SoE).

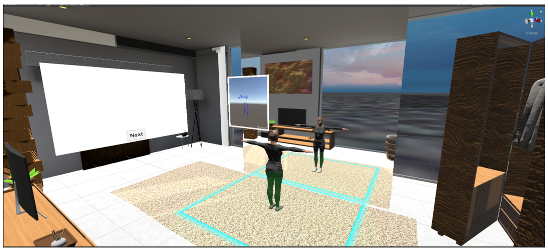


Figure 2: The virtual environment, including room layout, mirror placement, and key interactive elements, is designed to facilitate participant interaction with avatars during VR sessions.

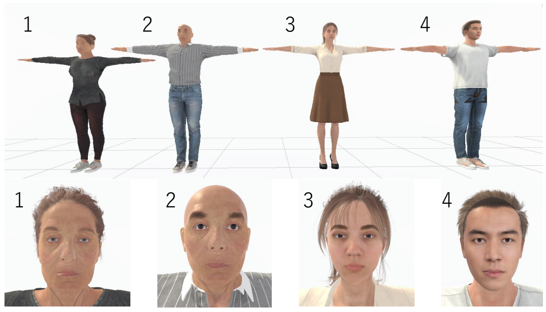


Figure 3: Four avatars are used in the study, showcasing elder and young versions in both male and female forms to examine the Proteus effect.

tal software was developed using Unity 2020.1.4f1, integrating SteamVR and the FinalIK v2.1 plugin created by Pärtel Lang. Additionally, a C# script was employed to capture the motion of the hand controllers. To present questionnaire material within the VR environment and record user responses, we leveraged the VR Questionnaire Toolkit [45].

The VR environment was constructed using free room assets (See Figure 2). A mirror was placed in front of the user to observe his or her reflection in the virtual environment.

3.3. Avatar stimuli

Four types of avatars were created using Character Creator4: elder avatars in their 80s in male and female versions, and young avatars in their 30s in male and female versions (see Figure 3).

Preliminary checks were conducted to determine whether there was a difference in the perceived age of the elder avatars and the young avatars created. Fifteen people (five males, ten females), different from the participants in the main experiment, were asked to guess the ages of four types of avatars in a within-subjects experiment. Shapiro-Wilk tests showed that the residuals were not normally distributed for Agency ($W = 0.839, p = 3.72 \times 10^{-4}$) and between female elderly and female young avatars ($W = 0.866, p = 1.40 \times 10^{-3}$). Wilcoxon rank sum tests were conducted to check the difference in the perceived age for each gender representation. The results of the pilot study showed significant differences between male elder and male young avatars ($W = 225, p = 1.37 \times 10^{-6}, \eta^2 = 0.886$) and between female elder and female young avatars ($W = 222, p = 4.02 \times 10^{-6}, \eta^2 = 0.846$), confirming that they are avatars of different generations (See Figure 4).

3.4. Calibration and Animation

The avatar movements underwent a two-step calibration process. First, the user was instructed to stand upright while wearing the VR equipment so that the experimenter could scale their avatar's height using the headset's tracked position. Subsequently, the VRIK Calibration script from the FinalIK plugin was used to calibrate arm and leg lengths and to position the user's

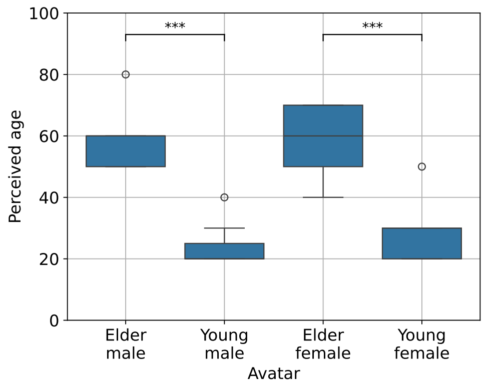


Figure 4: Results from the pilot study demonstrate significant differences in perceived age between elder and young avatars, confirming generational distinctions.

camera. Complementary adjustments were executed by manipulating the transforms of the target points associated with the head, hands, and feet, if necessary. Finally, the avatar's height was set to match the average height of Japanese individuals, 170 cm for men and 157 cm for women.

3.5. Measures

- **Virtual Embodiment Questionnaire (VEQ)**: The VEQ is a 12-item questionnaire developed by Roth and Latoschik [46]. We used the Japanese translated version published by Roth, one of the authors [47]. The questionnaire provides a reliable and consistent way to assess the components of virtual embodiment, which are considered influencing factors of the Proteus effect [48, 49, 50, 21, 19]. The questionnaire was administered while in VR.
- **Custom Questionnaire**: Supplementary data were collected through a 7-item custom questionnaire on a 7-point Likert scale. It included a measure of the avatar's age perception. This questionnaire also included an optional comment section, allowing participants to provide open-ended feedback. It was administered after the session, outside of the virtual environment. The following is the detailed content.
  - Do you feel that you are more athletic now than you usually are? Or do you feel like you are declining? 1:Feeling diminished, 7:Feeling superior
  - Compared to your own motor skills before the experiment, how much do you expect your motor skills to have changed now? 1:Decline diminished, 7:Improvement.
  - How do you feel the avatar you used affected your walking speed? Open-ended.
  - How good did the avatars you used look? Multiple-choice: under 10, teens, 20s, 30s, 40s, 50s, 60s, 70s, and 80s above.
  - Please describe any comments you have. Open-ended.
- **Walking speed**: To detect the Proteus Effect, we measured the 3D positions of the participants' feet before and after the VR embodiment. The participants' feet positions were recorded at a sampling rate of 30 Hz using mocopi sensors from Sony. Measurements were initially taken over a distance of 24 meters, as done in previous studies [21]. However, to ensure more consistent speed measurements across conditions and to better highlight the differences between them, we focused on the longest straight segment of 18.5 m. Walking speed was measured by asking participants to walk through a corridor to another room (see Figure 1(left)). The participant was unaware that walking speed was being measured. We calculated the walking speed by dividing the distance moved by the time taken to move in meters per second.
- **Demographic information**: We collected demographic information such as age, gender, prior exposure to VR technologies, and weekly video game playtime.

3.6. Participants

We calculated the required total sample size assuming an alpha error probability of 0.05 and a desired test power of 0.8, given an expected effect size of ($\eta^2 = 0.25$). The computed necessary sample size to achieve the desired power was 116 participants. However, recruiting that number in the time constraints we had was unrealistic, so we referred to previous research to determine the number of participants for each condition [7]. Sixty-eight volunteers aged 18 to 63 ($\overline{m} = 26.9, SD = 9.49$) participated in the study. Each participant took part in a different condition, with each condition including ten male and seven female participants. Among these participants, 42.6% had used a VR headset once or twice, 14.7% used it several times a year, 1.5% used it frequently but not anymore, 32.4% had never used it, and 8.8% had frequent experience with a VR headset. Participants were recruited through the laboratory's social media networks and a dedicated recruitment website [51] and were paid 1000 JPY in cash. All participants were unaware of the experiment's objective and were randomly assigned to one of the four conditions. This experiment was conducted with the approval of the local ethics committee.

3.7. Experiment Conditions

The experiment employed a between-subjects design with four conditions to explore the Proteus effect:

- **Condition Y (Young avatar with puzzle)**: Participants embodied a young avatar and completed a neutral puzzle-solving task before the VR experience.
- **Condition E (Elder avatar with puzzle)**: Participants embodied an elder avatar and, like Condition Y, completed a puzzle-solving task prior to the VR experience.
- **Condition EC (Elder avatar with the stereotype-consistent protocol)**: Participants embodied an elder avatar and underwent a Mental and Acting Protocol reinforcing age-related stereotypes before the VR session.
- **Condition EO (Elder avatar with the stereotype-contradicting protocol)**: Participants embodied an elder avatar and completed a Mental and Acting Protocol that introduced information contradicting age-related stereotypes before the VR session.

The puzzle-solving task in Conditions Y and E served as a control activity, ensuring consistency in the duration of the experimental procedure across all conditions.

4. Procedure

The procedure is summarized in Figure 1. In the beginning, participants gathered in front of Room B and were guided along a walking path to Room A. The experimenter followed them from behind. Upon arrival, participants received an explanation of the experimental procedure and provided consent to participate. Subsequently, participants completed a demographic questionnaire.

Next, mocopi motion tracking sensors from Sony were attached to the participants' heads, wrists, ankles, and waist for gait measurement, followed by calibration. The purpose of the mocopi sensors was not disclosed to the participants; they were simply informed that they would need to wear the device throughout the entire experiment. After the sensors were fitted, participants were instructed to walk back to Room B, following the same path as before, without guidance. This step was taken to measure their normal walking speed before embodiment.

During the preparation phase, the experimenter left Room B and the participant completed the task alone to minimize external influences and distractions. For the rest of the time, the experiment was conducted with the experimenter present with the participants.

In Room B, without a VR headset, participants performed one of the following four preparation tasks:

- **Conditions Y, E**: Participants sat in a chair and engaged in solving puzzles for 12 minutes. Participants then started the VR experience without prior Mental and Acting Protocol about the avatars.
- **Condition EC**: Participants received Mental and Acting Protocol following the stereotype for 12 minutes via video instructions.
- **Condition EO**: Participants received Mental and Acting Protocol contrary to the stereotype for 12 minutes via video instructions.

The experimenter returned to the room at the end of the task. Then, for all conditions, the participants were immersed in VR and performed the same visuomotor stimulation Figure 1. During this time, the experimenter remained in the same room with the participants, ensuring safety but facing away from them. Participants were then asked to look at a virtual mirror and reproduce gestures depicted in videos placed beside it. These gestures involved simple arm and leg movements to induce visuomotor stimulation, such as raising arms or lifting legs, and were repeated for two minutes. After this induction phase, participants were instructed to spend the remaining time freely. This free time was provided to ensure participants had ample time to experience the avatar, and the VR experience duration, including the induction phase, was set to ten minutes. Finally, participants responded to the VEQ using the questionnaire interface within the VR environment. Participants selected responses using an activated handrail. The experimenter stopped the experimental software and removed the VR equipment from the participants.

Afterward, calibration of the mocopi sensors was performed again for gait measurement. Participants were then instructed to return to Room A independently, following the path they took to Room B. Upon arrival, participants removed the mocopi sensors and were asked to respond to a post-experiment questionnaire.

5. Analysis and Results

5.1. Proteus Effect

We extracted the straight 18.5m section immediately after exiting Room B from the measured 3D feet positions (see Figure 1) and calculated the walking speed. The mid-point of both feet is used as the user's position. To account for the persistence of the Proteus effect, a straight line was measured immediately after exit [21]. As a result of excluding participants with incomplete measurements, one subject was excluded from the E condition.

We conducted a two-factor analysis with four experimental conditions (Y, E, EC, and EO) and two measurement timings at which walking speed was mea-

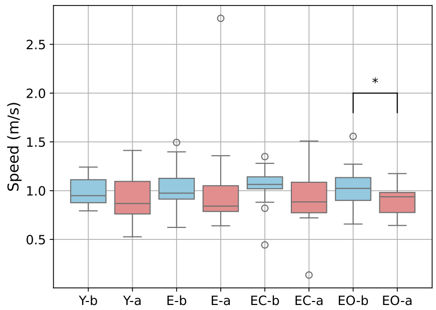


Figure 5: Walking speed measurements before and after VR exposure across four experimental conditions. "-b" and "-a" denote the walking speed before and after VR exposure, respectively.

sured (before and after VR exposure) as independent variables and walking speed as a dependent variable (see Figure 5). A Shapiro-Wilk test confirmed that the residuals significantly deviated from the normal distribution ($W = 0.842, p < 1.17 \times 10^{-10}$). Therefore, we used an aligned rank transform (ART) ANOVA. This test found a significant effect of the two measurement timings at which walking speed was measured, $F(1, 126) = 14.2, p = 2.47 \times 10^{-4}, \eta_p^2 = 0.101$. On the other hand, the main effect of the four conditions of the experiment was not confirmed, $F(3, 126) = 0.383, p = 0.765, \eta_p^2 = 9.04 \times 10^{-3}$. No significant interaction between the timing at which walking speed was measured and the four conditions of the experiment was found, $F(3, 126) = 0.882, p = 0.882, \eta_p^2 = 5.23 \times 10^{-3}$.

Since the Proteus effect was not observed in the E and EC conditions, the fundamental premise for hypothesis verification has been undermined. Thus, **H0**, **H1**, and **H2** were not confirmed.

5.2. Sense of Embodiment

The VEQ questionnaire responses were used to calculate three distinct scores: Ownership, Agency, and Change [46] (see Figure 6). Shapiro-Wilk tests showed that the residuals were not normally distributed for Agency ($W = 0.927, p = 6.92 \times 10^{-4}$), while they were for Ownership ($W = 0.978, p = 0.283$) and Change ($W = 0.977, p = 0.249$). Levene's tests showed that the variances are homogeneous ($p > 0.05$ for all dimensions). Ownership and Change were analyzed using ANOVA, while Agency, which did not meet the assumption of normality, was analyzed using ART ANOVA. However, no significant differences were found in the main effects or in the interaction of any of the three scores. The main effect of Ownership was insignificant ($F(3, 64) = 0.102, p = 0.958, \eta^2 = 4.77 \times 10^{-3}$). The main effect of Agency was insignificant ($F(3, 64) = 0.722, p = 0.542, \eta^2 = 3.27 \times 10^{-2}$). The main effect of Change was insignificant ($F(3, 64) = 1.22, p = 0.311, \eta^2 = 5.39 \times 10^{-2}$). Thus, **H3** could not be confirmed.

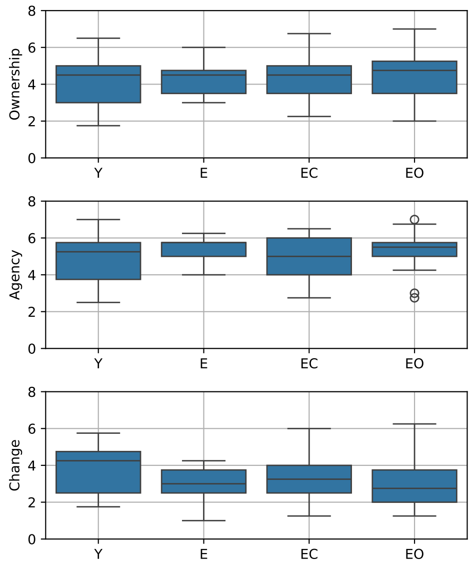


Figure 6: Results of the Virtual Embodiment Questionnaire (VEQ).

6. Discussion

In comparing the walking speed before and after VR exposure for each condition, the Proteus effect did not appear, and the assumptions were violated. Additionally, no significant differences were observed in SoE. In this section, we discuss the reasons why no significant results were obtained and offer guidelines for future studies.

6.1. Age Perception

We conducted further analyses to understand why the Proteus effect was not observed. We examined how participants perceived the age of their avatars. Data on perceived age was collected via a questionnaire at the end of the experiment. Given the subjective feedback, this perception might have varied among participants. The perceived age of the avatar was gathered through a post-experiment questionnaire. Figures 7 and 8 show the relationship between the perceived age of their avatars and their relative change in walking speed before and after VR exposure.

A regression slope test was performed on the change

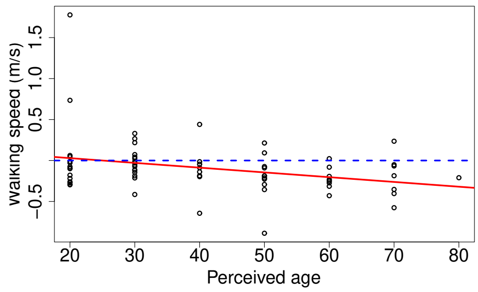
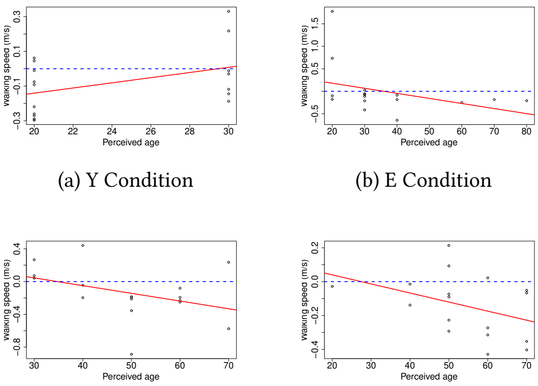


Figure 7: Scatterplot showing the relative change in walking speed before and after VR exposure concerning perceived age, irrespective of the four experimental conditions.



(a) Y Condition (b) E Condition

(c) EC Condition (d) EO Condition

Figure 8: Scatterplot showing the relative change in walking speed before and after VR exposure concerning perceived age in each of the four experimental conditions.

in walking speed before and after VR exposure and the perceived age based on the avatar's appearance. A significant difference in the slope was observed across all data (Figure 7), indicating a negative correlation ($p = 1.24 \times 10^{-2}, \delta = 0.633$). These results suggest that the perceived age did indeed affect walking speed. However, no significant difference in the slope was found in each of the four conditions (Figure 8). The results for the Y, E, EC and EO conditions are ($p = 0.09, \delta = 0.913$), ($p = 0.158, \delta = 0.771$), ($p = 0.121, \delta = 0.821$), and ($p = 0.122, \delta = 0.820$), respectively. Sample size based on a power analysis was 116 participants. After considering the feasibility of recruiting participants and previous studies, data was collected from 68 participants in this experiment. The lack of significant differences may be due to the small sample size (16 or 17 participants per condition).

As to why the Proteus effect did not appear during the experiment, the age of the avatars used may not have appeared as intended. According to post-hoc interviews on the perceived age of avatars, the average age of the elder female and male avatars appeared 6.48 and 14 years younger in VR than the average age in the pilot study, respectively. On the other hand, the average age of the young female and male avatars appeared only 3.81 and 1.67 years younger in VR than the average age in the pilot study, respectively. Thus, the appearance of the avatars may have differed significantly between the monitor and the VR HMD, potentially affecting the perceived age. This possibility was difficult to predict in advance. Note that, however, the pilot study used a within-subjects design, while the main experiment employed a between-subjects design, which prevented direct comparison through statistical tests.

Additionally, the cross-race effect, which is the tendency to more easily recognize faces of one's own racial group [52], may have influenced age recognition in this study. The avatars, while created to look as Asian as possible, were based on European-looking assets, which may have impacted their perceived age.

Avatars appearing younger than 70 years old in VR likely contributed to the insignificant results of the Proteus effect. Studies on the relationship between age and walking speed indicate that it decreases after the age of 70 [53]. This effect may have been further influenced by Japan's longer life expectancy. In Japan, studies show no reduction in walking speed even at 70 years old [54], and this higher life expectancy compared to other countries may shape perceptions of elderly individuals as relatively active. Previous studies on the Proteus effect using elderly avatars have targeted European and American participants [8, 9]. This suggests that cultural differences in perceptions of elderly capabilities between Japan and Western countries could have influenced the manifestation of the Proteus effect.

6.2. Experimental Procedure

In the Mental and Acting Protocol scenario, the term "elderly" was mentioned for avatars in the EC and EO conditions. In the EO condition, elements contradicting to the stereotype were explained after mentioning this. While the participants in the EO condition were expected to walk faster, they actually walked slower after VR exposure (Figure 5). Perhaps the participants in the EO condition were more conscious about the contrast between the young and the elderly, which may have caused cognitive dissonance. Cognitive dissonance is the phenomenon of attempting to eliminate discomfort or anxiety when contradictory information or feelings exist within oneself by justifying or glossing over one or the other [55]. Under the EO conditions, participants used avatars perceived as "elderly" while introducing elements that contradicted the stereotype (e.g., youthful features). This contrast may have caused cognitive dissonance and discomfort, leading participants to act unconsciously by slowing down their walking speed.

The fact that the experimenter followed the participants during walking speed measurement and that the measurement was conducted after removing the HMD may have also influenced the walking speed. We have no precise models of how the Proteus effect evolves after VR exposure, so the timing and method of measuring walking speed might not have been optimal.

6.3. Guidelines for the Future Studies

This study offers insights into the influence of avatar age perception, the measurement environment, and cultural background on the Proteus effect. Incorporating the following guidelines into future studies can significantly enhance the quality and impact of research on the Proteus effect in virtual reality.

1. **Detailed Assessment of Avatar Perception**
   Conduct detailed surveys before and after experiments to accurately capture variations in participant perception of avatar age, ensuring nuanced understanding and reliable conclusions.
2. **Considering the Visual Medium**
   Evaluate avatars using the same hardware for both pilot and main studies to ensure consistency in avatar representation across different viewing mediums and to address potential biases. For example, a pilot study involving an avatar viewed on a desktop monitor may yield significantly different results compared to a main study using a VR headset.
3. **Improvement of Measurement Environment**
   Maximize control over experimental environments, ensuring participants perform tasks independently to minimize experimenter influence.
4. **Cultural Considerations in Research**
   Assess differences in perceptions of elderly activity levels between cultures to understand cultural impacts on the Proteus effect, broadening the applicability of findings. As the perception of elderly avatars used in this study differs between Japan and Western countries, cultural differences may influence the manifestation of the Proteus effect.
5. **Optimizing Data Collection Timing**
   Develop models to understand how the Proteus effect evolves post-VR exposure for optimal timing of data collection, enhancing measurement precision.
6. **Longitudinal and Detailed Evaluations**
   Conduct detailed evaluations on how perceived avatar age influences behaviors and follow up long-term to assess persistence of effects, deepening understanding of VR's impact on behavior.

7. Conclusion

This paper investigated methods to enhance and reduce the Proteus effect by employing the Mental and Acting Protocol. Our study compared walking speed and Sense of Embodiment (SoE) across three conditions: the Elderly avatar (E) condition, the Elderly avatar with stereotype-contradicting Mental and Acting Protocol (EO) condition, and the Elderly avatar with stereotype-consistent Mental and Acting Protocol (EC) condition. The results did not demonstrate significant differences, suggesting that the method of providing prior knowledge may not substantially impact the Proteus effect or the Sense of Embodiment.

Additionally, our research has provided insights into factors that must be considered when designing and conducting experiments in this field. While this study did not succeed in developing effective methods to counteract the Proteus effect, it underscored the importance of considering various experimental aspects, such as the precise setup of the avatar appearance and the careful monitoring of participants' interactions with their avatars. These insights pave the way for future research to propose innovative solutions to the challenges posed by the Proteus effect. It is necessary that subsequent studies build upon these findings, employing refined methodologies and expanded theoretical frameworks. By doing so, we can enhance the understanding of avatar-mediated experiences in virtual reality and possibly develop more effective strategies to manage the Proteus effect.

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A. Mental and Acting Protocol Instructions

The following instructions (translated from Japanese) were used to deliver the Mental and Acting Protocol. The participants were briefed about the process before going through it. All procedures were carried out by video. To alleviate embarrassment, the experimenter left the room, and the participants proceeded with the procedure themselves.

A.1. Consistent Mental and Acting Protocol

A.1.1. Introduction

This script was delivered to participants:

The experimenter showed pictures of the avatar model.

"This is what you look like in VR. You are physically disabled. The following video introduces such an elderly person. "

An excerpt of the following video was shown:
https://www2.nhk.or.jp/archives/movies
/?id=D0002160910_00000

A.1.2. Mental imagery

This script was delivered to participants: *"Your appearance is that of an elderly person. Wrinkles and sagging whitened hair are noticeable. And you have a slight limp in your movements. What I'm about to tell you is a day in your life. Wake up slowly and have a carer help you to get up. Breakfast is taken with the help of a carer. Enjoy reading while listening to music. With the help of a carer, they eat a nutritionally balanced diet. Relax and enjoy the view outside. Family members come to visit and enjoy conversation. Light exercises are performed with the help of a carer. Dinner is taken with the help of a carer. TV viewing before going to bed ."*

A.1.3. Acting

This script was delivered to participants:

"You are an energetic elderly person. For acting, change your mind to be a healthy elderly person. For the act, you will do a morning exercise in the park. First, stand with a smile on your face. First, perform a spirited appearance. Your fists are clenched tightly, and your back is arched. You are so fired up that you feel like shouting. Next, the body warm-up is performed. Unwind your body by doing some light stretching and large arm movements. In doing so, try to make it feel fun and lively. Finally, act out the figure engaging in the exercise. Act it out with an energetic image."

A.2. Contradicting Mental and Acting Protocol

A.2.1. Introduction

This script was delivered to participants:

The experimenter showed pictures of the avatar model.

"This is what you look like in VR. You have the appearance of an elderly person, but you are energetic and active. The following video introduces such an elderly person."

An excerpt of the following video was shown:
https://www.youtube.com/watch?v=pEPdU3m1tk4

A.2.2. Mental imagery

This script was delivered to participants:

"Your appearance is that of an elderly person. Wrinkles and sagging whitened hair are noticeable. And you are powerful and motivated. What I'm about to tell you is a day in your life. In the morning we go out to the park and do pull-ups on the bars. Find a child drowning in a pond and swam to save him. Drink protein smoothies for breakfast. Go to the gym and do full-body workouts and yoga to strengthen their bodies. Unintentionally bending the spoon during lunch. Play football with my grandchildren. You dribble through and shoot without any adult supervision. Carry your tired grandson home on your back. Dinner is served with your favourite steak. You sweat it out in the sauna before bed."

A.2.3. Acting

This script was delivered to participants:

"You are an energetic elderly person. For acting, change your mind to be a healthy elderly person. For the act, you will do a morning exercise in the park. First, stand with a smile on your face. First, perform a spirited appearance. Your fists are clenched tightly, and your back is arched. You are so fired up that you feel like shouting. Next, the body warm-up is performed. Unwind your body by doing some light stretching and large arm movements. In doing so, try to make it feel fun and lively. Finally, act out the figure engaging in the exercise. Act it out with an energetic image."

B. Additional feedback questionnaire

- Do you feel that you are more athletic now than you usually are? Or do you feel like you are declining? 1:Feeling diminished, 7:Feeling superior
- Compared to your own motor skills before the experiment, how much do you expect your motor skills to have changed now? 1:Decline diminished, 7:Improvement

- How do you feel the avatar you used affected your walking speed? Open-ended response
- How good did the avatars you used look? Multiple-choice: under 10, teens, 20s, 30s, 40s, 50s, 60s, 70s, and 80s above
- Please describe any comments you have. Open-ended response