Investigating the Proteus Effect on Physiological Responses While Resting in VR

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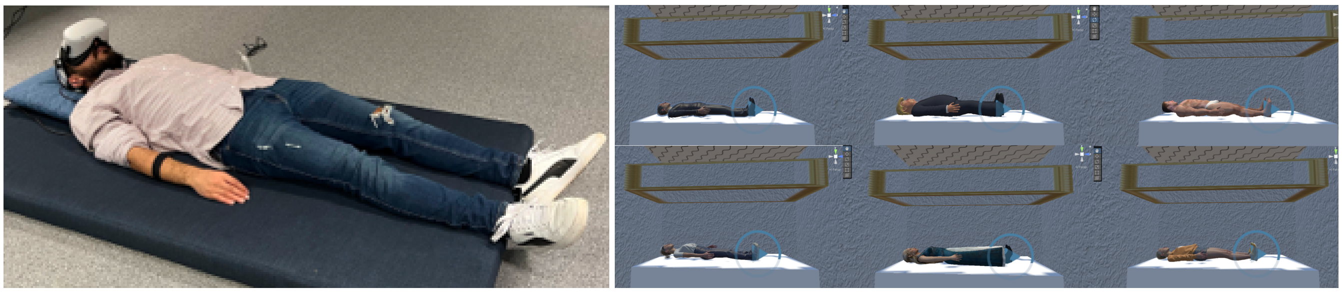

Figure 1: Participants lying on a mattress (left) while embodying different avatars of their identified gender (right). From left to right: neutral avatars, famous avatars (Donald Trump and the protagonist Daenerys from the TV series Game of Thrones), and athletic avatars.

Abstract

Virtual reality (VR) allows to embody any possible appearance using avatars. Previous work found that the visual characteristics of an avatar can cause behavioral, attitudinal, and perceptual changes — a phenomenon known as the Proteus effect. Recent work revealed that athletic avatars can even change heart rate responses while exercising in VR. However, it is unknown if such effects occur due to behavioral changes caused by the avatar or the mere virtual embodiment. Therefore, we conducted a study to understand if avatars' effects can be replicated while resting in VR. 21 participants embodied neutral, famous, and athletic avatars while lying on the ground. We could not find effects of the avatars' appearance on heart rate and perceived identification. Results indicate that the mere virtual embodiment of stereotypical avatars cannot induce physiological effects. We discuss that physiological effects are caused by behavioral adaptations due to the avatars' visual appearance.

CCS Concepts

• **Human-centered computing → Virtual reality**.

Keywords

Virtual Reality, Proteus Effect, Avatars, Heart Rate, Virtual Embodiment

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1 Introduction and Background

Researchers and designers of VR applications leverage avatars — digital representations of users in virtual environments — to create embodied experiences and facilitate intuitive interaction [3]. In 2007, Yee and Bailenson [19] discovered that an avatar's appearance can significantly impact users' behavior — a phenomenon known as the *Proteus effect*. They found that users with more attractive or taller avatars exhibited increased self-confidence and altered behaviors [19, 20]. Researchers explain that users adapt their behavior in accordance to the avatar's appearance and the connected stereotypical associations [4, 15, 16]. Since then, numerous studies have confirmed behavioral changes caused by an avatar's visual appearance across different settings [1, 5, 7, 13, 15, 16].

Recently, a large body of work revealed that avatars can even induce physiological changes [6, 8, 9, 12]. Kocur et al. [6], for example, showed that athletic avatars reduced heart rate responses while cycling in VR compared to non-athletic avatars. The authors attribute the effects to the Proteus effect and argue that users' confidence level to perform well at the task while embodying an athletic avatar reduces arousal. This, in turn, results in a decreased heart rate. Kocur et al. [12], however, postulates that the variance in heart rate originates from behavioral adaptions caused by the avatars' appearance. Athletic avatars change the way users are cycling [6, 11] or rowing [12], which, in turn, influences physiological responses. While the different explanations appear plausible, the exact underlying mechanisms are still unclear.

To leverage avatars' effects and design more effective VR interactions, it is important to learn about the Proteus effect and why physiological changes occur. If avatars change emotions and confidence, the physiological effects during physical activity could be less sustainable due to habituation effects. If avatars change behavior such as exercising in a more "dynamic" or "athletic" way and that, in turn, changes heart rate, such effects could be more effective and desirable for VR systems.

In this paper, we aimed to learn whether heart rate responses are caused by the mere virtual embodiment of the avatar. We therefore investigate the effects of an avatar's appearance on heart rate while resting on a mattress to prevent behavioral changes to occur. We conducted a study with 21 participants who embodied neutral, athletic, and famous avatars while lying on a mattress and being immersed in a virtual world. We could not find any effects of the avatars' appearance on heart rate. We conclude that the mere virtual embodiment of stereotypical avatars cannot induce physiological effects. We discuss that physiological changes induced by the Proteus effect are caused by behavioral adaptations.

2 Method

To learn about the effects of an avatar's appearance on heart rate responses, we conducted an experiment with participants who were lying on a mattress while embodying different avatars. We used this resting task to prevent behavioral changes to occur. This allows to isolate effects originating from behavioral changes and the virtual embodiment.

2.1 Study Design

We conducted a user study in VR with the independent within-subject variable Avatar with the three levels *neutral*, *famous*, and *athletic*. For all levels, we used a male- and female-gendered version. Hence, participants embodied avatars of their identified gender. For the *neutral* avatars, we used regular body shapes and outfits that are not associated with sports. For the *famous* avatars we used Donald Trump and the protagonist Daenerys from the TV series Game of Thrones. For the *athletic* avatars, we used muscular avatars with sports clothes such as skintight shorts. We counterbalanced the order of conditions to avoid sequence effects.

2.2 Measures

To explore the heart rate responses while embodying the respective avatars, we continuously measured participants' heart rate using an optical heart rate sensor (Polar OH1+) attached on the forearm. Additionally, we explored participants' experienced identification with the avatars using a Likert item ranging from 1 to 5 ("How much do you identify with your avatar in VR?").

2.3 Participants

We recruited 21 participants (7 female, 14 male), who originated from various computer science courses from our institution as well as from private contacts. Participants' age ranged from 21 to 45 years ($M = 29.6$, $SD = 6.05$). None of the 21 participants suffered from known cardiac conditions. Six participants reported that they had no prior experience with VR headsets. Participants were informed that they could withdraw or discontinue participation at any time without penalty. The study was given ethical clearance in accordance with our institution's user study regulations and hygiene protocols. Participants were compensated with credit points for their study course.

2.4 Apparatus

The participants were lying on a mattress measuring 90 by 200 cm, and were provided with a neck pillow to ensure a high level of relaxation. We used a Oculus Quest 2 continuously connected to the PC via a Quest Link cable running the VR application. We created the VR application using the Unity game engine. The virtual environment consisted of the avatars lying on a white mattress and a virtual mirror attached on the virtual ceiling. This allows participants to constantly perceive their virtual body. Additionally, participants were equipped with an optical heart rate sensor (Polar OH1+) attached to the forearm. This device measured the heart rate of the participants every second and transmitted the data directly to the Polar application on a smartphone via Bluetooth.

2.5 Procedure

After welcoming the participants, they were asked to read and sign the informed consent form. Afterwards, they completed a demographic questionnaire. Participants were asked to sit on a mattress and attach the optical heart rate monitor on their forearm. They were then instructed to put on the VR headset, adjusting it until the display was in sharp focus. Participants were asked to lie down on the mattress with their arms in a relaxed position (see Fig. 1). Following this, they were again asked to remain still while being immersed in the virtual environment. To assess the resting heart rate, we measured the heart rate for a period of 4 minutes [17]. Afterwards, participants embodied the first of three avatars and the heart rate continued to be monitored for exactly 2 minutes. To foster embodiment, a mirror was placed in the scene attached on the virtual ceiling so that participants could constantly perceive their virtual body while lying on the ground.

Once the 2 minutes elapsed, participants were asked to sit up, remove the VR headset, stand up, and complete a questionnaire about avatar identification. This process was repeated for all avatars. To adhere to the hygiene standards of our institution, the VR headset and optical heart rate sensor were cleaned after each participant before the next session. The entire study lasted approximately 30 minutes per participant.

3 Results

In this section, we present the quantitative results from our study. We employed a 3(Avatar: *neutral* vs. *famous* vs. *athletic*) $\times$ 2(Gender: *male* vs. *female*) mixed-design analysis of variance (ANOVA) on the heart rate and experienced identification. The Avatar was changed as within-participants variable, the Gender was changed as between-participants variable.

3.1 Heart Rate Responses

We did not find a significant effect of Avatar, $F(2, 38) = 0.331, p = .721, \eta_p^2 = .017$, and of Gender, $F(1, 19) = 0.060, p = .808, \eta_p^2 = .003$, on participants' heart rate responses. There was also no significant interaction effect of Avatar $\times$ Gender, $F(2, 38) = 0.293, p = .748, \eta_p^2 = .015$. To obtain more information about the relevant non-significant main effect of Avatar on heart rate responses, we conducted a Bayesian ANOVA on the averaged heart rate. A Bayes factor of $BF_{01} = 6.471$ indicated that the data are 6.47 times more likely under the null hypothesis that postulates an identical heart

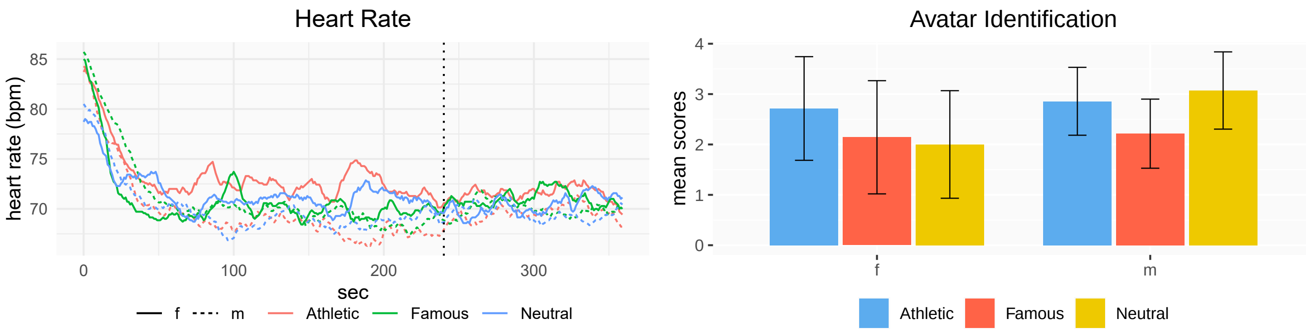

Figure 2: Average heart rate responses over time (left) and mean scores of the avatar identification (right) for female and male participants. The vertical dotted line indicates the onset of the avatar embodiment phase. Error bars show the standard error of the means.

rate between avatar conditions than under the alternative hypothesis that postulates a difference in heart rates between conditions. These findings indicate that the visual appearance of the avatars did not influence participants' heart rate.

To test whether the heart rate differently evolves over time while experiencing the avatars, we also included the factor Time with the five levels *0, 0.5, 1, 1.5, and 2* minutes representing the last two minutes during the avatar embodiment phase (see Fig. 2). A 3(Avatar: *neutral* vs. *famous* vs. *athletic*) × 2(Gender: *male* vs. *female*) × 5(Time: *0* vs. *0.5* vs. *1* vs. *1.5* vs. *2*) ANOVA revealed a significant interaction effect of Gender × Time, $F(2, 38) = 5.185, p = .010, \eta_p^2 = .214$. All other effects were not significant (all $p > .05$).

3.2 Avatar Identification

We did not find a significant effect of Avatar, $F(2, 38) = 1.780, p = .182, \eta_p^2 = .086$, and of Gender, $F(1, 19) = 1.058, p = .317, \eta_p^2 = .053$, on participants' heart rate responses. There was also no significant interaction effect of Avatar × Gender, $F(2, 38) = 1.488, p = .239, \eta_p^2 = .073$. Hence, findings indicate the the perceived identification with the avatars was not significantly different.

4 Discussion

In this paper, we aimed to learn whether physiological changes are caused by the mere virtual embodiment of stereotypical avatars or behavioral changes induced by their visual appearance. Consequently, we used a task consisting of lying on a mattress during virtual embodiment of different avatars to prevent behavioral changes to occur. This allows to isolate effects from behavioral changes and the virtual embodiment. Our findings indicate that the virtual embodiment of avatars with athletic and famous appearances do not affect users' heart rate. Hence, it seems that is not the virtual embodiment of stereotypical avatars per se that influences physiological responses. In line with previous work [12, 19], we argue that behavioral changes caused by stereotypical associations connected with the avatar are responsible for physiological changes induced by the Proteus effect.

If the mere virtual embodiment of stereotypical avatars would cause physiological effects, changes in heart rate while resting should be observed. This would be in line with Kocur et al. [6] who postulated that athletic avatars change users' confidence level and emotional arousal reducing heart rate. However, this was not the case. Neither the athletic nor famous avatars could influence resting heart rate. Hence, we assume that the Proteus effect on physiological responses requires behavioral changes to occur, e.g., more efficient weight lifting [10], cycling [6], or reacting [2]. However, this does not mean that avatars cannot change users' perception and emotions even in the absence of behavioral changes [14, 18]. Weeth et al. [18], for example, used virtual arms with iron armour or an unprotected version. Participants who rested their arm on a table while receiving electrical stimulation experienced less pain while embodying the protected virtual arm compared to the non-protected version. However, there were no effects on physiological responses such as skin conductance. We, therefore, assume that without any active motion and room for behavioral changes to evolve, such effects are mainly experiential and subjective and possibly do not change physiology. If physiological changes should occur, then users' need to actively interact with the avatar to adapt their behavior. Future work should further investigate this assumption by directly comparing avatars' effects during a resting phase and a active phase afterwards

5 Conclusion

In this paper, we investigated whether an avatar's athletic and famous appearance affect physiological responses while resting in VR. We aimed to learn whether heart rate responses are caused by the mere virtual embodiment of the avatar. We conducted a study with 21 participants who were lying on a mattress while embodying a neutral, athletic, and famous avatar. We could not find effects of the avatar on participants' heart rate. We even found that heart rate is more likely the same for athletic, neutral, and famous avatars. Consequently, our results show that the mere virtual embodiment does not change physiological responses. We argue that physiological effects caused by the avatars' appearance originate from behavioral changes. Future work should further analyze the Proteus effect on users' physiology with a more diverse population and larger variety of avatars.

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