Towards an Investigation of Avatars' Sweat Effects during Physical Exertion in Virtual Reality

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ABSTRACT

An avatar's athletic appearance can affect users' perceptual and physiological responses to physical exertion in virtual reality (VR). Although sweating during physical effort is a natural human response, it is currently unknown whether and how visualizing sweat on an avatar's skin affects the user while exercising in VR. Therefore, we plan to conduct a study with 30 participants to explore the impact of an avatar's sweating on users' physical performance and perception of effort while cycling in VR. We expect that visualizing sweat increases the perceived effort and decreases physical performance as sweating is associated with physical strain and fatigue. Hence, we assume that the avatars' sweat could contribute to a more vivid and realistic VR exercise experience on the one hand, but also result in adverse effects on the users' physical performance on the other.

KEYWORDS

virtual reality, avatars, Proteus effect, sweat effects, exergames

1 INTRODUCTION AND BACKGROUND

Rapid advances in VR technology enable researchers and designers to create embodied VR experiences. To establish the sense of having an own body in virtual environments (VEs), designers commonly use avatars—virtual characters, which represent the user in virtual worlds. In line with results from real-world experiments [16, 18], previous work found that a first-person perspective—being located "inside" the avatar and perceiving the virtual world through the avatar's eyes—in combination with multisensory correlations can create such strong cues, that users have the feeling of embodying these avatars and accepting them as their new virtual bodily self [6]. Through tracking devices or modern motion capture technologies the users' movements can be registered and mapped onto the avatar resulting in a visuo-motor synchrony—a synchrony between movements of the real body and the virtual body. The brain integrates these sensory cues across different modalities, i.e., seeing the avatar moving (vision) as a reaction to the own "felt" movements (proprioception), and creates a robust and coherent overall percept [5]. This, in turn, can result in an illusion of perceived ownership over a virtual avatar and is commonly known as the body ownership illusion (BOI) [17].

Research from human-computer interaction (HCI) demonstrated that BOIs induced by virtual avatars can elicit the *Proteus effect*. This phenomenon describes the notion that users change their behavior or attitude in accordance to the visual appearance of the embodied avatars and its salient characteristics [7, 12, 19]. Kocur et al. [10] found, for example, that muscular avatars can increase the grip strength and reduce the perception of effort during a physical exercise. Beyond that, Kocur et al. [8] demonstrated that the avatars' athleticism can even affect the users' physiological response while cycling in VR. These findings are promising for the design of immersive health or sports interventions, as they imply that the Proteus effect can be leveraged to positively affect the user during physical effort in VR, which, in turn, can potentially result in enhanced exercise benefits. Consequently, HCI researchers seek to understand how to create appropriate avatars and design their visual characteristics [11], e.g., increased muscularity or reduced body fat, to positively affect the users, e.g., boosting the physical performance [13] or enhancing the physical activity [15]. While obvious stereotypical characteristics such as a high level of an avatar's athleticism seem to be effective for inducing the intended perceptual and behavioral changes during exercising in VR, there is still little known about other features that can be manipulated to make users perform better than they would in casual embodiments.

A natural human response vital for survival is sweating. Sweating serves as a heat-regulatory function and cools the body to maintain a balanced body temperature. Particularly during physical exertion, the body temperature increases and

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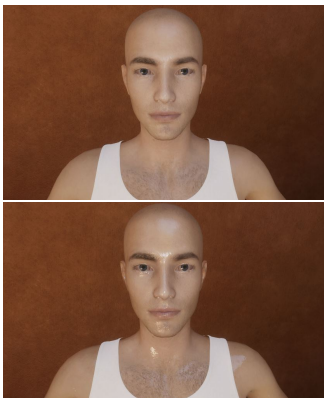

Figure 1: Non-sweaty (top) and sweaty (bottom) male-gendered avatar created for our experiment.

causes the autonomic nervous system to activate sweating mechanisms to counteract this rise in temperature [2]. As sweating is a natural response to physical exertion, designers of sports video games, e.g., NBA 2K21 [1] or FIFA 21 [4], use sweat effects to generate a realistic simulation and also create a feedback mechanism to inform the player about the fatigue of the virtual characters. However, the impact of visual sweat effects on the user in immersive VR applications is currently unknown. Hence, we plan to investigate the question how visualizing sweat on the avatar's skin affects the users during VR exercise. For this reason, we propose an experiment where we create different sweat effects of an avatar to understand how they affect the users' physical performance and perceived exertion while cycling in VR.

2 PLANNED EXPERIMENT

The Proteus effect could be demonstrated during physical exercise in VR, e.g., the avatars' athletic and muscular appearance can affect the users' physical performance and perception of effort [8, 10]. As sweating during exercise is a natural response, visualizing sweat on the avatars' skin could contribute to a more vivid and realistic experience resulting in a higher sense of presence and body ownership over the avatar [9]. However, adding sweat effects could also negatively influence the users while exercising in VR, as sweat indicates some degree of physical effort and fatigue. Even if sweat could enhance the experienced realism in the VE, the users could associate the sweaty avatar with fatigue and strain, which, in turn, could prime them and increase the perception of effort and deteriorate exercise performance.

To understand an avatar's sweat effects on the user, we want to investigate whether a sweaty appearance of an avatar influences the users' perception of effort and physical performance while cycling in VR (see Figure 1). For this reason, we are planning to conduct a study using a within-subjects design (N = 30) with the factor Sweating with the three levels *no sweating*, *incremental sweating*, and *decremental sweating*. While *no sweating* shall serve as our control condition, the *incremental sweating* feedback will visualize an increase in sweating over time whereas the *decremental sweating* condition will show the contrary, i.e., the avatar will sweat the most at the beginning of the exercise and the amount of sweat will decrease over time with no sweat visible at the end of the exercise. To reduce order effects we will counterbalance the conditions.

The participants will enter VR embodying an avatar and perceiving the VE from a first-person perspective. Following the procedure by Kocur et al. [8], we will use an ergometer bicycle and place a virtual replica into the virtual environment. The participants will sit on the ergometer placed in front of a virtual mirror and follow a standardized exercise protocol [14]. The users' movements will be registered by optical trackers and transferred onto the virtual skeleton of the avatar so that they will have the feeling of cycling in VR. We will assess the perception of effort using the Borg's RPE scale [3], the physical performance using the covered distance and pedaling frequency as well as the heart rate responses. To quantify the experienced body ownership, we will use the Virtual Embodiment Questionnaire (VEQ) [17].

We hypothesize that the participants will perform better and perceive the exercise less physically strenuous with a decreased heart rate response while experiencing the *decremental sweating* feedback compared to the *no sweating* and *incremental sweating* condition. We also expect the lowest VEQ scores during the *decremental sweating* condition, as this type of sweating is contradictory and counterintuitive.

3 CONCLUSION

In this proposal, we suggest a study design to investigate an avatar's sweat effects on the users' physical performance and perception of effort while cycling in VR. If results confirm our hypothesis, this would imply that visualizing sweat can positively affect the experienced realism and body ownership over the avatars. However, VR designers and researchers would have to consider adverse effects regarding the physical performance and perception of effort in VR exercise applications. Even if sweat effects could contribute to create realistic and lifelike VR experiences, they could also moderate the Proteus effect and, therefore, attenuate the effects caused by the avatars' athletic appearance. With this proposed study, we therefore attempt to gain a deeper knowledge about the effects of visualized sweat and contribute to a better understanding of how to design the avatars' visual characteristics to create effective VR exercise systems.

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