The Superhero Pose: Enhancing Physical Performance in Exergames by Embodying Celebrity Avatars in Virtual Reality

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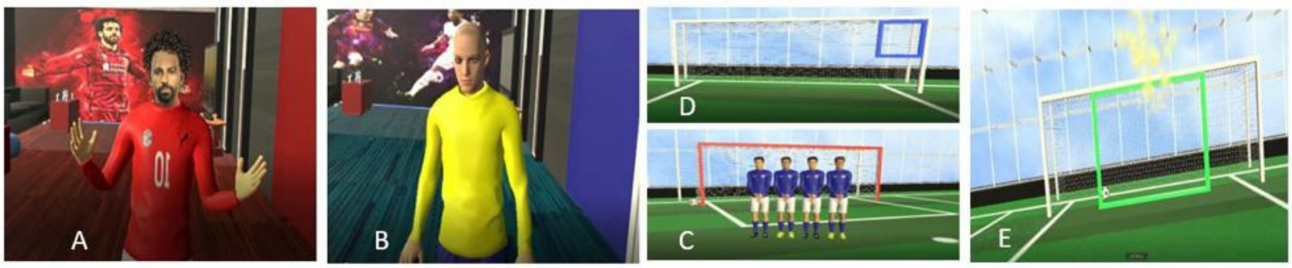

Figure 1: The experimental apparatus where users are embodied in avatars and play a soccer game. Figure A and B show the two embodiment conditions for a participant, Mohamed Salah the celebrity soccer player and the generic avatar respectively. Figure C shows a missed free kick. Figure D shows the blue hoop, where the player must aim to score a goal. Figure E shows a successfully scored goal.

ABSTRACT

Altered virtual reality self-representations can augment human capabilities by exploiting the Proteus effect. For example, previous work has shown that embodying an avatar that signifies super-intelligence, Einstein, enhanced the users' performance in cognitive tasks. In this paper, we show that embodying an avatar that signifies superior athletic skills enhances the users' physical performance. We conducted a between-subject experiment (n = 50) where participants played a soccer game while being embodied in a famous soccer avatar and in a generic avatar. We reflect on how self-esteem, embodiment illusion, and presence moderate the Proteus effect. Our results showed that participants embodied as a professional soccer celebrity performed better in the tasks and had a higher sense of embodiment compared to those with a generic avatar. Our results can be used to design engaging exergames and technological interventions to expand human capabilities.

CCS CONCEPTS

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

KEYWORDS

virtual reality, Proteus effect, avatar embodiment, body ownership illusion, stereotypes

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1 INTRODUCTION

Recent technologies have opened many opportunities for supporting sports and physical activities. Exergames specifically are considered one of the novel approaches to support sport skills. They provide a safe environment for the players to master fundamental movement skills and enhance their physical performance [10, 11, 19]. Fully immersive virtual environment (IVE) enhanced the impact of the exergaming experience. Previous work showed that users exergaming in virtual reality (VR) showed lower fatigue ratings, higher enjoyment, and better performance, compared to exercising using standard methods [26, 35]. An integral part of the exergaming experience is the digital representation of the users in the virtual environment (VE) using avatars. Such immersive experiences usually support tracking the user's body gestures and mapping them to the virtual body in real-time [47]. This visuomotor synchronous stimulation can induce the illusion of owning a virtual body rather than the physical one. This allows the users to embody virtual personas with different body representations in terms of structure, size, identities, and morphology [2, 4, 20, 29].

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Prior work showed that such changes in the visual characteristics of the embodied avatar may result in behavioral change in a phenomenon known as the *Proteus effect* [49, 50]. The Proteus effect predicts that users will behave depending on the stereotypes connected with the perceived body representation and what is expected from this virtual identity. For example, Banakou et al. [2] showed changes in the size perception after embodying the users in a virtual child body. Complementarily, embodying users in heroes or villains avatars caused the individuals to behave in ways that conformed to their embodied avatars [40, 51]. Similarly, embodying avatars with stereotyped physical characteristics may influence the individuals' physical performance. Previous work showed that participants who embodied normal-weight avatars showed higher performance during the physical activities compared to participants embodied in obese avatars [33, 34]. Kocur et al. [23] showed that participants in muscular avatars showed higher grip strength compared to non-muscular and medium avatars. Such studies show that the avatars' appearance affects the users' physical performance level. However, they focused on generic changes in the physique of the avatar. It is still unknown if embodying an avatar that signifies superior athletic skills and is considered a role model can enhance the users' physical performance, as people are more likely to adapt and learn a behavior if they resemble their role models [5].

Our work here fills this gap by investigating the effect of embodying celebrity athletic avatars (CAA), represented as Mohamed Salah, who is associated with superior soccer skills, on the users' physical performance levels. We specifically target three research questions:

- **RQ1:** Do users perform with better accuracy when they embody CAA compared to generic avatars?
- **RQ2:** Does the embodiment of CAA affect the embodiment illusion, the presence, and the subjective soccer shooting skill of the users?
- **RQ3:** How do the embodiment illusion, the presence, and the self-esteem impact the strength of the Proteus effect?

To achieve this goal, we conducted a between-subject experiment with 50 male participants, embodied as Mohamed Salah, a celebrity soccer player, or in a generic male avatar in an immersive virtual environment (IVE). The participants were fully tracked and represented as virtual avatars while playing a soccer game. We found that participants embodied as a celebrity soccer player showed better physical performance compared to those embodied in the generic avatar. Participants in the celebrity condition scored more goals than those in the generic condition, and the velocity of the shootouts in the celebrity group was significantly higher than in the generic group. We also found that the individuals' self-esteem and sense of embodiment moderated the Proteus effect. Our insights would benefit HCI researchers designing solutions for augmenting human physical capabilities. They also have the potential to be used as a tool for encouraging amateur users to be involved in regular physical activity through virtual games and maintain a healthy lifestyle.

2 BACKGROUND AND RELATED WORK

In this section, we start by introducing the body ownership illusion and how it is optimized in virtual environments. Afterwards, we discuss prior work investigating the impact of the Proteus effect on the user's cognitive and physical performance. Lastly, we specifically discuss the role of avatars in moderating the physical performance of users in virtual environments.

2.1 Body Ownership Illusion

Body ownership illusion (BOI) refers to the perception illusion of owning some non-bodily objects or even an entire virtual body other than one's own physical body. BOI was investigated through the well-known rubber hand illusion (RHI) experiment. In the RHI, participants experienced a rubber hand as their own, while their real hand was hidden and a life-sized rubber hand positioned in a similar posture, where their rubber hand and their real hands were stroked simultaneously, such that participants experienced an illusion where they reported that they felt the touch as it was coming not from their real hand but from the rubber hand [8]. This illusion occurs due to synchronous visual-tactile stimulation. Similarly, BOI can also be achieved by immersing the users in a virtual environment (VE) and embodying them into virtual bodies, substituting their real ones, where the users' body gestures and postures are being tracked and mapped to this virtual avatar representing them within the VE. So, by achieving visual-tactic stimulation, an illusion of virtual body ownership can be generated. For example, RHI was replicated in VR [52], and it showed illusion to the same extent as [8]. Also, participants showed stress responses towards the virtual threats introduced during the experiment [52]. Another study showed the effect of an appropriate synchronous visuotactile stimulation on body ownership illusion, but instead of a rubber arm, participants saw a virtual arm projecting out of their right shoulder [44]. Sanchez-Vives et al. [41] showed that the illusion of ownership over a virtual arm can be induced by visuomotor synchrony between movements of the real hand and the virtual hand. Since the illusion also applies to the whole virtual body, not only body parts. Slater et al. [46] reported a whole-body ownership illusion by embodying men in female avatars. Gonzalez-Franco et al. [14] showed a whole-body ownership illusion by observing the virtual avatar in front of a virtual mirror synchronously reflecting the users' upper-body movements. Previous work showed that it is possible to induce the illusion of having different virtual bodies than the real ones. For example, Normand et al. [28] also showed a whole-body ownership illusion by embodying normal-sized men into a fat virtual body. Kilteni et al. [21] also showed the illusion of ownership over an asymmetrical virtual body. Other works showed the illusion of ownership over avatars with different skin color [3, 16, 20, 31], or older [4, 38] or younger [2], or even with well-known identities in real-life [4, 29]. These results show a high degree of brain plasticity in our perception of the human body representation.

2.2 Proteus effect

Recently, fully immersive virtual reality (IVR) research easily allows users to change their avatar-based self-representation, so users will be able to navigate and explore the virtual world while being embodied in a different body. Users are able to change their desired avatar's appearance, their identity, or even their social roles. Such changes in body transformations can result in some behavioral and attitudinal changes, which is a phenomenon known as the Proteus effect [50]. This effect occurs during the interaction of the users via their avatars in the VE [49], and it may also last for a short time after the end of the virtual experience, where the effect is transferred to the subsequent face-to-face interactions [50]. Small changes to the visual characteristics of the virtual avatar can lead to significant changes in the way the users behave and interact in the VE. For example, it was shown that participants in attractive avatars interacted in more confident and friendlier ways than those in unattractive avatars [49]. In another study, it was shown that participants embodied in taller avatars negotiated in a more confident and aggressive way than participants in shorter avatars [50]. Ratan et al. [36] provided a meta-analysis of previous research on the Proteus effect, and it showed that it's a reliable phenomenon with a small to medium effect. Studies showed that users behave within the VE according to their stereotype assessments connected with the virtual avatar's appearance. Peña et al. [32] showed that participants embodied in black-cloaked avatars showed aggressive behavior in comparison to participants in white-cloaked avatars, they also showed that participants in black-cloaked avatars showed lower cohesion than participants in white-cloaked avatars. The authors also showed that participants embodied in Ku Klux Klan avatar provided less affiliated stories than those embodied in doctors avatars [32]. Another study investigated the Proteus effect through using avatars of different age groups, such that participants who embodied older avatars took a longer time to traverse the same distance covered by participants in younger avatars [38]. Another study examined the Proteus effect through enhancing creativity performance, such that embodying inventors avatars, which are known as a stereotype for creativity, were perceived as more creative than participants in neutral avatars [15]. The authors also showed that participants in inventors avatars were more creative in the subsequent face-to-face interactions [15].

Studies were conducted to examine the Proteus effect on the user's physical performance level. For example, Kocur et al. [23] have shown that muscular avatars had a higher grip strength compared to non-muscular avatars. The authors also showed that the muscular appearance of the virtual avatar affected the perceived exertion during physical activity [23]. Another study [22] examined the Proteus effect on the heart rate and perceived exertion by embodying the users into 3 different avatars with 3 different athletic appearances. It was found that the participants in the athletic avatar showed the least heart rate in comparison to the non-athletic avatar and the medium avatars.

2.3 Avatars' Effects on Sports and Physical Activities

According to the Proteus effect, individuals will adapt their behaviors and attitudes to their avatar's identity and what they believe is expected from this virtual character [49]. So avatars' visual characteristics affect numerous outcomes. However, it's still little known about the influence of the Proteus effect on physical activities. Peña & Kim [34] showed that women who were randomly assigned to a normal-weight avatar and then played a tennis exergame, were more physically active than players in obese avatars. This study was replicated with a sample of male participants. It showed that male players in normal-weight avatars were also more physically active than those in obese avatars [33]. They also showed that the opponents' character body size acted as a moderator on the effect of the avatar appearance on the physical activity [33]. Li et al. [25] also showed that overweight children assigned to normal avatars scored significantly better than those who were assigned to large body size avatars. Another study also showed that embodying a normal-weight avatar with healthy behavior can increase users' exercising behavior [18]. A study conducted to analyze the effect of avatars' different body dimensions showed that embodying avatars with ideal body dimensions showed lower levels of anxiety compared to participants embodied avatars with body dimensions similar to their own in real life [27]. The authors also showed that the walking behavior was also affected by the virtual avatar's appearance [27]. Reinhard et al. [38] showed that participants embodied older avatars took a longer time than participants in younger avatars to walk a set of distances after they have left the virtual environment. Kocur et al. [23] also illustrated the connection between the muscular avatars' stereotypes and the user's behavior. They showed that embodying muscular avatars showed lower perceived exertion during physical activity. They also showed that male participants in muscular avatars showed higher grip strength compared to participants in medium avatars [23]. Kocur et al. [22] also showed that muscular avatars have significant effects on the heart rate and perceived exertion. Recently, avatars' appearance effects have been investigated in physical tasks. However, embodying avatars considered as role models led to an improvement in users' moods [29], affected their cognitive levels [4], even enhanced their engagement levels [43], but it's still unclear how embodying a role-model avatar affects the users' physical performance while being completely alone in VR, without any avatars competing with the player in the virtual environment.

3 METHODOLOGY

The aim of this experiment is to investigate the impact of embodying celebrity athletic avatars (CAA) in virtual reality on the physical performance of the users in exergames. We show in the following sections how we investigated and answered the three research questions:

- **RQ1:** Do users perform with better accuracy when they embody CAA compared to generic avatars?
- **RQ2:** Does the embodiment of CAA affect the embodiment illusion, the presence, and the subjective soccer shooting skill of the users?
- **RQ3:** How do the embodiment illusion, the presence, and the self-esteem impact the strength of the Proteus effect?

3.1 Study Design

To answer the aforementioned research questions, we conducted a laboratory *between-subjects* experiment in virtual reality with one independent variable, namely *avatar type* with two conditions (see Figure 2): (1) celebrity athletic avatar represented as Mohamed

Salah [1] (referred to as *CAA*), the famous Liverpool soccer player, and (2) a generic avatar represented as a male adult avatar (referred to as *GA*).

The experimental tasks take place in the context of a soccer game. There are two experimental tasks: (1) shooting penalties (*T1*), where the participants had to kick the ball through a hoop positioned within the goal, and (2) shooting free kicks (*T2*), where the participants had to kick the ball into the goal, away from a wall of players. The participants had five consecutive trials for each task in their respective condition, yielding a total of 10 trials per participant. Participants always started with the first task, followed by the second task.

We varied the complexity of the trials randomly for each participant. We explain the variation approach in Section 3.5. We also gave participants feedback to indicate how successful they were in each trial, along with keeping track of their score.

3.2 Experimental Measures

To investigate the effect of our independent variable, we measured the velocity of the kicks, as Bekris et al. [7] showed that ball velocity of kicking ability is considered as a significant predictor of performance, such that higher level players performed greater rate of ball velocity than lower level players. We also considered the maximum number of goals the users have scored. Thus, the combination of ball velocity and kicking accuracy determines the kicking effectiveness. In addition to the quantitative measures, participants were asked to assess their subjective impressions after the game by filling out three questionnaires. They filled the IPQ [42] questionnaire to measure the subjective feeling of presence in the virtual environment. They also filled an embodiment illusion questionnaire, adapted from the standardized embodiment questionnaire [12] to measure the degree of embodiment with regard to the utilized avatar. The participants also filled shooting skill questionnaire to evaluate the actual soccer shooting skill in VR. Furthermore, participants were asked to fill in a self-esteem questionnaire [39] before starting the experiment, as Brockner et al. [9] proposed the behavioral plasticity hypothesis, which suggests that low self-esteem individuals are more influenced by external environmental factors and will consequently react more strongly than those who have high self-esteem. Therefore, we measured the possibility of having the participants' self-esteem act as a moderating factor in the relationship between the avatar type and the participants' physical performance. We describe below the rationale behind each metric.

3.2.1 Game Performance. We measured the participants' performance using two main game metrics. The score of the game, which is the total number of successfully scored goals, and the velocity of the kicks. The velocity was calculated by calculating the time taken by the virtual ball to reach the goal and by having the distance of the virtual ball from the goal at the beginning of the game.

3.2.2 Embodiment Illusion. We assessed the embodiment illusion through a questionnaire measuring the sense of embodiment with regard to the utilized avatar, adapted from [12] and was slightly altered to suit this experiment. In this questionnaire, 8 items were answered using a 7-Likert scale with differing descriptive anchors. The questionnaire is split into ownership-related (O1), agency (A1, A2) and external-appearance (EA1-EA5). A reliability analysis test was performed by computing the Cronbach's alpha coefficient. The eight-item scales yielded an acceptable coefficient of $\alpha_{EI} = .70$, strongly indicating that the items measure the same underlying idea.

3.2.3 Presence. The feeling of presence in the virtual environment was assessed using the Igroup Presence Questionnaire (IPQ) [42]. The questionnaire consists of 14 items, which were answered using a seven-point response format with differing descriptive anchors. The questionnaire consists of 3 main subscales. It measures participants' spatial presence, the sense of being present in the virtual world; involvement, the feeling of being engaged with the virtual world; and experienced realism, the feeling of how consistent the virtual world is with the real world.

3.2.4 Shooting Skill. The soccer shooting skill in the virtual environment was assessed using six custom questionnaire items. The custom questions on the subjective shooting skill have not been validated as standardized scales. Therefore, we conducted a reliability analysis to check for the internal consistency of the items. The tests yielded Cronbach's Alpha values of $\alpha_{SS} = .72$, clearly, the items are measuring the same fundamental notion.

3.2.5 Self-esteem. We assessed participants' self-esteem using Rosenberg's self-esteem scale [39]. This questionnaire consists of 10 items, 5 of which are positive and 5 of which are negative, and they are scored using a 4-point Likert scale format, ranging from strongly agree to strongly disagree. Negative items were reverse-scored prior to analysis. Thus, higher scores indicate higher self-esteem.

3.2.6 Moderator Effects of Presence, Embodiment Illusion, and Self-esteem. We measured the possibility of having the presence, embodiment illusion, or the participants' self-esteem act as moderators on the effect of the avatar's body type on the participants' performance score. We used Process Macro Hayes [17] for moderation analysis. As our independent variable, *avatar type* is a categorical variable, we statically coded it in the regression analysis. Participants in the CAA group were assigned a value of 1, and participants in the GA group were assigned a value of 0. In case of significant moderation, Johnson-Neyman techniques were used for significance region specification.

3.3 Choice of Celebrity

Mohamed Salah was chosen after a number of informal surveys amongst the population from whom the participants were ultimately drawn. 100 students were asked to pick their favorite sport. Soccer game turned out to be the most popular choice. We then asked 70 students to choose a famous soccer player that they supported and wished to meet. Amongst the choices, the most popular ones were Mohamed Salah, Lionel Messi, and Cristiano Ronaldo. Mohamed Salah was the top choice.

3.4 Participants and Recruitment

50 male participants were recruited for the experiment, 25 embodied in Mohamed Salah avatar and 25 embodied in a generic male avatar. Their age ranged from 19 to 29 years (Mean = 22.8, SD =

[1] https://en.wikipedia.org/wiki/Mohamed_Salah

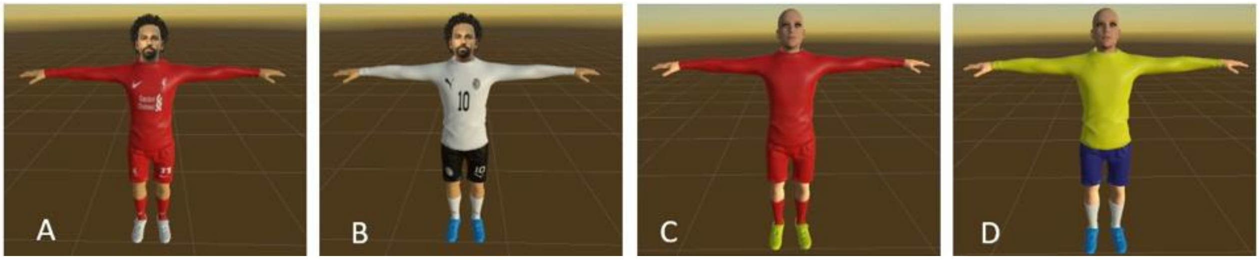


Figure 2: Avatars design in our apparatus. Figures A and B show our first condition, Celebrity Atheltic Avatar (CAA) represented as Mohamed Salah, the famous Liverpool player. Figures C and D show our second condition, Generic Avatar (GA) represented as an adult male. The figures show the possible customization of the clothes in the game.

1.47). Participants had no prior knowledge of the experiment. They also had a non or small experience with virtual reality. All of the participants are not professional soccer players. They also don't practice soccer as a hobby. They are only soccer fans. All of the participants are big fans of Mohamed Salah. They all supported the Egyptian National Team. 20 participants supported Liverpool club. Participants were randomly assigned to one of the two conditions. They were compensated with snacks for their participation.

3.5 Apparatus

We describe below the stimuli we used for our experiment, the gameplay flow, and lastly, the technical implementation of the apparatus.

3.5.1 Avatars' Setup. We used two avatars as stimuli: (1) Mohamed Salah's avatar to represent the CAA condition, and (2) a generic male avatar to represent the GA condition. Figure 2 summarizes the looks for each avatar. We designed for each avatar four jerseys, shorts, socks, and pairs of shoes. For Mohamed Salah's avatar, the outfits were Salah's club and national team home and away outfits. For the generic avatar, the outfits had no logos and no indication of a certain player or team to avoid accidentally cuing the participants to another famous team/player.

3.5.2 Game Setup. We designed a single-player virtual environment consisting of two scenes: (1) the dressing room and (2) the soccer field. Each scene represents a phase in the experimental session. The experimental tasks take place on a soccer field, while the first scene is designed to increase the sense of embodiment. First, the participants enter the dressing room scene. The scene's purpose is to familiarize the participants with their new self-representation. The user starts the game by standing in front of a table with water bottles and soda cans to interact with the virtual objects. The objective is to engage with the virtual representations to induce the Proteus effect [1]. This phase is the same in both conditions. Next, the participants teleport in front of a virtual mirror in order to perceive their virtual bodies while moving their real limbs and inducing BOI [14]. The participants can also change their outfits in front of the mirror. Lastly, the participants teleport to the second scene, the soccer field. The participants stand and start doing the experimental tasks, i.e., shooting penalties (T1) and shooting free kicks (T2).

Complexity of Trials. We vary the complexity of T1 by changing the hoop's position every penalty shootout. There are five possible positions: at the center of the goal, or at each of the goal corners. Regarding *T2*, the number of players in the wall kept changing with each kick. In order to reduce ordering effects, the difficulty of the trials in *T1* and *T2* was randomized, with the hoop's position and the number of players in the wall being chosen at random per trial.

Validation of Trials. We gave participants feedback about how successful they scored in their trials. In the penalty shooting task (T1), on successfully scoring the goal, the hoop's color changes to green, However, on missing the goal, the hoop's color turns red. On successfully scoring goals in the free-kick shooting task (T2), the goal's borders turn green, and on missing the goal, the goal's borders turn red. In both tasks, on successfully scoring the goal, a generic cheering sound plays in the background of the GA condition, while in the CAA condition, a special famous cheering song for Salah is played. Additionally, whenever a goal is scored, the participants' score gets updated immediately in both tasks. The participant can also check the updated score at any time throughout the game by looking at a virtual scoreboard.

3.5.3 Technical Implementation. The experiment was conducted in a virtual reality laboratory. To achieve BOI, participants were embodied in the generic avatar and Mohamed Salah avatar using an HTC Vive head-mounted display (HMD). The HMD has a wide horizontal field-of-view of 100°, with a resolution of 1080 × 1,200 pixels per eye displayed at 90 fps. So participants were able to view the virtual world from the avatar's eyes, as they perceived the virtual world from a first-person perspective (1PP). To track the participants' body movements in real-time, a Kinect sensor was used, which tracks up to 25 body joints of the human body. It supports a maximum resolution of 1280 x 960. So the participants' body gestures were being tracked by the Kinect sensor and mapped to the virtual avatars in real-time. Both the avatars and their accessories were generated using Blender 3D. The virtual environment was implemented using the game engine Unity3D.

Before each trial, the ball's position was reset at a distance of 11 m from the goal. When the ball was kicked, an impulse value was calculated based on the collision of the shoe model's mesh collider with the ball's sphere collider, allowing for predictable and forceful shots: the foot's current relative velocity was multiplied by 400 and sent as an impulse value. In iterative pre-tests, this element was found empirically by determining which impulse value gave the most test users the sensation of realistic shooting mechanics. So, the force from the participants' biological foot was transferred to the virtual ball to determine the shot's speed and direction. The virtual ball was kicked in the air without a haptic response on the participants' foot. The players may have been able to estimate how to hit the virtual ball most effectively only with visual feedback. The virtual ball's subsequent curve trajectory was calculated by Unity's physics engine.

3.6 Procedure

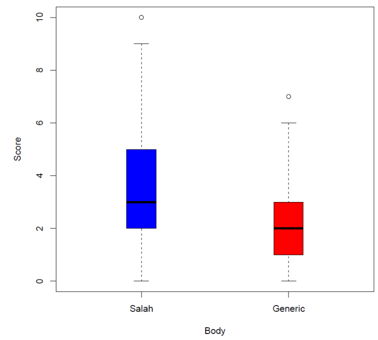
Before starting the virtual experience, participants signed a consent form, and then they were asked to complete a self-esteem questionnaire. Next, a brief introduction about VR and the Kinect sensor was provided. A researcher then supported the participants to re-position in front of the Kinect sensor to be able to achieve full tracking, and then we adjusted the HMD to the participants' head. Afterwards, the researcher started the game for the participant. At the beginning of the experiment, the participant was assigned to one experimental condition and was embodied in one of our two avatars, Salah or the generic avatar. The participant saw the first scene of the dressing room as described in Section 3.5.2. They were also asked to grab the water bottles and soda cans to make them interact with the virtual objects in the virtual room. Next, the participants teleported in front of the virtual mirror, and they were asked to look down to be able to view their body from 1PP. Then, they were asked to perform a simple set of stretching exercises in order to explore the mapping of their real-time motion to their embodied virtual avatar, including movements of their arms, legs, and feet. They were also able to change their outfits in front of the mirror. After finishing this orientation period, the participants started the soccer experience. Before starting the penalty shootout trials, the participants were instructed to aim the hoop positioned within the goal, with a secondary aim to kick as fast as possible. Before starting the free kick trials, the participants were instructed to aim the goal itself, with a secondary purpose of kicking as quickly as they could. After finishing the ten trials, the game ends and the participant answers the remaining three questionnaires: the embodiment illusion questionnaire, the IPQ questionnaire, and the shooting skill questionnaire. All questionnaires are answered in a paper format.

4 RESULTS

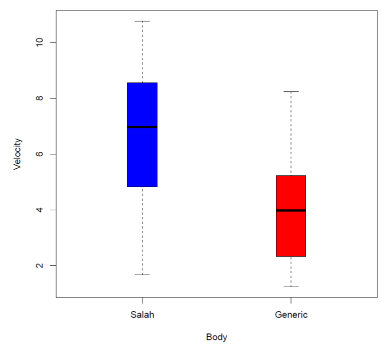
In this section, we answer the three research questions. We first show that embodying a celebrity soccer player enhanced the performance quality of the participants. Next, we show the impact of the avatar type on the embodiment illusion, presence, and the subjective soccer shooting skill in VR. Lastly, we show how the embodiment illusion, presence, and the participants' self-esteem impacted the behavioral Proteus effect.

4.1 RQ1: Do users perform with better accuracy when they embody CAA compared to generic avatars?

For the metric data on the successfully scored goals and the velocity of the shot, we applied a two-tailed independent t-test for



(a) Score Summary



(b) Velocity of the Kick Summary

Figure 3: Summary of performance results. Participants scored more goals (Figure a) and kicked stronger (Figure b) when embodied in a celebrity athletic avatar compared to being embodied in a generic avatar.

independent samples. It was normally distributed as assessed by Shapiro Wilk tests ($p = [0.064..0.368]$). The homogeneity of variances was confirmed with Levene's tests for all metric data ($p = [0.101..0.156]$).

4.1.1 Game Score. A two-tailed independent t-test revealed a significant effect of the avatar type on the performance level. We detected a difference in the final scores between the two conditions (see Figure 3a). The results showed that the final scores of the CAA group ($M = 3.72, SD = 2.63$) were significantly higher than the GA group ($M = 2.40, SD = 1.93$), $t(48) = 2.017, d = 2.314, p < 0.05$). This indicates that participants scored more goals when embodied in a celebrity athletic avatar (CAA).

4.1.2 Velocity of the Shot. A two-tailed independent t-test revealed a significant effect of the avatar type on the performance level (see Figure 3b). We detected a difference in the velocity of the shoot-outs between the two conditions. The results showed that the kicking velocity in the CAA group ($M = 6.83, SD = 2.64$) was significantly higher than the GA group ($M = 4.16, SD = 1.85$), $t(48) = 4.125, d = 2.287, p < 0.05$. This indicates that participants kicked stronger, and thus shows an improvement in the players' kicking ability when embodied in a celebrity athletic avatar (CAA).

4.2 RQ2: Does the embodiment of CAA affect the embodiment illusion, the presence, and the subjective soccer shooting skill of the users?

The questions from the questionnaires were analyzed individually, using Mann-Whitney U test.

4.2.1 Embodiment Illusion. According to the external appearance results (EA1-EA5), the excitement level of the participants (EA1) was significantly higher in the CAA group ($M = 32.20, Median = 5$) compared to the GA group ($M = 18.80, Median = 4$), $Mann - Whitney\ U = 480.00, Z = 3.338, p < 0.05$. However, the body ownership (O1) and the agency (A1, A2) showed no significant difference between the two conditions (all $p > 0.05$). Table 2 provides the summary of the mean rank differences. This implies that the users embodied in a celebrity athletic avatar that they considered a role model had a higher sense of embodiment compared to users embodied in a generic avatar.

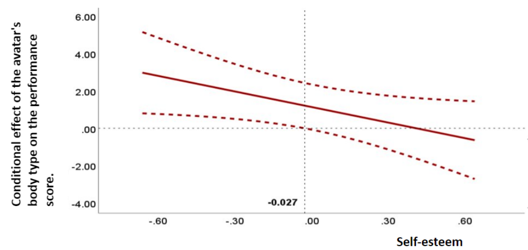
4.2.2 Shooting Skill. The subjective results on the soccer shooting skill showed no significant difference between both groups (all $p > 0.05$). The subjective evaluation of the skill showed higher ratings in both conditions. Table 3 provides the summary of the mean rank differences. This implies that the apparatus was of a good quality and provided the users with an impression of realistic shooting physics in both conditions.

4.2.3 Presence. Subjective results on presence did not show any significant differences between both conditions ($all p > 0.05$). Sense of presence was equally high for both those embodied in CAA and those embodied in a GA. This implies that the quality of the apparatus was good for both conditions, and participants felt present during the play.

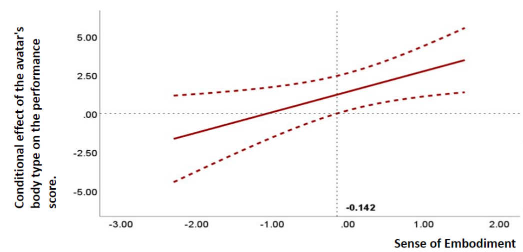
4.3 RQ3: How Do the Embodiment Illusion, the Presence, and the Self-esteem Impact the Strength of the Proteus Effect?

4.3.1 Moderator Effects of Embodiment Illusion. An analysis of possible moderator effects of the embodiment illusion on the relationship between the avatar type and physical performance showed that it significantly impacted the users' physical performance, $b = 1.324, t(46) = 2.429, p < 0.05$. The Johnson-Neyman technique revealed a significant region at an embodiment value = -0.142, with 44% of the values falling below this threshold and 56% of the values falling above it (see Figure 4b). The data indicates that those individuals who develop a stronger feeling of embodiment illusion will also be more strongly impacted by a Proteus effect.

4.3.2 Moderator Effects of Presence. Presence as a moderating third variable, did not significantly impact the strength of the embodied avatar's appearance on the participants' physical performance, $b = 0.115, t(46) = 0.277, p = 0.782$. This implies that the apparatus quality did not cause a discrepancy in the presence and thus performance between both conditions.



(a) The Johnson-Neyman graph for the model relating avatar type to performance score, self-esteem, and their interaction. The effect of avatar type on performance score is significant only for negative self-esteem ratings; values less than -0.027.



(b) The Johnson-Neyman graph for the model relating avatar type to performance score, sense of embodiment, and their interaction. The effect of avatar type on performance score is significant only for higher embodiment illusion ratings; values greater than -0.142.

Figure 4: Figure a and b show the predicted group differences with 95% confidence intervals for self-esteem and sense of embodiment acting as moderating variables respectively. Moderation analysis showed that higher embodiment illusion ratings impacted the users' performance while being embodied in a celebrity soccer avatar. Additionally, users with lower self-esteem are more likely to benefit from being embodied in a celebrity soccer avatar as they are more susceptible to the Proteus Effect.

4.3.3 Moderator Effects of Self-esteem. Self-esteem measure, which had been obtained prior to the VR exposures (see Table 1) significantly moderated the relationship between the avatar type and participants' physical performance, $b = -2.781, t(46) = -2.076, p < 0.05$. The Johnson-Neyman technique revealed a significance region at a self-esteem value of -0.027, with 50% of the values falling below this threshold, and 50% values falling above (see Figure 4a). The data indicates that participants with lower self-esteem that were embodied in a celebrity avatar performed better in the game in comparison to participants with higher self-esteem embodied in a celebrity avatar.

5 DISCUSSION

This study investigated the effect of embodying an avatar who signifies superior soccer skills (Mohamed Salah) on the individuals' soccer performance. The data from our experiment showed a significant effect of embodying a celebrity's avatar, a.k.a. Mohamed Salah, on enhancing the users' performance.

Table 1: Descriptive statistics showing the mean (*M*) and standard deviation (*SD*) of the Self-esteem questionnaire responses (4-Likert scale).

Items	Salah (N = 25)		Generic (N = 25)	
	M	*SD*	*M*	*SD*
On the whole, I am satisfied with myself.	2.52	0.77	2.76	0.87
At times I think I am no good at all.	2.48	0.58	2.60	0.76
I feel that I have a number of good qualities.	2.68	0.98	2.64	0.86
I am able to do things as well as most other people.	2.48	0.91	2.56	1.00
I feel I do not have much to be proud of.	2.28	0.79	2.68	0.80
I feel that I'm a person of worth, at least on an equal plane with others.	2.52	0.58	2.72	0.79
I wish I could have more respect for myself.	2.96	0.78	2.84	0.74
I am inclined to feel that I am a failure.	2.60	0.64	2.76	0.66
I take a positive attitude towards myself.	2.92	0.81	2.84	0.80
I certainly feel useless at times.	2.68	0.62	2.80	0.76
Total scale score	26.04	4.97	27.20	4.20

Table 2: Statistical summary for the Embodiment Illusion questionnaire responses (7-Likert scale). Mann-Whitney U test was used. The mean rank for both groups is provided. The (*) marks statistically significant results. Participants were more excited when they were embodied as a celebrity soccer player compared to a generic avatar.

QID	Questions	Salah	Generic
O1	I felt as if the virtual body was my own body.	24.02	26.98
A1	I felt as if the movements of the virtual body were influencing my own movements.	26.42	24.58
A2	I felt like I could control the virtual body as if it was my own body	26.12	24.88
EA1*	*I felt an excitement sensation in my body when I saw myself embodied in the virtual avatar in front of the mirror in the dressing room.*	32.20	18.80
EA2	It felt as if my (real) body were turning into an 'avatar' body.	24.92	26.08
EA3	At some point, it felt as if my real body was starting to take on the posture or shape of the virtual body that I saw.	24.10	26.88
EA4	I felt like I was wearing different clothes from when I came to the laboratory.	24.62	26.38
EA5	At some point, it felt that the virtual body resembled my own (real) body, in terms of shape, skin tone or other visual features.	21.86	29.14

Table 3: Statistical summary for Shooting Skill questionnaire responses (7-Likert scale). Mann-Whitney U test was used. The mean rank for both groups is provided. No significant difference between the two groups was observed.

QID	Questions	Salah	Generic
1	I was able to control the force of the shot.	28.82	23.14
2	I was able to control the direction of the shot.	28.60	22.40
3	The trajectory of the ball seems realistic.	23.62	26.38
4	The ball hit the spot I aimed to.	29.02	25.30
5	I felt the force of my biological foot transferred to the ball.	27.38	22.24

5.1 Embodying Athletic Role Models Avatars can Enhance Physical Performance in Exergames

Previous studies showed that users in IVE adapt their behaviors and attitudes depending on the stereotypes connected with the embodied avatar's appearance and what is expected from this virtual body [4, 29]. Prior work shows that the avatar's appearance influences users' behaviors [49, 50]. Participants who embodied Einstein in prior work showed higher performance in cognitive tasks [4]. Similarly, in our experiment, participants who embodied Mohamed Salah, a well-loved celebrity soccer player, showed higher performance in physical tasks compared to those embodied in a generic avatar. Thus, we postulate that exposing individuals to avatars that act as role models in real life engages and motivates them in exergames and may increase their performance level. This interpretation conforms with prior work showing that individuals get motivated by successful people if they are similar to themselves [5].

5.2 Users are Excited to Be Embodied in Celebrity Avatars

Previous studies showed that the embodiment scores can influence participants' behaviors and attitudes [13, 30, 45]. Thus, manipulating any factor in the avatars' appearance may potentially affect the participants' performance level. Individuals who experience a high sense of presence within the virtual environment feel more engaged with the virtual representations than with the physical world, which results in a high sense of embodiment [1, 6]. Both of the virtual avatars in our experiment showed equally high presence ratings. This excludes the possibility of attributing the performance enhancements using the celebrity avatar to differences in the game design between conditions that affected presence.

Interestingly, the subjective evaluation of the soccer shooting skill in VR showed higher ratings in both conditions. This demonstrates that the system is more accurate and has a better level of precision in reflecting the actual soccer skill in VR. This rules out the option of having better shooting accuracy in the celebrity avatar condition due to differences in the shooting mechanics between the conditions.

It is worth noting that a higher difference in the quality of the external appearance when users were embodied in a celebrity soccer avatar compared to a generic avatar is mainly attributed to higher excitement feelings (EA1) when they saw their body as Mohamed Salah in front of the mirror. This finding is not surprising since Mohamed Salah is considered a universally famous talented character.

On the other hand, both avatars had high agency ratings. This is because both of the virtual bodies followed the participants' real bodies' movements in real-time, which indicates higher embodiment illusion [24]. Our design decisions also enhanced the embodiment illusion ratings in both conditions by placing the self-avatars in front of virtual mirrors [14]. Our findings showed higher ratings also in the body ownership (O1) and the quality of the external appearance (EA2, EA3, EA4), which enhanced the embodiment illusion in both conditions. The physical resemblance ratings (EA5) were lower for those in the celebrity group than for the generic avatar group. We postulate this is due to the differences between the participants' visual features and Salah's visual features.

5.3 Self-esteem and Embodiment Illusion Moderate the Proteus Effect in Exergames with Celebrity Avatars

Our results show that presence did not moderate the proteus effect, while sense of embodiment and self-esteem moderated it.

5.3.1 Embodiment Illusion. Our findings showed that the embodiment illusion functioned as a moderating third variable for the relationship between the effect of embodying a well-known soccer player and the individuals' physical performance levels. This conforms with the results of Ratan et al. [37] showing that the sense of embodiment as a moderator variable significantly impacted the Proteus effect.

5.3.2 Presence. Previous studies showed that spatial presence acted as a mediator third variable between the embodiment of animals and subsequent individuals' attitudinal changes [1]. Similarly, Reinhard et al. [38] showed that the spatial presence acted as a moderating third variable for the relationship between the age of the embodied avatar and the post-embodiment walking speed. However, we did not find a significant effect of spatial presence on the relationship between embodying a celebrity athletic avatar and the participants' physical performance. We speculate this is attributed to the difference in the experimental media between our work and the prior work. For example, our experiment focused on the behavioral changes within the virtual environment. By contrast, Reinhard et al. [38], their findings investigated the walking behavioral changes within a short time span after the VR experience. This experiment focused on comparing two IVR experiences, while Ahn et al. [1] compared embodiment conditions with passive viewing. The lack of difference in the presence also could imply the quality of the apparatus that equally involved the participants in both experimental conditions.

5.3.3 Self-esteem. Interestingly, the self-esteem ratings moderated the effect of the embodied avatar's appearance on the participants' physical performance. Our findings showed that participants with lower self-esteem embodied as Salah showed higher scores in comparison to participants with higher self-esteem embodied also as Salah. These results conform with Brockner et al.'s work [9] showing that individuals with lower self-esteem are more likely to exhibit plasticity to external variables. Additionally, studies on individuals' self-esteem have shown that the self-perceived likeness of the role model to the participants highly affects the individuals' self-esteem [48]. Therefore, we postulate that embodying Salah's avatar led to low self-esteem participants having higher self-confidence, which positively affected their physical performance.

5.4 Limitations and Future Work

Despite the findings and implications of the study, a few limitations should be acknowledged. First, we acknowledge the limitation of limiting the participants' sex to males. However, we wanted to avoid representing females with male avatars as it would break the embodiment illusion because of the visual discrepancy. Alternatively, we wanted to avoid having a different female role model avatar to maintain the consistency of the experimental condition. So, to increase the generalizability of the findings, future studies should replicate the findings using female participants embodying a female role model. Second, in the generic condition, participants saw themselves embodied in a young-looking male avatar, thus resulting in no higher excitement levels during the experiment. Future research may focus on creating personalized avatars for users rather than generic ones. Also, participants in this study were recruited to be inexperienced soccer players. Future studies could quantify the level of expertise in soccer and investigate how that prior soccer experience will influence the Proteus effect. Further, participants who were assigned to the celebrity athletic avatar condition had skin color similar to Mohamed Salah. According to Kilteni et al. [20], Caucasian participants who were embodied in a dressed dark-skinned avatar demonstrated greater variation and frequency of movement during an African drumming task when compared to participants who were embodied in a light-skinned, formally dressed avatar. Therefore, further research can confirm the findings using a sample of individuals with skin color different from Salah's. Also, participants' heights in the virtual world were different from their actual heights in real-life, because the participants' bodies were calibrated to match the utilized avatar body dimensions. The height disparity was not taken into account as a factor influencing the sense of embodiment. Therefore, additional research might look into how the Proteus effect will be affected by the height difference.

Additionally, this study was restricted to evaluating the Proteus effect in a virtual soccer game, a single exergame. Further studies are needed to replicate the findings using different types of exergames. Furthermore, our study included free kicks and penalty shootouts, two aspects of the soccer experience. Other aspects of playing soccer, such as passing the ball to other players in a multi-user scenario, dribbling it while moving, juggling the ball, and goalkeeping, where hand interaction will be permitted, could be studied in order to learn more about soccer skills in VR. Finally, the haptic sensation on hitting a ball was absent while kicking the virtual ball in the game, in contrast to kicking a ball in reality, which produces a detailed haptic response on the foot, so we can improve the kicking action by incorporating haptic responses, such as kicking a real ball while allowing this ball to be tracked in real-time in VR or providing force feedback to the foot on collision with the virtual ball.

6 CONCLUSION

In this paper, we investigated the effect of embodying a celebrity athletic avatar associated with superior soccer skills on the individuals' physical performance. We conducted a laboratory study (n = 50, all males) varying the avatar type to two conditions: (1) embodying a celebrity athletic avatar represented as Mohamed Salah, and (2) embodying a generic avatar represented as a young male adult. Our results show that participants scored better and kicked stronger when they were represented as a celebrity soccer player. They were also excited to be represented by a celebrity and had a higher sense of embodiment. Additionally, our results show that higher embodiment illusion ratings impacted the users' physical performance while being embodied in a celebrity soccer avatar. Also, participants with lower self-esteem are more susceptible to benefiting from being embodied in a celebrity soccer avatar to enhance their physical performance in exergames. Such findings can aid designers in optimizing users' performance and augmenting it in exergames to encourage users to adopt them.

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