# The Impact of First-Person Avatar Customization on Embodiment in Immersive Virtual Reality

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## ABSTRACT

In virtual reality (VR), users can embody a wide variety of avatars; from digital replicas of themselves, through diverse human body styles and appearance to non-humanoid representations. While choosing a body to inhabit is part of what makes VR such an engaging experience, various studies have shown how embodiment may change the way we perceive ourselves and others both inside and outside VR. In our study, we explored whether first- vs. third-person avatar customization would lead to changes in embodiment. Further, participants were embodied in larger-sized avatars, based on the hypothesis that embodiment would lead to a change in implicit bias towards larger-sized people. Our results show that third-person avatar customization led to a decrease of perceived embodiment of the larger-sized avatar, and that, on the contrary, higher embodiment was associated with a reduction of implicit biases towards larger-sized people in the first-person avatar customization mode. These findings suggest that third-person avatar customization leads to reduced feelings of embodiment, while first-person avatar customization may support more radical body changes.

**Keywords: Body ownership, avatar customization, bias reduction, immersive virtual reality**

## 1 INTRODUCTION

In reality, we experience the world from the inside out, from the first-person perspective. Moreover, in the real world we do not get to choose much about the body we inhabit. Instead, we are acquiesced to make the most of what we have, and that generally happens through long processes requiring physical effort, and sometimes even surgery. More frequently our daily interventions happen in first-person in front of a mirror. However, in Virtual Reality (VR), we can choose the body we want to embody from a much larger range. We can experience the world from any body size Bailey et al. (2009); Piryankova et al. (2014), shape Kilteni et al. (2012b); Yee et al. (2009, 2011) or color we wish Banakou et al. (2016); Maloney (2018); Peck et al. (2013). In many ways, this is part of what makes VR such a unique experience Gonzalez-Franco and Lanier (2017).

Research has found that the embodiment of a virtual avatar can have profound effects on how we perceive ourselves and the virtual environments in which we are situated Jayaraj et al. (2017); Lenggenhager et al. (2007); Hoort et al. (2011). In VR we can inhabit the body of people of different skin colors and of a different sex to experience the world, not only by 'walking a mile in someone else's shoes', but to do so in a facsimile of their body Gonzalez-Liencres et al. (2020); Peck et al. (2013); Seinfeld et al. (2018).

Research into the behavioral effects of embodying different avatars has found that individuals who embodied avatars that were more attractive were more likely to stand closer to other avatars; and that individuals embodied in taller bodies were more likely to act aggressively towards other virtual avatars, suggesting that the body we experience as our own can lead to changes in how we behave towards others Yee et al. (2009). Not only has this line of work demonstrated altered behavior on the basis of the body we inhabit, but also the implicitly held beliefs and biases, such as racial bias Maloney et al. (2019); Peck et al. (2013).

In this paper we are interested in the mechanisms by which users might modify the virtual body that they will embody. Prior experiments have shown a lot of body plasticity towards changing body parts on participants Kilteni et al. (2012b); Normand et al. (2011); Berger et al. (2022). We introduce a novel *first-person* mechanism where they can grab and pull the avatar they see from a first person perspective to resize it (see Section 3.4 for implementation details). This is contrasted with a *third-person* mechanism where they use sliders to manipulate an avatar they see in front of them. The third-mechanism mimics the situation encountered in many VR experiences when the user selects and manipulates avatar components or properties but is not altering the self-embodied avatars, giving a disembodied approach to the avatar personalizing. Given the prior work on embodiment, we hypothesise that altering one's avatar from a first-person point of view will generate higher levels of embodiment. Because embodiment has been shown to change biases, we set the participants the task of changing their self avatar to a larger-sized avatar (in our case an avatar that represents a human shape that would be assessed as having a body-mass index (BMI) in the obese range[1]), with the hypothesis that by supporting embodiment in a larger-sized avatar, participants' implicit bias towards larger-sized people will be reduced as measured by an Implicit Association Test (IAT).

In our experiments, we find that first-person avatar customization led to an increase of perceived embodiment of the larger-sized avatar. Also, we find that higher embodiment was associated with a reduction of implicit biases towards larger people in the first-person avatar customization mode. These results suggest that first-person avatar customization might be a useful technique when embodiment is important, but also might be relevant to reduce disembodied effects on the populations of social avatar situations.

Further, our protocol does not require an explicit body ownership induction (c.f. Normand et al. (2011)), but elicits this body ownership through task-based activity, consistent with previous work that showed that body ownership could be achieved through having participants engage in games (e.g. Yuan and Steed (2010)).

In Section 2 we give more background on avatar customisation, embodiment and implicit bias. Section 3 describes the method of an experiment that explores how avatar customization style impacts the relationship between body ownership and bias. Section 4 gives the main results of the study. Section 5 discusses and interprets these results in the context of the related work. Section 6 presents some conclusions and suggestions for new research directions.

[1] `https://www.cdc.gov/healthyweight/assessing/bmi`

# 2 BACKGROUND

## 2.1 Avatar Customisation

Avatar customisation is most commonly explored within the context of social virtual reality or collaborative virtual environments Churchill and Snowdon (1998); Schroeder (2010). The past few years has seen a surge of new social VR applications. Platforms vary greatly in the types of avatar they support Phadnis et al. (2023). For example, Rec Room Rec Room (2021) allows users to select various parts of their self representation from a relatively limited palette that fits a consistent style for the whole application; Spatial Spatial Systems Inc. (2021) allows users to customise their avatars using a model fitted to an image of their head; VRChat VRChat Inc (2021) allows a very broad range of anthropomorphic and non-anthropomorphic avatars. Recent surveys have started to examine how these features vary across platforms (e.g. Jonas et al. (2019); Tanenbaum et al. (2020); Freeman and Maloney (2021); Liu and Steed (2021)). Many avatar customisation systems (e.g. Rec Room's) include a mirror so that the participant can see the immediate effect of changing their representation. Indeed mirrors have for long been shown to be key to enhance body ownership of participants González-Franco et al. (2010). However, fine-scale modulation of body size is rarely included in customization tools. Pujades et al. describe the virtual caliper technique to scale a body and limbs to fit the tracking of controllers Pujades et al. (2019). Thaler at al. demonstrate that the perspective with which a user experiences their self-avatar has a significant impact on the accuracy of body size estimates Thaler et al. (2019). BodyLab is an immersive system for sculpting a wide variety of avatars Zeidler and McGinity (2023). Some work has been done to explore the generation of realistic virtual humans and shapes Anguelov et al. (2005); Achenbach et al. (2017), using AI methods and or surface deformation methods Botsch and Sorkine (2007).

## 2.2 Embodiment and Bias

While a large body work on avatars is concerned with presentation to others, the self-avatar (henceforth just "avatar") representation has important impacts on the user. Inside VR users have their bodies substituted by the avatar's body that they see in first person perspective, and which moves as they move. That virtual body is at a visual, motor and proprioceptive level substituting their own, and thus participants experience an embodiment illusion Gonzalez-Franco and Lanier (2017); Kilteni et al. (2012a); Padrao et al. (2016).

The effects associated to such embodiment of avatars Dunn and Guadagno (2012) include changes on implicit attitudes towards others. For example, light-skinned participants who experience embodiment over a dark-skinned avatar show a significant reduction on their racial bias Peck et al. (2013), which can be sustained overtime Banakou et al. (2016). Moreover, aging a virtual body might reduce prejudice towards older people Yee and Bailenson (2007). Furthermore, it has been studied that when entering a VR participants undergo a strong presence illusion Sanchez-Vives and Slater (2005), they experience that they are in a new location and that the things that are happening are plausible, which leads them to realistic responses Gonzalez-Franco et al. (2018); Slater (2009). Mottelson et al. have recently contributed a meta analysis of research on the effective of body illusions in virtual reality Mottelson et al. (2023).

Indeed, embodiment opens new doors for psychology experiments allowing for a new level of perspective-taking Maloney et al. (2019). Embodiment can also help to increase compassion Falconer et al. (2014), or reduce social bias Maister et al. (2013); Peck et al. (2013). Embodiment may be very important to the current use of avatars in applications such as weight management consultation Horne et al. (2020) and other body-related disorder Piryankova et al. (2014). More recently studies have focused also on altering photo-realistic self-avatars and the effects on body weight perception Wolf et al. (2020); Thaler et al. (2018).

These studies have found that participants with lower BMI tended to underestimate the weight of their photo-realistic avatars while participants with a higher BMI overestimated the avatar's body weight.

While many of the works described emphasize change in appearance to self, the specific avatar they are given is usually not customizable from a first-person perspective by the participants. Although the experiment might provide some small number of options (e.g. selecting gender, body size or skin color), or even a large set of options for BMI morphing Hudson et al. (2020), the avatar size is generally a metric or a condition on the experiment. One exception is Döllinger et al. (2022) who enable the user to embody their self-avatar by using the controller in different ways including gestures. For the purpose of our study we allow the user to manipulate a morphable body using a technique that allows the user to directly manipulate their own avatar. We constrain the manipulation to a pair of dimensions: upper body size and lower body size.

### 2.3 Implicit Bias

Implicit bias in attitudes towards others (henceforth simply "implicit bias") exists in multiple forms: gender, racial, weight, sexual orientation, age Greenwald and Krieger (2006). It is very difficult to introduce changes to such implicit bias, precisely because of its deep roots in our society and the power with which the media and our cultures reinforce pre-existing stereotypes and prejudices Jolls and Sunstein (2006); Kang et al. (2011). However, its effects are so profound in the collective society – and also at individual levels – , that this problem has gained increasing relevance for scientists as well as for the general public Teachman and Brownell (2001): we need to reduce existing social biases (implicit and explicit) to create more just and equal societies. In recent decades awareness of the noxious effects of implicit bias has increased, and important anti-discrimination laws have been put in place in many parts of the globe. In some cases, successful policies in education, healthcare, and employment have helped change the course of implicit bias and established ways to reduce it.

It has been shown that most biases take roots on broad cultural environmental factors Greenwald and Banaji (1995); Greenwald and Krieger (2006) and can be drawn to original in-group favoritism and in many cases are reinforced by the economic benefits that are distilled from the original discrimination Cain (1986). The complexity of the problem increases even more so for people suffering from multiple forms of bias, such as the types of violence experienced by women of color Davis (2000). Therefore, the nature of the discrimination is different depending on the particular bias.

In that regard, there are biases that are more overt and explicit than others, and sometimes they are more socially accepted. That is the case of age related bias, or weight-based bias Teachman and Brownell (2001). Many people assume that, as opposed to other nature given aspects such as your gender or race, your weight, is a choice. Hence overweight people not only suffer the effects of implicit bias – such as discrimination – but also suffer from blame, and bullying Teachman and Brownell (2001). In many cases this stigma increases the probability of mental problems such as depression Carels et al. (2010); Puhl et al. (2007) in these people, and reduces their ability to overcome the situation.

## 3 METHODS

### 3.1 Participants

Twenty male participants participated in the experiment (mean age = 38.59 years, SD = 11.56). All participants were healthy, none of them had a BMI greater than 30, they reported no history of psychiatric illness or neurological disorder, and had normal vision (or had corrected-to-normal vision). The participants were recruited internally. They gave written informed consent, and received monetary compensation in exchange for their participation. The experimental protocol was approved by the Microsoft Research Review Board, and followed the ethical guidelines of the Declaration of Helsinki. Informed consent of participants was also obtained to publish images or videos captured during their participation in subsequent research publications (including online open-access publications).

### 3.2 Experimental Design

Half (n=10; mean age = 38.75, SD = 11.75) of the 20 participants were randomly assigned to the third-person avatar customization condition, the other half (n=10; mean age = 40.6, SD = 12. 05) customized their avatars inside VR in front of a mirror in the first-person avatar customization condition. The experiment followed a between-subjects experimental design. In each condition, the participants had two VR experiences: a self-Avatar virtual experience, and a sat-avatar virtual experience. At the beginning of each experience, the participants created their avatar from either a first-person or third-person perspective in the first- and third-Person Conditions, respectively.

### 3.3 Apparatus

The participants used an HTC Vive Pro VR system driven by a desktop PC. They wore the head-mounted display and carried the two hand controllers. In addition, the participant wore a waist belt with two additional Vive Puck trackers attached. These were positioned symmetrically at the front, above the participant's pockets. These trackers gave a position that was used to control the waist orientation, and also a reference line that was used in the waist measuring task (see Section 3.6.3 section for details). The scene was modeled and run in the Unity3D software. A generic male avatar was created in the Daz3D software, and it was rigged with a standard skeleton. The avatar model selected was a male avatar, without hair, wearing shorts and a t-shirt (see Figure 1). This was appropriate for the scenario which was set in a gymnasium.

The avatar was animated using the Final-IK animation system which uses the tracked positions from the Vive system. The feet were not tracked, so a simple built-in stepping animation from Final-IK was used to have the feet follow underneath the head. However, participants were not asked to walk around the scene. The avatar had two blend shapes incorporated: one representing a very large person (Figure 1(B)), and the other a very skinny person (Figure 1(A)). The Unity run-time system implements blend shapes using linear-blend skinning. This means that the final mesh that is rendered was a linear blend of the blend shapes, where each shape is also modified by the weighting of individual vertices to the bones of skeletal rig. In subsequent frames of animation after selection, we needed to find the blend weighting value that moves the selected vertex as close as possible to the current position of the hand-held controller. Because the blending is linear, the closest vertex will lie on a line between the vertex's position when the target blend shape's value is set to 0, and when the target blend shape's value is set to 1. We found the closest point on this line and the corresponding linear interpolation value (clamped to [0,1]) was then set as the target weight for the corresponding blend shape. Because of the way the Unity animation system works, it was necessary to extract two full avatar meshes each frame (even though, theoretically, only one was need to find two vertex positions); however, no run-time issues were incurred by using this technique and the application ran at the native frame rate of the display (90Hz).

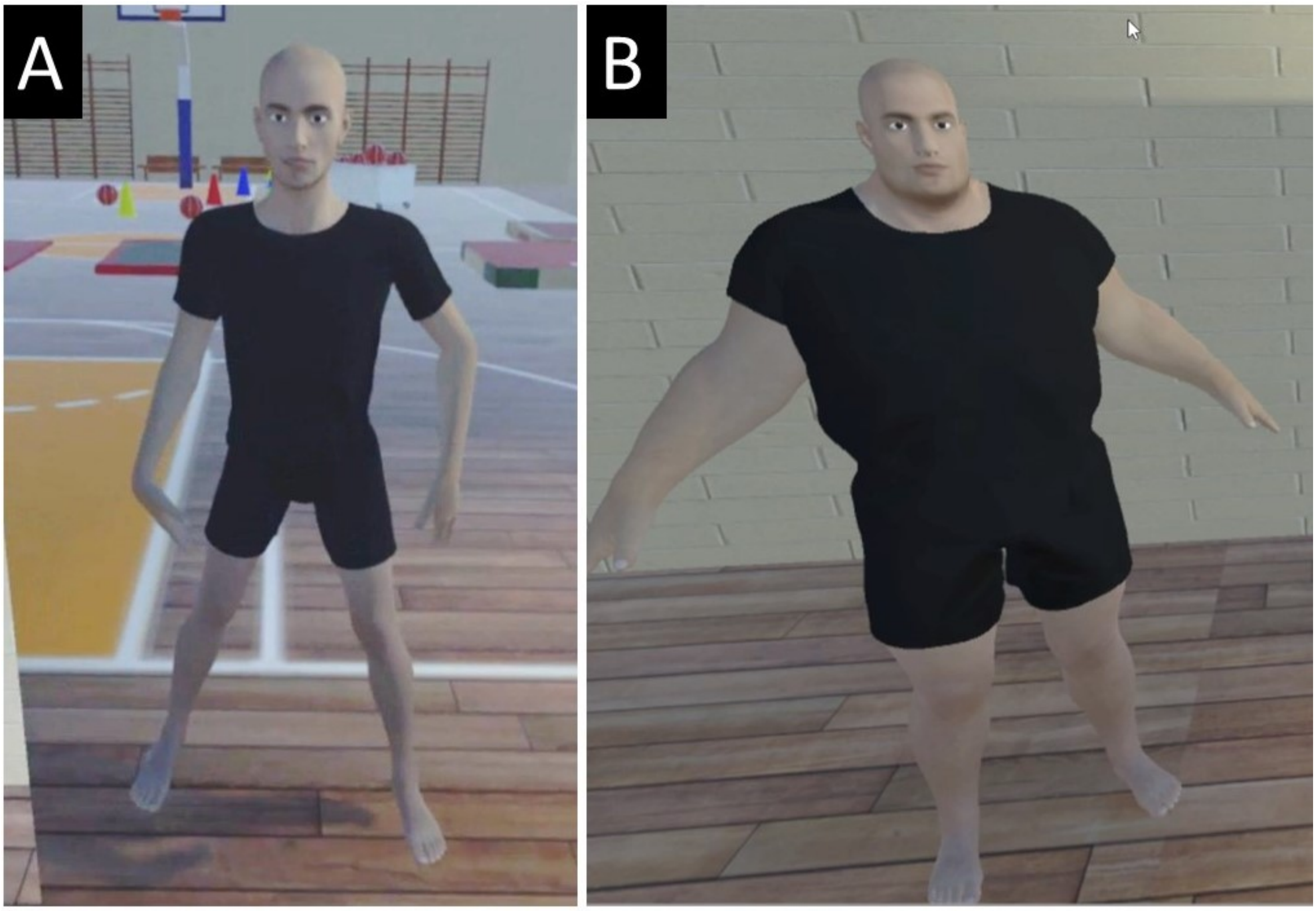


**Figure 1. Skinny and Large avatar blendshapes**: Participants customized the avatar between two blend shapes. (A) Blend shape of the thinnest avatar. (B) Blend shape of the largest avatar

### 3.4 Avatar Configuration

The avatar was configured with two blend shapes. The first blend shape modified the size of the upper body between thin and larger, (see Figure 1). The second blend shape modified the lower body in a similar manner. The blend shapes thus form a space of two independent parameters both in range [0,1]. Participants controlled the same underlying two parameters in both first-person and third-person conditions, but by different mechanisms:

- In the *first-person condition*, when modifying an avatar, the participant faced a mirror and could pull and push their own avatar. Participants could grab their self-avatar by either hand by pulling on the trigger of the hand-held controller (see Figure 2). To implement this, on the trigger pull, the nearest vertex point of the current avatar mesh was found. If the participant grabbed below their navel, we subsequently modified the weighting of the lower blend shape, otherwise we modified the upper blend shape.
- In the *third-person condition*, when modifying an avatar, the participant interacted with two 3D slider bars just in front of them (see Figure 2). They were modifying a mannequin facing them. This mannequin used the same avatar blend shapes as the participant's self-avatar. Participants had to grab the sliders with either controller. The percentage values of the sliders were directly mapped to the two parameters of the mannequin's blend shapes.

### 3.5 Protocol

The participants arrived, read a participant information sheet, confirmed and provided their written consent, and completed a short demographic questionnaire. They then completed the Implicit Association Test for the first time (see Section 3.6 and Figure 5(B)).

Next, participants donned the waist belt and the HMD, and then were passed the handheld controllers. They underwent two VR experiences (Figure 2). In the first one they were asked to create an avatar to match themselves (self-avatar experience), the second one they were asked to create an avatar that was very large (large-avatar experience).

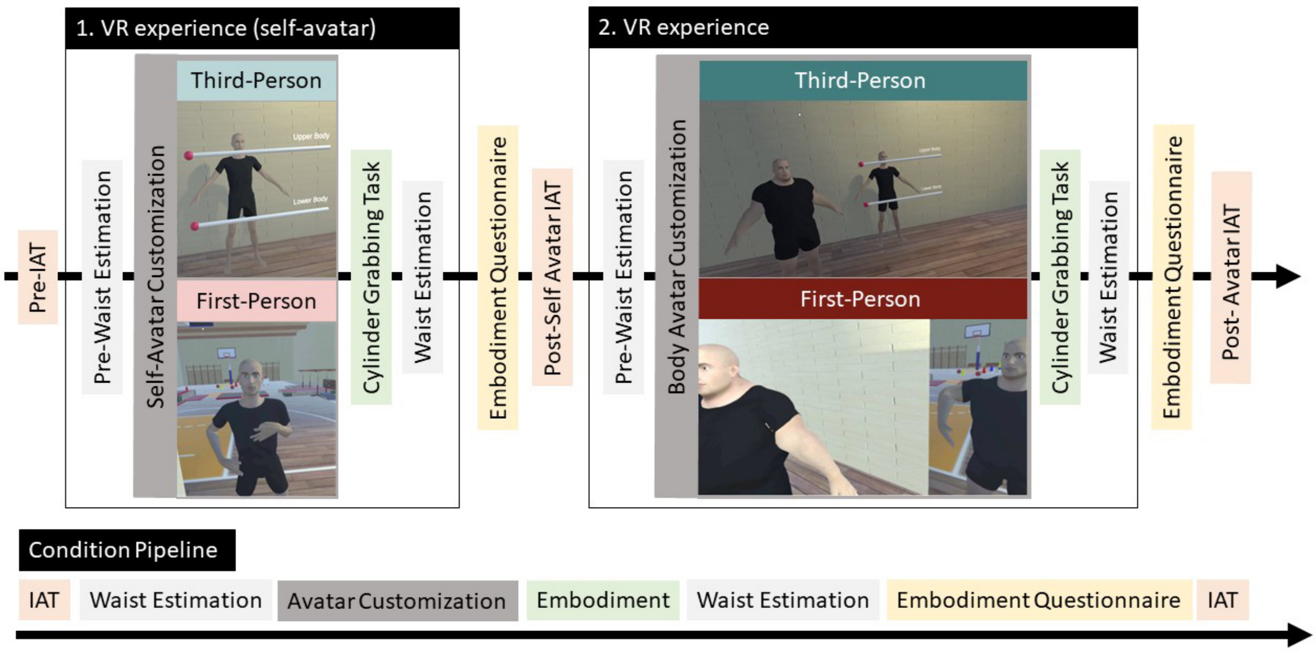


**Figure 2. Experimental Protocol** Each participant underwent two VR experiences to create first a self-avatar and then a larger-avatar. Participants were assigned either a first-person or a third-person condition. All participants completed the condition pipeline for each VR experience comprising of pre-post measurements of IAT and waist estimation as well as a post embodiment questionnaire

Each VR experience was comprised of four stages (Figure 2), transitions between stages were masked by the visuals fading to and from black over 1 second:

1. Waist Perception Scene 1: In this stage, we asked participants to indicate where they perceived their real waist to be. We also configured the height of the self-avatar used for the rest of the experiment.
2. Avatar Configuration Scene: In the second stage, participants transitioned to a scene where they would configure their self-avatar in either the first-person or third-person manner. In the self-avatar experience, they were asked to make the avatar the same shape as themselves (Figure 2). In the larger-avatar experience, they were asked to match the self-avatar to an larger model (Figure 2).
3. Embodiment Scene: Right after the avatar configuration, the participants embodied their recently created avatar from stage 2, and played a simple Whack-A-Mole type game where they had to repeatedly reach

cylinders that appeared in front of them. The aim of the game was to generate high embodiment over the avatars as triggered by synchronous sensorimotor stimulation (González-Franco et al., 2010; Kokkinara & Slater, 2014). The game was played for 90 seconds after which participants transitioned to the fourth stage.

4. Waist Perception Scene 2: In this stage, participants repeated the waist measuring task (Figure 5(A)).

The participants then removed the HMD and other devices and completed an embodiment questionnaire and another IAT (Figure 5(B)).

Right after the self-avatar experience participants geared up again and completed the second VR experience making their avatar larger. The difference between both experiences was that in the second stage of the procedure, they were asked to manipulate the avatar to match another model placed off to the left that had an larger body shape (perceived BMI $> 30$) (see Figure 1(B) and 2). After completing this second VR experience, they completed a second embodiment questionnaire and a third IAT.

## 3.6 Measures

### 3.6.1 Avatar Acceptance

We use a standard embodiment questionnaire to evaluate avatar acceptance Gonzalez-Franco and Peck (2018). Embodiment questionnaires are a common way to assess the level to which participants have accepted their self-avatars as their own body. Low embodiment indicates a rejection against the avatar body. High embodiment scores indicate high acceptance of the avatar body.

We used 15 items from 25 questions from the Peck & Gonzalez-Franco questionnaire Gonzalez-Franco and Peck (2018). Participants filled out questions probing different aspects of embodiment (i.e., body ownership, sense of agency, sense of spatial co-location) following the self-avatar and larger-avatar virtual experiences in both the first and third-Person Conditions. We did not include the sub-scales on touch and external stimuli. The questions included were thus as follows:

Q1 I felt as if the virtual body I saw when I looked down was my body.
Q2 It felt as if the virtual body I saw was someone else.
Q3 It seemed as if I might have more than one body.
Q4 I felt as if the virtual body I saw when looking at myself in the mirror was my own body.
Q5 I felt as if the virtual body I saw when looking at myself in the mirror was another person.
Q6 I felt like I could control the virtual body as if it was my own body.
Q7 The movements of the virtual body were caused by my movements.
Q8 I felt as if the movements of the virtual body were influencing my own movements.
Q9 I felt as if the virtual body was moving by itself.
Q10 I felt as if my body was located where I saw the virtual body.
Q11 I felt out of my body.
Q12 I felt as if my (real) body were drifting towards the virtual body or as if the virtual body were drifting towards my real body.
Q13 It felt as if my (real) body were turning into an 'avatar' body.
Q14 I felt like I was wearing different clothes from when I came to the laboratory.
Q15 I felt as if the size of the world changed during the experience.

The participants rated their agreement to the above statements on a -3 to 3 Likert scale, where -3 was anchored to strong disagreement and 3 to strong agreement. Questions 1-5 probed feelings of ownership (questions 2, 3, & 5 served as control questions) over the virtual avatar. Questions 6-9 probed feelings of the sense of agency over the virtual avatar (questions 8-9 served as control questions). Questions 10-12 probed the participants sense of co-location with the virtual avatar (questions 11 & 12 designed as control questions), and Questions 13-15 probed the participants extent to which participants felt they took on the physical characteristics of the virtual avatar, and were designed as control questions. Control questions served to rule out response bias or demand characteristics.

### 3.6.2 Change in Body Size Ratings

We asked two additional questions following each VR experience. In these questions participants reported the extent to which they felt larger in the virtual environment:

Q1At 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.
Q2I felt as if the size of my body changed during the experience.

The participants were asked to rate their agreement with the statements on a -3 to +3 Likert scale, as they did on the embodiment questionnaire above. Responses to these questions were then averaged together to obtain a Body-Size rating estimate for each VR experience for each condition.

### 3.6.3 Real Waist Perception Measurement

In addition to the body-size ratings, participants were also asked to report the perceived location of their real waist before and after the experience in VR (see Figure 3.6(A)). As soon as participants put on their HMD, they were asked to set their waist size using their right-hand controller. They could not see a self-avatar nor their body during this process. The visual representation of the right-hand controller had a small ball on a short rod, that they needed to place where they thought their waist would be. The distance between the ball and the line on the actual waist as measured by the two Vive Puck trackers on the waist was recorded.

### 3.6.4 Implicit Association Test

The implicit negativity bias towards larger people was measured by requiring the participants to quickly categorize silhouette images of people (larger or thin) and words (positive or negative) into groups following a balanced paired test (see Figure 5B). Each time a participant run the IAT they underwent 6 blocks:

block 1) image learning trial of association. A siluete of a fat or thin body is associated with either the words ”Fat” or ”Thin”.

block 2) word learning trial of association. A positive or negative word ”good, joy, love, peace, wonderful, pleasure, glorious, laughter, happy, bad, agony, terrible, horrible, nasty, evil, awful, failure, hurt” is associated with positive or negative.

block 3) first paired test: positive words/images are to be associated to thin and negative words/images are to be associated to fat.

block 4) reverse image and words learning trial.

block 5) second paired test: positive words/images are to be associated with fat and negative words/images are to be associated with thin.


**Figure 3. Perception and IAT Measures**(A) Participant completing the blind waist perception estimation. (B) Instructions and examples of silhouettes used in the Implicit Association Test (IAT).

The implicit bias can then be calculated from the differences in accuracy and speed between these categorizations (e.g., Thin Person and Positive Words; and Overweight Person and negative words, compared to the opposite pairings). The scores were obtained using freeIAT software[2] and the GNB score was calculated using the method described in Greenwald et al. (2003).

Which can be summarized as follows: Computes mean and SD of Reaction Time (RT) for items in Blocks 3 and 5. GNB score is the average corrected RT from Block 5 minus the average corrected RT from Block 3 and divided by the pooled SD.

Elimination of outliers: ”TooSlow” trials with reaction times (RTs) ¿ 10,000 ms, a participant would be discarded from analysis if it has more than 10% of “TooFast” RTs ¡ 300ms trials.

More details on the computation can be found in Greenwald et al. (2003) Table 4.

Higher IAT scores indicate a greater association with the overweight body images and positive words and thin body images and negative words whereas negative scores indicate a greater association with overweight body images and negative words, and thin body images and positive words (see Figure 3(B)).

### 3.7 Analyses

Two-factor ANOVAs (with avatar customization condition, i.e., first vs. third-person avatar customization as a between subjects factor; and VR experience, i.e., self-avatar vs. larger-avatar, as a within subjects factor) were used to examine the questionnaires, IAT, and waist estimation data. Normality of the residuals were assessed using a Shapiro-Wilk test for normality, and visual inspection of the qq-plots. Paired-comparisons were made using t-test, or non-parametric Wilcoxon signed ranked tests when normality was not met. Normality of the paired differences for all planned comparisons were assessed using a Shapiro-Wilk test for normality. Further assessment of our results was carried out using Bayes Factor (BF) t-tests (i.e.,

$$BF_{10} = (P(D|H_1))/(P(D|H_0))$$

). These tests were conducted comparing the relative evidence of the alternative hypothesis (i.e.,

$$\mu_{self-avatar} - \mu_{larger-avatar} \neq 0$$

) over the null hypothesis (i.e.,

$$\mu_{self-avatar} - \mu_{larger-avatar} = 0)$$

using the R package BayesFactor Morey et al. (2018).

## 4 RESULTS

### 4.1 Embodiment Scores

To examine whether there were differences in the overall experience of embodiment across conditions, we averaged the responses to embodiment questions and the reverse-coded control questions. Calculating an embodiment score in this way provides an unbiased estimate of the feeling of embodiment of the virtual avatar that controls for potential response bias or demand characteristics (see Figure 6 in Appendix A). A two-factor ANOVA revealed that there was a significant effect of VR experience (F (1, 20) = 6.20, p = .023) (see Appendix A).

[2] https://meade.wordpress.ncsu.edu/freeiat-home/; version 1.3.3

Planned comparisons between VR experiences in the third-person avatar customization condition revealed a significant decrease in embodiment during the larger-avatar VR experience compared to the self-avatar VR experience t(10) = 2.69, p = .023, d = .95, 95% CI = [0.10, 1.07]. A Wilcoxon signed- rank test showed no significant difference in embodiment between self-avatar and larger-avatar experiences in the first-person avatar customization condition V(10) = 48, p = .196, d = .25, 95% CI = [-0.26, 0.44] (see Figure 4).

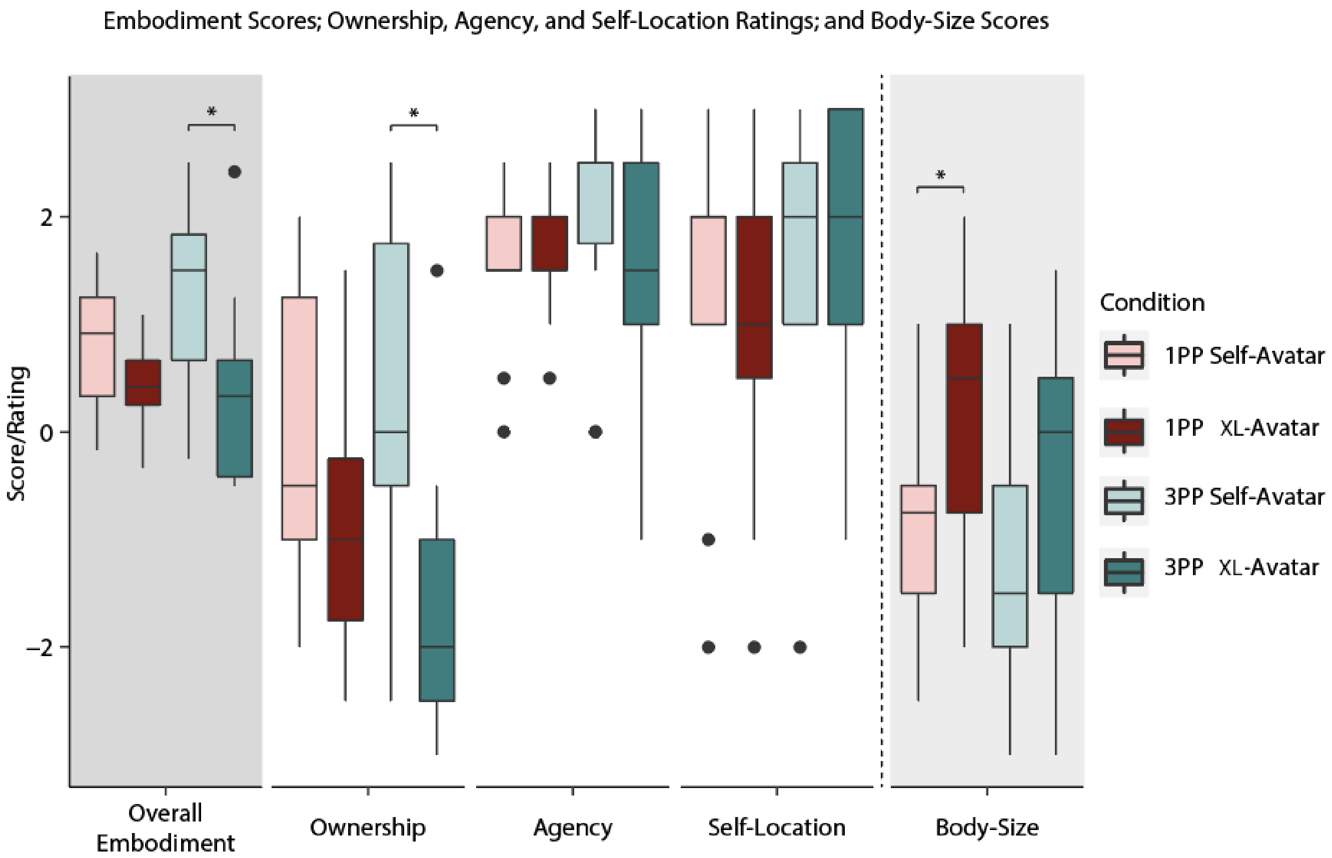


**Figure 4. Embodiment scores and summarized questionnaire ratings** Box and whisker plots of the embodiment score and ratings to key factors underlying embodiment. Median values are displayed as horizontal bars within colored boxes, interquartile ranges (upper and lower bounds of the boxes) and ± 1.5 times the upper and lower quartiles (upper and lower whiskers), with outliers beyond this shown as single points. Asterisks between bars indicate significant differences between self- and larger-body avatar experiences (*ps ¡ .05).

These results suggest that participants who configured their avatar in first-person were more likely to accept and less likely to disembody the larger-avatar than those in third-person. To further corroborate this interpretation, we ran an additional post-hoc Bayes Factor (BF) t-tests between self- and larger-avatar VR experiences in the third-person and first-person avatar conditions revealed anecdotal evidence ($BF_{10}$ = .35) Jeffreys (1998) in favor of the null hypothesis over the alternative hypothesis in the first-person avatar customization condition, and moderate evidence in favor of the alternative hypothesis in the third-person avatar customization condition ($BF_{10}$ = 3.15).

These findings show that creating a larger-avatar in a third-person perspective significantly reduced the subsequent experience of overall embodiment in a larger-avatar compared to when a self-avatar was created in a first-person perspective; and that creating a larger-avatar from the first person perspective did not change the overall experience of embodiment compared to creating a self-avatar from a first person perspective.

Embodiment is traditionally described as the combination of 3 factors: body ownership, agency and self-location Kilteni et al. (2012a). Thus, in order to explore which aspects of embodiment triggered the drop in acceptance of the body for the 3rd person avatar design, we analyzed the questionnaire items associated with each of these subcategories:

**Ownership Ratings** Planned comparisons checked the mean ratings to ownership questions between self- and larger-avatar VR experiences in the first- and third-person avatar customization conditions. A paired t-test revealed a significant decrease in the experience of body ownership of the larger-avatar compared to self-avatar VR experience in the third-person avatar customization condition ($t(10) = 3.65$, $p = .004$, $d = 1.50$, 95% CI = [0.83, 3.43]), however, no significant difference was observed between the ownership ratings between self- and larger-avatar VR experiences in the first-person avatar customization condition ($t(10) = 1.66$, $p = .127$, $d = 0.63$, 95% CI = [-0.27, 1.91]) (see Figure 5).

Additionally, Bayes Factor t-tests comparing the relative evidence of the alternative over the null hypothesis of a change in ownership ratings between self- and larger-body avatar conditions revealed anecdotal evidence in favor of the null hypothesis ($BF_{10} = .86$) in the first-person avatar condition, and strong evidence in favor of the alternative hypothesis in the third-person avatar customization condition ($BF_{10} = 11.78$). These findings suggest that creating a larger-avatar in the third person led to a significant decrease in the experience of body ownership compared to when a self-avatar was created in the third-person perspective, and that creating a larger-avatar in the first-person perspective had no effect on the experience of ownership or larger- or self-avatars.

**Agency Ratings** The mean ratings for questions probing the sense of agency in the self- and larger-avatar conditions were compared using planned comparisons for participants in the first- and third-person avatar customization conditions. This analysis revealed that there were no significant differences in the experience of the sense of agency in the first- ($V(10) = 6$, $p = 0.78$, $d = 0.21$, 95% CI = [-0.95, 0.21]) or third-person ($t(10) = 1.61$, $p = 0.137$, $d = 0.38$, 95% CI = [-0.17, 1.08]) conditions.

**Self-Location Ratings** Responses to the self-location questions were compared between VR experiences in the first- and third-avatar customization conditions using Wilcoxon-Signed Rank tests. No significant differences between self- and larger-avatar VR experiences were found in planned comparisons on participants perceived co-location with the virtual avatar for participants in the first- ($V(10) = 16$, $p = 0.79$, $d = 0.12$, 95% CI = [-1.49, 2.00]) and third-person ($V(10) = 8$, $p = 1$, $d = 0.0$, 95% CI = [-0.53, 0.53]) avatar customization conditions.

### 4.2 Change in Body Size Ratings

To examine whether there were significant changes in the experience of the size of the body between the self- and larger-avatar conditions, the mean body size ratings were compared using planned comparisons in the third- and first-person avatar customization conditions. A paired t-test revealed that there was a significant increase in the experience of the body-size in the larger-avatar condition compared to the self-avatar condition for participants in the first-person avatar customization condition ($t(10) = 2.22$, $p = 0.05$, $d = 0.93$, 95% CI = [-3.00, 0.00]). However, no significant difference in the perceived body size was found between self- and larger- avatar conditions for participants in the third-person avatar customization condition $t(10) = 1.61$, $p = 0.13$, $d = 0.56$, 95% CI = [-1.73, 0.27]) (see Figure 4).

Additional Bayes Factor t-tests revealed anecdotal evidence ($BF_{10}$ = 1.70) in favor of the alternative hypothesis over the null hypothesis in the first-person avatar customization condition, and anecdotal evidence ($BF_{10}$ = 0.81) in favor of the null hypothesis in the third-person avatar customization condition. These findings suggest that while participants in the first-person avatar customization condition experienced a significant increase in their body size when embodying the larger-avatar compared to their self-avatar, the participants in the third-person avatar customization condition did not experience an increase in their body size when embodying the larger-avatar.

## 4.3 Waist Measurement Perception

We examined whether the experimental manipulation significantly altered the perception of the participants real waist by first calculating the post- minus pre- VR experience (i.e., self-avatar and larger-avatar) waist location estimations for both the first- and third-person avatar customization conditions. An two-way analysis of variance with avatar customization condition as a between-subjects factor, and VR experience as a within-subjects factor, revealed that there was no significant main effect of avatar customization condition (F (1, 40) = 1.54, p = .22), no main effect of VR experience (F (1, 40) = 1.12, p = .296), and no significant interaction (F (1, 40) = 0.163, p = .688). These results are interesting because they suggest that although avatar embodiment affected the perception of body size within the virtual environment in the first-person avatar customization condition, it did not significantly alter the participants' perception of their real waist location when they were asked to explicitly report it during the waist-size estimation task.

Although there was no significant difference between the waist estimations in the self- and larger-avatar experiences for the first- or third- person avatar customization conditions, we were interested in examining whether individual differences in participants' self-reported waist size measurements were positively correlated with the experience of the body size. This analysis (Pearson's r) revealed that there was a positive correlation between the sense of ownership and the perceived increase in body size in the larger-body experience in the first-person avatar customization condition (r(9) = 0.49 p = .06, one-tailed). That is, the larger the participants indicated their real waist size to be following the larger-body VR experience, the more they reported experiencing an increase in their body-size during the experiment. In contrast, no significant correlation was found between the waist size estimates and the body size ratings following the larger-body VR experience in the third-person avatar customization condition (r(9) = -.64 p = .98, one-tailed). This result suggests that although there was no significant difference in waist size estimates between the self-and larger-body avatar VR experiences, there was a significant positive relationship between individual differences in the waist-estimations and the experience of feeling larger in the first-person condition. This relationship was absent, however, in the third-body condition.

## 4.4 Implicit Association Test

A two-factor Analysis of Variance (ANOVA) was conducted on the IAT data with condition (first-person avatar customization, third-person avatar customization) as a between-subjects factor, and Order (pre-VR experience, post- self-avatar experience, post-larger-avatar experience) as a within-subjects factor. The ANOVA revealed that there was a significant effect of Order, F (1, 20) = 5.35, p = 0.007. However, no significant effect of Condition was observed F (1, 20) = 1.27, p = 0.264. Additionally, no significant interaction between Condition and Order was observed F (1, 20) = 0.128, p = 0.879.

Planned comparisons revealed there was no significant difference between IAT data following the self-avatar VR experience compared to the pre-VR experience IAT data (t(10) = 1.67, p = 0.125), nor between the larger-avatar VR experience IAT data compared to the pre-VR experience IAT data (t(10) = 1.52, p = 0.158). Therefore, the order effect could be due to a learning effect, which has also been reported in the past as a weakness of IATs in general, and the reason why sometimes only the last trials of each IAT block are used for computing the biases (Greenwald et al., 2003).

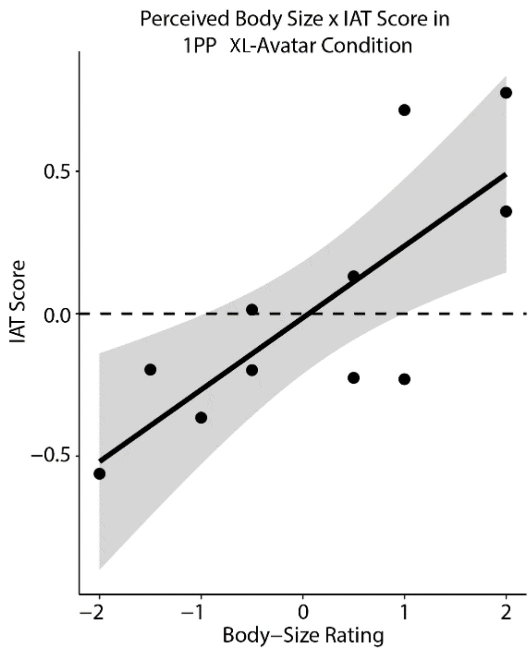


**Figure 5. Body Perception correlates with IAT** Positive relationship between perceived body size and IAT in the first person avatar customization condition. There was a significant positive relationship between the perception of an increased body size and the IAT score for participants following the larger-avatar virtual experience in the first-person avatar customization condition. Each point represents each participant in the first-person avatar customization condition. The solid line depicts the regression slope and intercept, and included the 95% confidence interval bands (shaded area). The dotted line represents the division between positive implicit associations (all values above the dotted line) towards larger people and negative implicit associations (all values below the dotted line).

Although no significant differences were observed in the IAT data obtained following the self- and larger-avatar experiences in either the first- or third-person avatar customization conditions, we also wanted to examine whether the individual differences in the IAT were significantly related to the perception of increased body size in the first-person avatar customization condition following the larger-avatar body experience.Individual differences have been found in the past to change outputs of VR experiences and results when it comes to embodiment and size perception Gonzalez-Franco et al. (2019).

A linear regression analysis revealed a significant positive relationship between body-size ratings and the IAT scores, whereby the perceived body-size ratings significantly predicted the IAT scores ($\beta$ = 2.41, t(9) = 3.75, p = .005) and that body size ratings also explained a significant proportion of variance in IAT scores (R2 = .60, F(1, 9) = 14.04, p = .005)(see Figure 5). No significant relationship between the perceived body size ratings and the IAT scores were observed following the larger-avatar VR experience for participants in the third-person avatar customization condition ($\beta$ = -0.88, t(9) = -0.91, p = .384) and there was not a significant proportion of variance of IAT scores explained by the perceived body size ratings (R2 = .09, F(1, 9) = 0.84, p = .384). These findings suggest that the greater the experience of having a larger-body in the larger-avatar VR experience was for participants the more larger-people were associated with positive words in the IAT task. However, this reduced bias only existed in the first-person avatar customization condition, and that association was absent in the third-person avatar customization condition.

## 5 DISCUSSION

Our research shows how the avatar customization processes, whether in first-person or third-person, affects the embodied experience in VR. This has potential implications for bias reduction in empathetic applications. Prior experiments have established that bias reductions based on the appearance of self-avatars depend on the embodiment level that participants experience towards the avatar Maister et al. (2013); Peck et al. (2013), however, these experiments did not ask participants to modify the appearance of their own avatars. The avatars were simply given to them. On the other side there have been several experiments dealing with body shape alteration and larger avatars, but they have generally not dedicated to the topic of Implicit Bias, but other aspects such as body schema, body anxiety, and other body disorders Hudson et al. (2020). Despite our morphing approach based on blend shapes is not complex, and was not designed to discriminate sportive people with high BMIs from people who would be classified by their BMI as being overweight or obese, we believe that our findings would also transfer in that context.

There are significant behavioral implications of users' avatar appearance and self-customization Bailey et al. (2009); Gonzalez-Franco et al. (2016a). For example, in a study using video games, researchers found that children were more aroused towards junk-food advertisements when they had designed their own avatars Bailey et al. (2009). This work, despite not being in VR, found that users' sense of presence was the key factor in their arousal response Bailey et al. (2009). In our study, we explored the importance of self-customization of avatars and its implications towards bias reduction, but inside VR. We found that, if the avatars were customized in a third-person manner, larger-avatar embodiment significantly decreased in comparison to a self-body avatar embodiment. That is, participants had a reduced acceptation of the larger body. On the contrary, we found that if the customization of the larger-avatar had occurred in first-person perspective the reduction in embodiment did not exist. That is, there was no difference in embodiment between the larger- and self-avatar VR experiences when the avatars were created inside out, suggesting that participants felt equally embodied in both experiences, but that was only true when they had customized the avatar in first-person.

An examination of the perceived body-size ratings revealed that only participants in the first-person avatar customization condition experienced a significant increase in their perceived body size when embodying the larger virtual avatar, and that participants in the third-person avatar customization condition did not. These findings suggest that the reduced sense of ownership over the larger virtual avatar may have prevented participants from having the experience of being larger in third-person avatar customization condition. We further found that the increase in perceived body size was positively correlated with the IAT scores following the larger-avatar body condition for avatars customized in first-person, whereas no significant difference in body-size ratings or correlation with the IAT was observed for participants in the third-person avatar customization condition.

The lack of significant difference at the IAT scores directly following the self-avatar and larger-avatar VR experiences might be due to the fact that altering the shape of the body to achieve significant bias reductions may require more time of embodiment than the 90 seconds that lasted our exposure. Considering that all participants were coming from similar demographics (men of normal bmi) the null IAT results also sh that both groups were similar in their original bias to body size. Nevertheless, even with the short exposure time, we observed that individual variability in the participants experience of having an increased body-size during the larger-avatar VR experience was significantly predicted by participants IAT scores in the first-person avatar customization condition. That is, the greater the feelings body-size ratings were, the stronger the association was between overweight images and positive words were.

We can relate our findings to the ongoing discussion about embodiment and agency in immersive systems Kilteni et al. (2012a). Sense of agency has been separated from embodiment as being the sense of ”global motor control, including the subjective experience of action, control, intention, motor selection and the conscious experience of will” Blanke and Metzinger (2009). Agency thus seems a natural consequence of being active in the environment and using ones body. Indeed early demonstrations of a body ownership illusion in virtual reality used self-motion rather than tactile inductions Sanchez-Vives et al. (2010); Yuan and Steed (2010) and some have even found bodily illusions might be more powerful with motion than in tactile stimulation Kokkinara and Slater (2014); Spanlang et al. (2014). Agency has also the capacity to create stronger self-avatar follower effect Gonzalez-Franco et al. (2020a) and can be used to redirect the actions of participants Maselli et al. (2023). This can be contrasted with methods that use self-observation and reflection on ones own body (e.g. Tajadura-Jiménez et al. (2017)). Our work somewhat switches between the two modes of engagement with the self avatar: in the first-person mode, participants actively engage with their bodies when changing the shape, but this is only a small component of the experience. During the cylinder grabbing task they are not focused on their own body. Indeed one of the participants commented that they were very aware of their body during the avatar phase, but once they had started the game, they were just “there” doing the game. We can draw two hypotheses from this: either being embodied in a task that doesn’t involve reflection on the avatar is still having an unconscious bias effect; or the initial embodiment phase is having an impact over a duration of at least a few minutes. Determining which could have a significant impact on embodiment systems. In the former case, the self avatar’s location and behavior might have an impact no matter the time the user spends on customizing it. This suggests that as a field we might need to reflect on the default avatars that users choose, or even whether users should be required to do some customization. In the latter, then the key question is the length of time of which the induction has, and whether it can be reinforced by occasional reflection (e.g. seeing oneself in a mirror). This sort of implicit embodiment with altering effects to later behavior was also patent in the Pinocchio VR illusion, where researchers found that despite the focus of attention was on the nose, changes to the arm size were internalized by users who later exhibited extended reach perception, despite most being unaware of the arm manipulation. Showing that even if there isn’t much attention on the body we do internalize the body of the avatar we embody Berger et al. (2022).

We can make a connection between our work and the work on attitudes of users towards avatars over longer exposure. While this has only recently been studied in an immersive context (e.g. Freeman and Maloney (2021)), there is a rich literature on how avatar customization motivates engagement and motivation in games Birk et al. (2016) and how this is related to identity Waggoner (2009). We can contrast that work with studies such as Fitton et al. who showed that minimal customization has a large impact on a training task Fitton et al. (2023). Additionally results from neuro-physiology of look alike avatars, has also shown that overtime self-avatars are perceived more like self in the visual cortex, even if they are not photo-realistic Gonzalez-Franco et al. (2016b), further showing that adaptation to the virtual body increases overtime. As opposed to disembodied interactions in social VR it is important that participants feel connected to their avatars and their actions to perhaps maintain their moral compass. Similar recommendations have been done by philosophers Madary and Metzinger (2016) in which they talk about ”Illusions of Embodiment and Their Lasting Effect”.

Our work gives users a different way to engage with their self representation, and thus quite a range of avatars are achievable. This raises an interesting question of how much precision and variety is required to support the different impacts (embodiment, task engagement, performance, etc.) that a system designer might want. Modifying avatars takes the user time, and while it is a rewarding activity in itself for some users, we speculate that some users will be content with very crude controls as long as they can reach something approaching their desired avatars, be it a representation of themselves at the current time, or a fictitious representation. In some situations, when self-identity should be preserved, users my opt for real scans and reproductions of their own bodies, while in other cases parameterized avatars might be a solution Gonzalez-Franco et al. (2020b). But independently of the approach that generates the first iteration of the user avatars, the results from our experiments point in the direction that if we want users to feel like this is their body, they should rather customize and adjust these avatars from a first person perspective.

We note a limitation of our study in that the participants were all male and we used a avatar that had a male appearance. We note that there are significant differences in response to body image between men and women (e.g. MacNeill et al. (2017); Quittkat et al. (2019)). We acknowledge that the study would need to be re-run with female participants in order to generalise, and indeed that virutal reality interaction might itself have a gendered effect (see Peck et al. (2020)).

Finally we reflect on the first-person embodiment mechanism itself. While participants had no trouble changing their size as instructed, because the scaling was based on contact, they would often scale the avatar to the ends of the scales quite quickly. We often saw users have to grab their upper or lower body and then gauge the small movements required. We can suggest that other mechanisms might be superior such as pushing and pulling in relative rather than absolute scales, and having the impact on a small region spread out over time, or using an indirect mechanism that shrunk or inflated the parts. Our mechanism should work for larger changes. We would also be very interested in other mechanisms such as putting on or removing clothes as mechanisms. In the end our appearances are shaped by our body but also by how we dress. And our performance in virtual worlds is highly affected by the appearance Kilteni et al. (2013).

## 6 CONCLUSIONS

In this paper we have explored the impact of self-avatar customization on embodiment and bias. Our findings suggest that selecting and designing a larger-avatar from the first-person perspective is positively associated with the experience of being larger when embodied in the larger virtual avatar.

We believe having users create and embody larger-body avatars from the first-person perspective may not only lead to greater embodiment, but also to greater feelings of empathy towards larger people in the longer term. Our findings also show that the standard method of selecting and designing avatars from a third person perspective may work fine when the avatars are designed to represent yourself, but backfire and reduce the experience of embodiment when the avatar is unlike yourself. Indeed, these findings are also important for our understanding of the sense of embodiment in virtual avatars, and how much the external appearance can play on the embodiment, and more importantly show how the choice for design of avatars has potential ethical implications for VR applications.

There are important practical and ethical significance derived from our research regarding the current use, design, and development of virtual avatars. With particular implications for the cases in which a therapeutic, empathetic or bias reduction effect is sought. Specifically, our results show that users were less embodied in the larger-body avatar and this might suggest that users were 'othering' the virtual avatar (i.e., psychologically distancing themselves) when creating it from the third-person perspective. Users are, therefore, likely to be less empathetic to larger-size avatars and people during and after VR experience in a larger-sized avatar in that condition. In contrast, our findings showed a significant positive relationship between positive implicit associations with larger-size bodies and feelings of having a larger body if the customization happened inside out, i.e. in first-person condition. When participants experienced the larger-size body truly as themselves. This interpretation is in line with previous work however, future research will need to be carried to further understand the short and long-term behavioral consequences of self-avatar customization and implicit biases.

Finally we highlight that the first-person avatar customization suggests that the way in which the self-avatar is manipulated or chosen should be explored in more depth. We expect that this can be extended to other aspects such as more degrees of freedom of the body shape, and potentially other characteristics such as skin color, clothing and jewelry. An active engagement in the process of self-avatar change might aid the embodiment in the changed avatar.

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## DATA AVAILABILITY STATEMENT

The datasets generated and analyzed for this study can be found attached.

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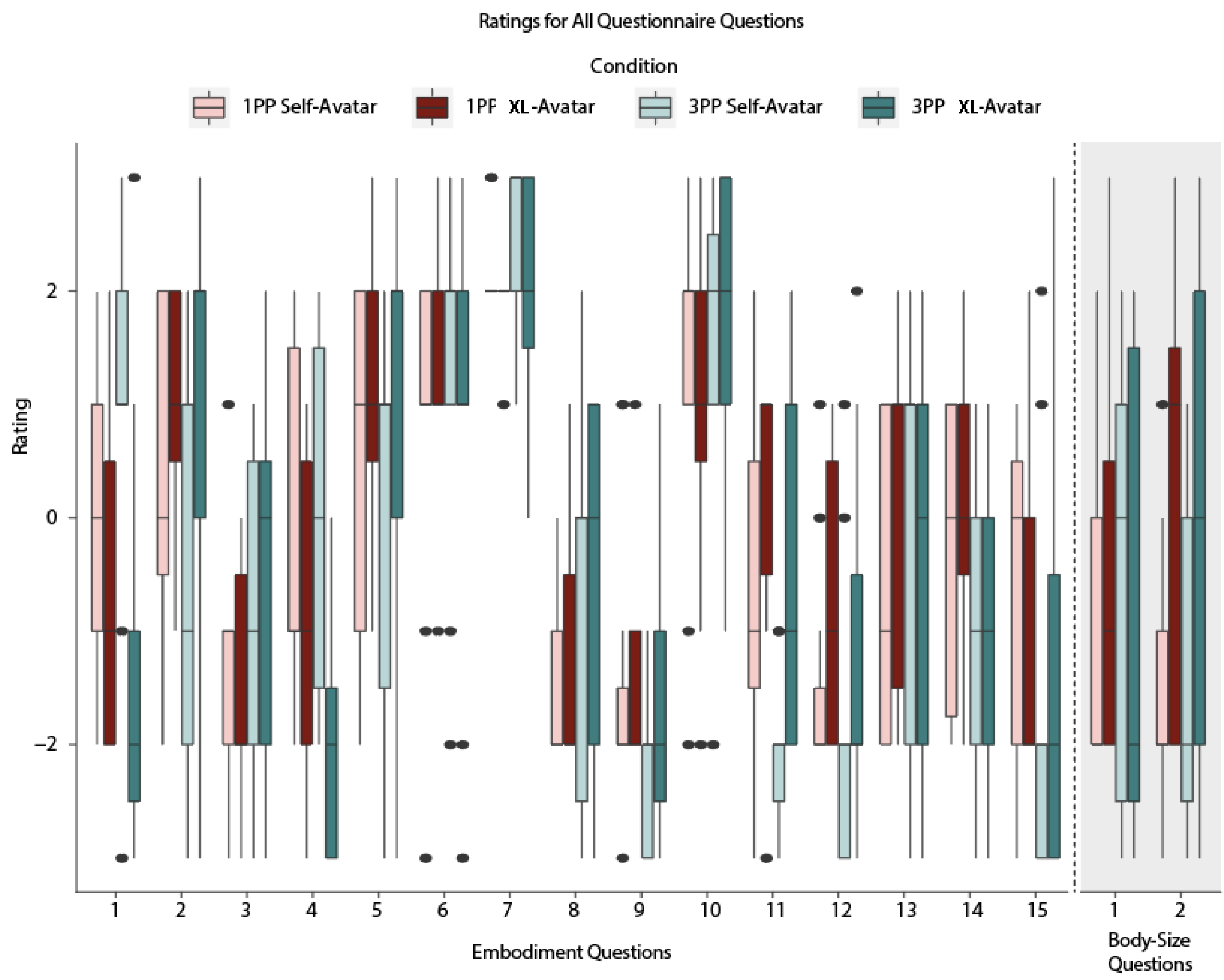
# SUPPLEMENTAL MATERIAL

## *Appendix A*

### Additional Analysis of Embodiment Scores

In the main two-factor ANOVA on the embodiment scores, with avatar customization condition as a between-subjects factor, and VR experience as a within-subjects factor, no significant main effect for avatar customization condition was observed (F (1, 20) = .0698, p = .0413). Additionally, no significant interaction between avatar customization condition and VR experience was observed F (1, 20) = 2.95, p = .101.

**Full Questionnaire Results** Figure 6 shows box and whisker plots of the questionnaire results for all Embodiment and Body-Size questionnaire showing the median responses (horizontal bars within colored boxes), interquartile ranges (upper and lower bounds of the boxes) and ± 1.5 times the upper and lower quartiles (upper and lower whiskers), with outliers beyond this shown as single points (Top panel). Questionnaire question number key for questionnaire plot (Bottom panel). Key experimental questions are marked with an asterisk. All other items are control or reverse scored questions.




Question Number Key

Embodiment Questions

1. I felt as if the virtual body I saw when I looked down was my body.*
2. It felt as if the virtual body I saw was someone else.
3. It seemed as if I might have more than one body.
4. I felt as if the virtual body I saw when looking at myself in the mirror was my own body.*
5. I felt as if the virtual body I saw when looking at myself in the mirror was another person.
6. I felt like I could control the virtual body as if it was my own body.*
7. The movements of the virtual body were caused by my movements.*
8. I felt as if the movements of the virtual body were influencing my own movements.
9. I felt as if the virtual body was moving by itself.
10. I felt as if my body was located where I saw the virtual body. *
11. I felt out of my body.
12. I felt as if my (real) body were drifting towards the virtual body or as if the virtual body were drifting towards my real body.
13. It felt as if my (real) body were turning into an 'avatar' body.
14. I felt like I was wearing different clothes from when I came to the laboratory.
15. I felt as if the size of the world changed during the experience.

Body-Size Questions

1. At some point if felt as if my real body was starting to take on the posture or shape of the virtual body that I saw.*
2. I felt as if the size of my body changed during the experience.*

**Figure 6.** Full Questionnaire Results