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Priming and personality effects on the Sense of Embodiment for human and non-human avatars in Virtual Reality

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Abstract

The increasingly widespread use of Virtual Reality (VR) technology necessitates a deeper understanding of virtual embodiment and its relationship to human subjectivity. Individual differences and primed perceptual associations that could influence the perception of one's virtual body remain incompletely explored. In the study outlined below, we exposed participants to human and nonhuman avatars, with half of the sample experiencing a concept primer beforehand. We also gathered measurements on subjective traits, in the Multidimensional Assessment of Interoceptive Awareness and the Ten Item Personality Inventory. Results support previous work which suggests greater body ownership in human as opposed to non-human avatars, and suggest that concept priming could have an influence on embodiment and state body mindfulness. Additionally, results highlight an array of personality trait influences on embodiment and body mindfulness measures.

CCS Concepts

• ***Human-centered computing*** → ***Empirical studies in HCI; Virtual reality; Human computer interaction (HCI);***

1. Introduction

In Virtual Environments (VEs), the concept of *Afforded Embodiment* has been used to describe the relationship between a user and the action possibilities offered by an avatar body compared to a real body [CKB13]. For the operation of humanoid avatars, this affordance is presented by algorithms which allow the human to drive the avatar as it is rendered in real time. Such algorithms control the appearance and animation of the virtual body, while also translating user actions into embodied agency, such as when the push of a controller button is mapped to the movement of a virtual hand in order to grab a virtual object [BB04].

From the user's perspective, the experience of this afforded relationship can be described in phenomenological terms as the Sense of Embodiment (SoE) [KGS12]. This definition of SoE allows for users to report on the experience of ownership, agency and self-location when embodied in a virtual avatar. Practically speaking, this is a very useful theoretical construct to employ when studying the subjective effects of simulated embodiment of a non-biological body. However, there is some ambiguity about the subjectivity of this experience. Individual factors have been reported to cause variation in reports of subjective experiences in VEs [SO03]. In particular, experimental work proposes traits like openness, extroversion, neuroticism [WWM10, KLR22, Shi18] and locus of control [DFA*19] to be impactful on the experience of virtual embodiment.

Yet, these works only explored human-like avatars, making it unclear if such correlations would be replicated in the context of non-human avatar embodiment. Although human avatars have been highly researched and proven to evoke high levels of SoE, non-human avatars can be useful in the context of video games, films and immersive media. As such, our research aimed to measure individual trait effects in two different avatar conditions, with one human and one more challenging non-human avatar condition experienced by each participant. Also, the present study included a measure of body mindfulness extracted from the State Mindfulness Scale [TB13], previously employed in VR settings [CMP*16,DWM*22] to assess aspects of body awareness, but not to explore its correlation with SoE towards non-human avatars.

In addition to internal traits which may influence users' SoE, our study was designed to understand the extent to which subtle external factors could potentially impact this phenomenon, specifically in the form of concept priming. Concept priming may be understood as the controlled introduction of a particular concept without a subject being explicitly aware of its influence [BC00]. Contextual priming [CFGDM21], which can be considered a form of concept priming, was found to influence participants sense of presence in a VE in a study where they were conceptually primed by reading a booklet either related to or unrelated to the VE and then were left to explore that VE [NB03]. Interestingly, this type of protocol was never explored in the context of virtual embodiment. For the purpose of this study, a novel priming method was created with the aim to elicit higher SoE scores towards an avatar. It consisted in having participants reading articles which portrayed the avatars that would be used prior to the immersion in the VE. As such, there remained

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a gap in the literature with regards to the influence of concept priming on SoE. Moreover, previous works have also outlined a need to explore how 'top-down' influences (i.e. how cognitive processes treat sensory stimulation) interact with avatar bodies that more or less resemble real ones [GNJKM23]. In this paper, we therefore present a user study (n=65) that included both control and primed conditions, with the aim to understand the roles of individual traits and priming effects on the sense of embodiment in VR, particularly towards a non-human avatar. In conducting a review of the literature, we formed the following research questions:

RQ1 Does concept priming prior to VR exposure improve SoE?
RQ2 Will participants experience the same level of body mindfulness in both human and non-human avatars?
RQ3 Which personality traits influence the SoE?

2. Background

2.1. Virtual Embodiment and Priming

The Sense of Embodiment refers to the sense of being inside and in control of a virtual body [FALH20]. Models of embodied cognition suggest that users who embody virtual avatars tend to map their own bodily representations onto the avatar, according to the affordances presented by the dimensions of the virtual body [BBC16]. These affordances can have different effects on user perception of an avatar. For example, both visual realism and the accuracy of virtually represented body movements have been shown to impact ownership and agency in virtual embodiment tasks [AHTL16].

Afforded embodiment in VR allows for opportunities to test how stimuli presented prior to avatar exposure might influence SoE. Our use of priming methods was intended to capture the wide range of content that may influence reports of SoE in a virtual avatar. Priming may be defined as the passive influence of environmental features on an internal activation or representation [BC00].

Although some research in this area has been criticized on replicability grounds [WCM*15], there have been efforts to extend this work further in the domain of virtual reality, with some of these outlined below. Since VR necessarily includes an interactive environment with provisions for different sense modalities, it is fitting that contemporary models of priming effects describe their underlying processes as inter-sensory, interactive heuristics based on perceptual associations [KC14].

Most research on priming and VR has focused on how avatars can prime subjects for different behaviours. This priming influence has been termed The Proteus Effect [YB07] which describes the behaviours that avatars can prime people to exhibit during or post-embodiment [PHM09]. Avatar appearance and behaviour have since been associated with, among other things, changes in walking speed [RSFCL20], self-objectification [FBT13] and creative ideation [dRvdLvE17]. Research in this area has proposed the effects of particular avatar cues on perceptual associations to be reliant on automaticity, mediated by activation and inhibition spreading mechanisms, as well as valence processes that are intrinsic to human memory function [Peñ11, BC00].

While the efforts to investigate avatar-human priming effects have been fruitful, less work has been done at the intersection of priming influences prior to VR exposure. Some work has found an effect of instructional priming on subjects' movement within virtual crowds, exhibiting greater collision avoidance behaviour when instructed that a real person's movement was represented by the crowd [GSB17]. Similarly, haptic priming has been implicated in the improvement of social responses to virtual humans [KKP18], while priming for meditation and positivity has also been shown to reduce student anxiety [HA21]. Aforementioned work has proven that our method of concept priming can increase the sense of presence in VR [NB03, CFGDM21]. While these studies focused on activation mechanisms developed from interacting with previous environments, other studies have chosen to prime participants with introductory concepts for improving experiences in VR. Presence in virtual environments has been shown to improve with the use of a visual preamble that mirrors their own environment [SCB17], while introductory limbo states can heighten perceptions of virtual body ownership [JWH18]. Additionally, mindfulness priming can enhance responses to neurofeedback training [dCBF*21], and has also been shown to negatively impact responses to the rubber hand illusion [CMP*16], and to reduce stress responses to high arousal VR situations [CCC*16]. These varied approaches to priming in VR provided strong motivation for the present study to explore for the first time other possible priming influences on SoE.

In our experiment, concept priming was conducted using articles which described and presented images of the avatars that were to be used by participants, in a similar method to [NB03,CFGDM21], with the additional theoretical focus of priming avatar relevance through manipulation of focal awareness [LB09, Pol66]. While the experience of embodiment remained subsidiary for this method, the appearance of the avatars were brought into immediate focal awareness by the articles (see Fig. 2) that were presented to participants. This prime differed from the previous cited methods, in that it was intended to provide the concepts which could be activated unconsciously [Bar16] during embodiment of both human and non-human avatar conditions. It was anticipated that this prior awareness of the avatar concept would influence user perceptions during avatar embodiment.

While SoE can be considered a perceptual experience stemming from the affordances of a virtual body, priming via conceptual associations for VR experiments [CFGDM21] invites higher level cognitive processes into the act of perception, dictating the sensations derived from a particular environmental context. The historical topic at issue here is the extent to which cognitive processes influence perceptual ones, and vice versa. Our priming methods were employed to test whether conceptual associations could impact the perception of virtual embodiment, in cases where participants were primed with avatar relevant material [NB03].

Our study was also partly motivated by the aim of establishing how the sense of embodiment may vary under conditions of challenged, non-human embodiment. More human-like avatars have been documented to improve reports of co-presence [BSH*05] although some research claims that anthropomorphic avatars elicit the same level of body ownership as less human counterparts [LLL15]. There is room for further clarification here, however, with other studies claiming that human-like avatars induce higher levels of SoE than non-human ones [KJKK20].

Krehov et al. [KCK19] investigated animal embodiment with rhino, scorpion, or bird avatars and found that the animal's additional body parts and skills enhanced rather than hindered players SoE. Providing rich multi-sensory feedback has also been shown to increase the SoE towards virtual animals [ABO*16, SPv20, VFBM23, PK22]. In our study, since we decided on using an anthropomorphic non-human avatar, kinematic mapping was identical for both human and non-human conditions, with the visual representations of the avatars considered to afford different perceptions of embodiment, which were predicted to interfere with SoE. In this sense, the term 'kinematic mapping' refers to the calculations of the joint parameters used to drive the virtual body. Using standard human body kinematics to test SoE in an animal body, albeit with humanoid limbs and motor function, allowed us to test SoE differences based on appearance changes rather than using animal based kinematics. Humanoid (but non-human) kinds of avatars are generally employed in games, film and television, as well as immersive media contexts, and hence it was considered important to understand how their use can influence user experience in VEs.

2.2. Body Awareness and Personality

While we were interested in examining whether subtle external cues, such as a primed concept or the appearance of an avatar body, could be measured to effect SoE in our experiment, the literature also presented an opportunity to expand previous findings on the role of internal cues, such as personality traits and body awareness.

Body awareness can be defined as the perception of bodily states, processes and actions, based on proprioceptive and interoceptive sense data within the awareness of an individual [MGD*09]. Some evidence suggests that trained mindfulness meditators can exhibit higher body awareness [TTDG19], but some objective measures of internal bodily awareness, also termed interoception, do not support this link [SAF*15]. Given this issue of understanding how mindfulness influences VR experiences, the present study included a measure of body mindfulness extracted from the State Mindfulness Scale (SMS) [TB13], which has previously been employed in VR settings [CMP*16, DWM*22] to assess aspects of body awareness. Our aim on the SMS body questions, deployed for each of the two avatar conditions, was to test for a novel finding on differences of state body awareness between human and non-human avatars.

It has been demonstrated that self-reports of interoceptive body awareness correlate with heartbeat perception scores in VR tasks [DWM*22]. Participants who exhibit lower body-awareness on self-perceived heart rate measurements also experience less ownership over a rubber hand [TTJC11]. While there is some evidence that body awareness is not disrupted by VR body-swap tasks [CHV*19], mindfulness meditators have reported lower agency during the rubber hand illusion [CMP*16]. The volitional aspect of self-regulation, measured in our study, has also been shown to benefit from, as well as support, mindfulness practice, with reports indicating greater agency in terms of both executive control [TI13] and motor control [NS12] for mindfulness meditators. Uncertainty around the influence of interoceptive body awareness on VR experiences demonstrated a gap in the literature which the study outlined here aimed to partially fill, through the use of the Multidimensional Assessment of Interoceptive Awareness (MAIA) [MPD*12].

Figure 1: *The avatars embodied during the experiment. Participants chose either the female (right) or male (left) depending on their own gender, and were also embodied in the non-human avatar (center). The avatars were scaled to the size of each participant.*

As well as individual differences in body awareness, individual differences in personality traits have been highlighted in the literature as potentially influential over experiences in virtual reality [SO03] and embodiment during the rubber hand illusion [BPA*19, LBS*20]. A common theoretical perspective on personality traits are to be found in the Five Factor Model [JS99]; a set of measured and widely replicated traits that are used in efforts to taxonomise the plurality of human personas, namely Extroversion, Agreeableness, Conscientiousness, Emotional Stability and Openness [CCS12]. These traits have been studied relative to spatial presence [SLH08] and immersion in VR [WWM10], as well as embodiment [DFA*19]. These traits, as measured by the Ten Item Personality Inventory (TIPI) [GRSJ03] have also been observed to interact with embodiment reports in video-conference based avatar interactions [HFM21] where Agreeableness was found to be positively correlate with Ownership. An additional focus of our experiment was to examine whether these elements of perceptual subjectivity could influence embodiment in a non-human avatar and in VR (as compared to the on-screen study [HFM21]). In addition, previous works have found female participants more likely to experience a sense of agency compared to males in low-fidelity virtual embodiment [KM20], which provided us with further motivation to include this factor in our analysis.

Of particular interest for this paper is the study conducted by Dewez et al. [DFA*19]. In this work, the experiment was conducted to assess the influence of individuals' personality traits and body awareness on the perceived SoE in a human avatar. This work found an effect of internal locus of control on perceived body ownership, but did not establish any connection between SoE and personality traits as measured by the TIPI. We looked to expand the findings of body awareness to focus on the eight specific traits measured to predict interoceptive awareness as defined in the MAIA, and whether they could influence non-human avatar embodiment. This study therefore explored for the first time how individual traits could influence the SoE towards a more challenging avatar i.e., a non-human avatar.

Based on this review of the literature, we have formed the following hypotheses:

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H1 From previous results of concept priming improving the sense of presence in VR, we expected higher reports of SoE from the concept priming group compared to the control group.

H2 We expected body mindfulness to be more difficult to maintain for the non-human avatar.

H3 Based on [HFM21], we predicted that trait Agreeableness would positively correlate with Ownership.

3. Experiment

To explore our research questions, we designed an experiment for users to embody two different avatars (Fig. 1, within-subject). There were also 2 groups subjected to a between subjects treatment of Priming or Control. The order of avatar presentation, either human first or non-human first, was counterbalanced across groups and genders to avoid a confounding factor of presentation order. The experiment was implemented using the HTC Vive Pro 2 headset. The hardware also included both hand held controllers, which were replicated in the hands of the avatars within the VE, as well as Steam VR base station motion trackers, which were mounted either side of the participant desk to detect their full range of upper body motion during the experiment. Tracking precision was tested in development in order to ensure that both hand movements and head movements were captured throughout, with the tracking field ensured to be sufficiently large so as to capture variation in participant size, while their position in relation to the trackers was kept consistent across participants. The VE was built using Unity software and was run via Steam VR.

3.1. Participants

Overall, 67 participants were recruited from two European universities. Two of them were unable to complete the experiment, so the analysis was conducted on 65 participants (38 Male 27 Female, mean age 23.5 years, 22 French native speakers, 43 English native speakers). The Primed group contained a total of 14 Female participants and 19 Males, with the Control group containing 13 Females and also 19 Males. The project received ethical approval (Application number: 16092022) prior to data collection. Participants received information and consent forms before the experiment began, and were asked to return consent prior to the lab appointment.

3.2. Protocol

After entering the experiment room, participants were asked to fill-in personality measurement questionnaires, prior to VR exposure, in order to gather trait and demographic data before the immersion.

For the Primed Group, participants experienced the concept priming condition. Participants read two text articles and viewed an accompanying image depicting a missing advertisement (human avatar) and an escaped advertisement (non-human avatar), see Fig. 2. The text and image were used to describe the visual details of the avatar before embodiment took place, with the gender of the avatar adjusted to match the participant. Participants experienced priming stimuli for both human and non-human avatars before putting on the VR headset. For the Control Group, participants did not experience any priming condition and proceeded directly to the virtual environment.

The height of the desk and size of the avatar were adjusted in accordance with the respective height of participants. The kinematic mapping was manually adjusted to suit the participant's size so as to ensure consistency in the point of view for the virtual body in front of the virtual monitor.

Daily News

19 JAN 2023

Missing Man

We are looking for our friend. He is a man of average height and build, slim, wearing a blue top and grey trousers. He has not been seen for more than 48 hours. Please call the number at the bottom of this ad if you can provide information. He is a beloved friend of the family and we would like him to be brought home safe and sound.

Reuters

According to Robbie McRobson, head of the UN Moose Preservation Council, worldwide moose numbers are expected to grow markedly on last year due to the traditional moose strongholds of Canada and the United States, with the larger developing moose ecologies also poised to make gains. The largest percentagege increase in moose will likely come from China", says McRobson, The Chinese government has invested heavily in moose infrastructure over the past decade, and their committment to macrofauna is beginning to pay dividends". Since 2004 China has expanded moose pasture from 1.5% of arable land to nearly 3.648% and moose numbers are expected to rise to 60,000 making China a net moose exporter for the first time. This is good news for neighbouring Mongolia, a barren moose-wasteland whose inhabitents nonetheless have an insatiable desire for the creatures. The increase in Beijing-Ulanbataar trade is anticipated to relieve pressure on the relatively strained Russian suppliers, but increase Mongolia's imbalance of trade with its larger neighbour.

Historically the only competitor to China in the far eastern moose markets has been Singapore but the

Daily News

19 JAN 2023

Escaped Ant

Please be on the lookout for an escaped humanoid ant. The ant is completely harmless, and we just want it to be brought home safe and sound. It is a humanoid ant, of average human height, thin, with four limbs, but with the eyes, carapace and mandibles of an ant. Please call the number at the bottom of this ad if you can provide any information.

Reuters

tion Council, worldwide moose numbers are expected to grow markedly on last year due to the traditional moose strongholds of Canada and the United States, with the larger developing moose ecologies also poised to make gains. The largest percentagege increase in moose will likely come from China", says McRobson, The Chinese government has invested heavily in moose infrastructure over the past decade, and their committment to macrofauna is beginning to pay dividends". Since 2004 China has expanded moose pasture from 1.5% of arable land to nearly 3.648% and moose numbers are expected to rise to 60,000 making China a net moose exporter for the first time. This is good news for neighbouring Mongolia, a barren moose-wasteland whose inhabitents nonetheless have an insatiable desire for the creatures. The increase in Beijing-Ulanbataar trade is anticipated to relieve pressure on the relatively strained Russian suppliers, but increase Mongolia's imbalance of trade with its larger neighbour.

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Figure 2: *Documents used for priming in the human (left) and the non-human (right) conditions. The documents were printed and the articles were isolated and presented in physical form prior to VR immersion.*

The VE was obtained from the study of Dewez et al. [DFA*19] and the same task was used. The VE was presented as a virtual office (Fig. 3, left) in which participants were seated on a chair near a table, facing a screen and with a mirror to the side, where they could view their virtual avatar. Participants were first invited to explore the motion of their avatar using the virtual mirror, where they could see their own upper body movements mapped to the movements of the avatar. When they were ready to begin, they were asked to make movements with their hands following a series of shapes (a circle, an infinity sign etc., see Fig. 3, right) during 2 minutes of task runtime. In total, the participants experienced 10-15 minutes of VE immersion, including the time taken to begin the task and answer questions. After moving their hands in the shapes displayed on the screen, participants were asked to fill out measurements questionnaires within the virtual environment. Directly after this questionnaire, participants were embodied in a second avatar, in the same virtual environment, and repeated the tasks. The avatar order was counterbalanced so that equal numbers of participants experienced different orders of avatar presentation, between non-human and human, as well as equal numbers of primed or not primed conditions.

The human avatars were gender-matched realistic avatars obtained from the Rocketbox library [GFOP*20]. As for the non-human avatar, we decided to use an avatar that looked like an anthropomorphic ant. Non-human avatars may respond to a wide range of representations (e.g., from avatars with human characteristics that look externally different to ones with significantly different body characteristics from humans such as a bird). In our study, we wanted to have a representation that would challenge the Sense of Embodiment one could feel towards it, but that easily allowed participants to perform the visuomotor task similarly in both human and non-human conditions, which motivated our final choice.

3.3. Measurements

The dependent variables chosen for this study are reflected in our choice of measurements. We were looking for changes in state body mindfulness between avatar conditions, and employed the *Body* component of the State Mindfulness Scale [RHTB22]. Our other between-conditions report measurement was the Virtual Embodiment Questionnaire (VEQ) [RL20] (see Tab. 3) which provided data on SoE as perceived by participants. We expected SoE to vary between avatar conditions, with scores intended to be analysed together with priming conditions, as well as personality trait scores.

Outside of the VR task, participants also provided other personality and interoceptive awareness trait data [GRSJ03, MPD*12]. These provided a total of thirteen separate traits to analyse for effects on embodiment data. These included the aforementioned Big Five personality traits, as well as interoceptive awareness traits of Noticing, Worrying, Distracting, Attention Regulation, Emotional Awareness, Self Regulation, Body Listening and Trusting.

4. Analysis

For both the SoE and SMS reports, items were analysed using IBM SPSS both by averaging over the individual items for global scores, and by analysing each item as an individual question.

We conducted a repeated measures ANOVA with a mixed design of within-subjects factor *avatar* (human, non-human) and between-subjects factors *priming* (yes, no) and *gender* (male, female) for every questionnaire item. Gender was considered as an additional factor in our analysis considering previous research that found different SoE results depending of participants gender [DFA*19]. Considering the acknowledged robustness of ANOVA analyses regarding not normally distributed data when applied to Likert-scale analysis [Nor10, MA17], we used parametric methods to analyse our results. The same analysis was also conducted for aggregate scores of Ownership, Agency and Change, in order to assess overall effects of priming and condition, as opposed to effects on individual items. There there no violations for Levene's equality of variance and thus, for post hoc tests, we conducted a Bonferroni interval adjustment, and report the modified pairwise comparisons.

Spearman's correlations were conducted to assess the relationship between individuals personality traits, as measured by the TIPI and MAIA, and their respective scores on the surveys for each of the human and non-human avatar conditions. These correlations were conducted using both global scores and individual item scores, as with the ANOVA.

5. Results

Below we report significant results for aggregate and individual items, all other effects were non-significant.

5.1. Analysis of Variance

5.1.1. Ownership

We first conducted an ANOVA on the aggregated items for Ownership and found a main effect of avatar ($F(1,61) = 37.711, p < 0.001, \eta_p^2 = 0.382$) where higher levels of Ownership were reported for the human than the non-human avatar ($p < 0.001$).

Figure 3: *Left: Office scene for experiment with a human avatar. The side mirror was included to show participants the movements of the avatar as mapped to their own movements. Right: Example of shape trace task from the user's point of view. The virtual environment was obtained from Dewez et al. [DFA*19].*

Then, we conducted individual ANOVAs for each item to determine if other effects were observed. Acronyms used for each item are presented in Tab. 3 with their associated question. We found a main effect of avatar for OW1 ($F(1,61) = 11.913, p = 0.001, \eta_p^2 = 0.163$), OW2 ($F(1,61) = 11.924, p = 0.001, \eta_p^2 = 0.923$), OW3 ($F(1,61) = 50.183, p \approx 0, \eta_p^2 = 0.164$), and OW4 ($F(1,61) = 13.093, p = 0.004, \eta_p^2 = 0.129$), where the human avatar was rated higher than the non-human on all items, OW1 ($p = 0.001$) OW2 ($p = 0.001$) OW3 ($p < 0.001$) and OW4 ($p = 0.004$). For OW4, we also found a main effect of Gender ($F(1,61) = 40.243, p = 0.040 \eta_p^2 = 0.067$) where male participants felt like the virtual body belonged to them more than females ($p = 0.040$).

5.1.2. Agency

For the aggregated items, we found a 3-way interaction between Avatar, Priming and Gender ($F(1,61) = 4.925, p = 0.029), \eta_p^2 = 0.075$) where female participants experienced significantly more agency for the human avatar in the control condition ($p = 0.030$), while there was no significant difference in agency for the priming condition. In comparison, there was increased agency in the non-human condition for females in the primed group.

For individual items, we found a main effect of avatar for AG1 ($F(1,61) = 4.259, p = 0.043, \eta_p^2 = 0.065$) where the movements of the virtual body felt like they were the participants movements more for the human avatar than the non-human avatar ($p = 0.043$).

For AG2, a 3-way interaction between avatar, priming, and gender ($F(1,61) = 5.263, p = 0.025, \eta_p^2 = 0.079$) showed a greater sense of control of the non-human body for Males in the Control condition compared to the Primed condition ($p = 0.024$).

For AG3, we found a 2-way interaction between avatar and gender ($F(1,61) = 5.730, p = 0.02, \eta_p^2 = 0.086$) where perception of causing avatar movement was higher for female participants in the non-human avatar than in the human avatar ($p = 0.042$), while there was no effect for male participants.

There was also a main effect of Avatar for AG4 ($F(1,61) = 4.909, p < 0.001, \eta_p^2 = 0.074$) where participants felt more in sync with the movements of the non-human avatar compared to the human avatar ($p < 0.001$). Additionally, there was an interaction effect between Avatar and Gender ($F(1,61) = 4.909, p = 0.018, \eta_p^2 = 0.074$) where female participants felt more in sync with the movements of the human avatar compared to males ($p = 0.029$).

5.1.3. Change

For aggregated items, we found no main effects or interactions. For the individual item analysis, we found a main effect of avatar for CH4 ($F(1,61) = 4.280, p = 0.043, \eta_p^2 = 0.066$) where participants felt that the width of their own body had changed more for the non-human avatar. No other main effect of avatar.

Gender had a main effect for CH4 ($F(1,61) = 7.438, p = 0.008, \eta_p^2 = 0.109$) where female participants felt that the width of their own bodies had changed more than males ($p = 0.043$).

5.1.4. State Mindfulness Scale

There were no main effects for overall SMS scores. There was a main effect of avatar for SMS8 ($F(1,61) = 5.507, p = 0.022, \eta_p^2 = 0.083$) where participants more clearly physically felt what was happening in their body after embodying the human avatar ($p = 0.022$). There was also a main effect of Avatar for SMS18 ($F(1,2.466) = 5.349, p = 0.024, \eta_p^2 = 0.081$) where participants felt more in touch with their body after using the human avatar ($p = 0.024$). There was also an Interaction between Avatar, Priming and Gender for SMS18 ($F(1,1.874) = 4.064, p = 0.048, \eta_p^2 = 0.062$). Male participants in the primed group felt more in touch with their body after the non-human avatar ($p = 0.003$).

5.2. Correlations

5.2.1. Personality Inventory

Before analysing individual items across both priming and non-priming groups, we first report correlations between aggregate items for sense of embodiment and state body awareness metrics with the items measured by the TIPI and MAIA.

For the primed group (N = 33), there were significant positive correlations in the non-human condition for Extroversion and Change ($r = .374, p = 0.032$) and for Body mindfulness ($r = .346, p = 0.049$) as well as in the human avatar condition for Agreeableness and Ownership ($r = .375, p = 0.032$), and Openness with both Ownership ($r = .362, p = 0.038$) and Change ($r = .393, p = 0.024$). There was also a significant negative correlation between Emotional Stability and Change for the non-human condition ($r = -.529, p = 0.002$), see Fig. 4.

Surprisingly, there were no significant correlations recorded for the control group (N = 32).

When analysing each individual item, significant positive correlations were observed between trait Extroversion and SoE Item CH3 for the human avatar condition ($r = .308, p = 0.013$) and CH3 in the non-human avatar condition ($r = .336, p = 0.006$). There was also a significant negative correlation for SMS14 for the non-human avatar condition ($r = -.265, p = 0.033$).

Trait Agreeableness was positively correlated with scores for item OW2 ($r = .266, p = 0.032$), SMS8 ($r = .255, p = 0.040$) and SMS14 ($r = .335, p = 0.006$) in the human avatar condition, as well as SMS14 ($r = .412, p > 0.001$), and SMS18 ($r = .258, p = 0.038$), in the non-human condition.

For the trait Conscientiousness, there was a positive correlation recorded for CH3 ($r = .252, p = 0.043$) in the human condition.

Emotional Stability was negatively correlated with SoE item CH4 in the non-human avatar condition ($r = -.282, p = 0.023$).

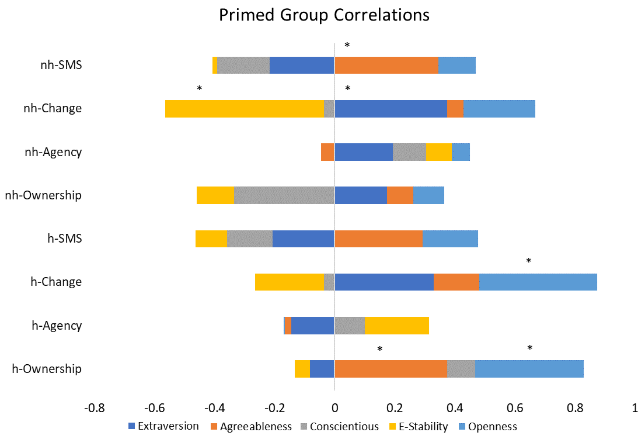

Figure 4: *Plotted correlation coefficients for primed group personality traits with SoE and SMS results. Significant results are noted with a * for both human (h) and non-human (nh) avatar conditions.*

Primed Group		**r**	**p**
Human	Worrying x Agency	0.449	0.009
Non-human	Emotional Awareness x Change	0.406	0.020
	Self-Regulation x Agency	0.494	0.004
	Self-Regulation x Change	0.353	0.044
	Body Listening x Agency	0.364	0.037
	Body Listening x Change	0.404	0.020
	Body Listening x Body Mindfulness	0.392	0.024
	Worrying x Change	−0.374	0.032
Control Group		**r**	**p**
Human	Worrying x Ownership	0.390	0.028
	Worrying x Agency	0.497	0.004
	Self-Regulation x Ownership	0.365	0.040
	Self-Regulation x Body Mindfulness	0.446	0.011
Non-human	Self-Regulation x Body Mindfulness	0.433	0.013

Table 1: *Correlations for the global Interoceptive Awareness traits.*

Trait Openness was correlated with the most items, including positive correlations in the human condition for items OW1 ($r = .254, p = 0.041$), OW2 ($r = .275, p = 0.027$), OW3 ($r = .273, p = 0.028$) and CH3 ($r = .414, p > 0.001$). Additionally there was a positive correlation for SMS9 in both human ($r = .276, p = 0.026$) and non-human ($r = .350, p = 0.004$) conditions.

5.2.2. Interoceptive Awareness

Significant correlations for MAIA items are reported in Tab. 1 and that of MAIA individual items are reported in Tab. 2.

6. Discussion

There were two main objectives of this study. First, we aimed to deploy an adapted priming method to explore the external factors which can affect virtual embodiment scenarios. The second focus was to assess whether subjectivity in personal traits might

Human		r	p	Non-Human		r	p
Noticing	OW2	0.332	0.007	Worrying	OW3	−0.294	0.018
	AG3	0.265	0.033		CH2	−0.353	0.004
	AG4	0.305	0.014		CH3	−0.347	0.005
Worrying	OW3	0.296	0.017		CH4	−0.300	0.015
	AG2	0.390	0.001		SMS13	−0.258	0.038
	AG3	0.391	0.001	Emotional Awareness	OW2	0.252	0.043
	AG4	0.358	0.003		OW4	0.251	0.044
	CH3	−0.291	0.019		CH1	0.277	0.025
	SMS13	−0.286	0.007		CH2	0.281	0.023
Attention Regulation	OW2	0.339	0.006		CH4	0.254	0.041
	CH3	0.277	0.026		SMS9	0.353	0.004
Emotional Awareness	OW4	0.282	0.023	Self Regulation	CH2	0.287	0.021
	CH1	0.297	0.016		SMS9	0.325	0.008
	SMS13	−0.245	0.049		SMS18	0.281	0.023
Self Regulation	OW1	0.282	0.023	Body Listening	OW1	0.267	0.032
	OW2	0.345	0.005				
	OW4	0.290	0.019		OW2	0.272	0.028
	SMS9	0.389	0.001				

Table 2: *Correlations for Interoceptive Awareness individual items.*

also be influential on reports of perceived embodiment. Primarily, the Sense of Embodiment reports indicate a preference for human avatars in terms of ownership, as discussed by Kim et al. [KJKK20]. Moreover, each of our hypotheses were at least partially supported by our results.

RQ1: Does concept priming prior to VR exposure improve SoE?

H1: Given previous reports of concept priming methods improving the sense of presence in VR, we expected higher reports of SoE from the concept priming group compared to the control group.

Some evidence exists in our correlation data to support H1, although our ANOVA results appear to support the null hypothesis. However, our findings suggest that a heightened SoE, as related to concept priming, is heavily dependent on individual factors.

The most significant finding in terms of analysis of variance was that priming had a negative effect on the sense of agency for female participants in the human avatar. In this sense, the primed awareness of the avatar has been observed to diminish SoE for human avatars. This awareness appears to reduce agency, which may be due to the avatar concept highlighting the interruption of interoceptive signals that indicate agency. In other words, for the human avatar condition, it is possible that the awareness of the avatar-as-avatar as opposed to avatar-as-afforded body meant that female participants felt less control of the avatar and its movements. Conversely, however, this result appears to suggest that agency for the non-human avatar was higher in the primed condition for female participants, which implies a role for humanness in dictating perceptual responses to concept priming for afforded bodies. Interestingly, similar gender specific results on SoE for female participants were found by Dewez et al. [DFA*19].

Results from our correlation analyses paint a different picture in terms of subjectivity of priming effects. There is evidence to suggest that priming enhanced SoE and body mindfulness reports for participants who were higher on traits Extroversion, Openness and Agreeableness, for both human and non-human avatars. Additionally, for MAIA traits there were significant correlations between Emotional Awareness, Self Regulation and Body Listening with perceived body change in the non-human avatar, that were present for the primed group and not present for the control group. This implies that these particular traits are potentially influential on our responses to non-human embodiment. This contingency may be due to the subjectivity inherent to bodily perceptions in general, which are then mapped to our experiences of virtual bodies.

For the Five Factor Model traits, there is an intuitive interpretation to be found in the idea that positive prosocial behaviours, such as the externality of persona, the ability to welcome novel experiences, and the tendency to agree to predefined patterns, are influenced by simple concept priming in a way that enhances the embodiment experience. Similarly, the findings that three awareness focused traits in the MAIA enhance the perception of body change may highlight an experience of awareness that allows for the flexibility of interoceptive signals when it comes to afforded embodiment. Moreover, it is plausible to suggest that certain external or awareness focused traits may predispose people to have a heightened sensitivity to perception and cognition of concepts. These interpretations must be interpreted as preliminary rather than elementary, as confirmatory studies with larger samples would be required to validate the findings above. However, these findings are novel and potentially impactful on the development of VR applications, and as such may motivate further research on the subjective experiences of both human and non-human avatar embodiment.

Previous works which employed the use of text and picture based articles to prime participants for VE immersion [NB03,CFGDM21] found significant effects on the sense of presence. While embodiment and immersion can be understood as similar phenomena, the important difference arises with the sense of self that is naturally attuned to bodily states. This can be seen in our analysis of variance findings, as the female participants experienced less agency when primed for human avatar embodiment. While concept priming for virtual environments appears to be effective for increasing the sense of presence, the same method does not necessarily achieve the same effects for virtual embodiment, although there is reason in our results to explore further as to whether this could be the case for non-human embodiment. An additional contribution may be found in the subjectivity of the observed effects; people acquire bodily affordances in different ways, depending on their respective relationships to their bodies and to the world. This may motivate future works to use similar experimental formats to explore more challenging avatars with different body structures, so that our findings on personality influences may be understood more generally.

RQ2: Will participants experience the same level of body mindfulness in both human and non-human avatars?

H2: We expected body mindfulness to be more difficult to maintain for the non-human avatar.

Our results appear to support H2. There were main effects for two SMS body items when analysed in isolation, which suggests that non-human avatar embodiment could hinder body mindfulness. Our interpretation is that there is a more natural perceptual mapping from human bodies to human avatars, which requires more cognitive resources to achieve when the avatar is non-human. Hence, body mindfulness is more difficult to maintain.

Other changes in body mindfulness appear to be dependent on personality traits. From the Five Factor Model, there was a significant correlation between trait Agreeableness and state body mindfulness in both human and non-human avatar conditions, specifically in the primed group. As stated before, it makes intuitive sense that Agreeableness may aid in maintaining body mindfulness regardless of changes to exteroceptive cues and bodily affordances.

There is evidence that both primed and control groups were more likely to experience greater body mindfulness dependent on degrees of awareness and control, as Self-Regulation correlated with body mindfulness for the control group, in both avatar conditions, while trait Body Listening correlated with body mindfulness for the non-human avatar in the primed group. It seems likely that self-regulation would be useful for maintaining coherence of bodily cues across both virtual and analog affordances, which in turn could make visual differentiation between human and non-human avatar bodies to be arbitrary in determining body mindfulness.

While previous studies have identified relationships between SMS body mindfulness measurements and reports of ownership and agency [DWM*22], our study was among the first to explore reported state mindfulness in conjunction with challenged embodiment and personality traits. As such there are novel findings in our data which expand on the conclusions of DÃűllinger et al. [DWB*23] by assessing state body mindfulness in a virtual task scenario with non-personalised avatars.

RQ3: Which personality traits influence the SoE?

H3: We predicted that trait Agreeableness would positively correlate with Ownership.

While there exists enough evidence to confirm H3, there were additional findings, as well as significant effects of personality traits in both the human and non-human avatar conditions.

Our main prediction on Agreeableness was based on the prior work of Higgins et al. [HFM21], and their findings are replicated in this work for the human avatar.

In the human avatar condition, there was also a significant effect of trait Openness on body ownership reports. This novel result adds to previous work which correlated Openness with improved task performance in VR [KLR22]. It suggests that Openness may improve the reaction to the affordances of virtual bodies. Adopting a virtual body may interrupt regular interoceptive signals that link bodily sense perceptions to a coupled environment, as normal bodily and environmental perception is forced to shift in the case of VE immersion. Trait Openness may aid in the perception of this transition, and novel bodily affordances are likely treated more readily as regular bodies by subjects who are more open to the experience.

For the non-human condition, there was a significant effect of Extroversion on the perception of body change, mainly with perceived change in size. As such, trait Extroversion may improve the sense of body change in non-human avatars, although significant confirmatory research would be required to verify that link.

It is notable that the three traits measured to positively correlate with SoE and body mindfulness in the primed group were the three externally motivated personality traits of Extraversion, Openness and Agreeableness. Conversely, the negative correlation with perceived body change was one of the internally motivated traits, namely Emotional Stability. There is an interesting problem to be explored in this finding, in that our relationship to external objects, as defined by our respective personas, may positively influence our relationships to those objects and our access to their affordances.

There were two novel MAIA trait results that were specific to the non-human avatar, as well as novel significant effects for the human avatar. In the non-human condition, traits Emotional Awareness and Body Listening were positively correlated with multiple SoE measurements, amounting to influences on agency and ownership respectively. This result expands the range of measured trait influence in non-human avatar embodiment. A possible explanation might be that the ability to pay attentive control to interoceptive body signals allows for an easier transition to driving external avatar bodies. Further studies which aim to assess how the subjectivity of interoceptive signals interferes with the sense of embodiment would be required to fully explicate this finding.

7. Conclusions and Limitations

Given our findings, there is sufficient evidence to suggest that there are significant trait influences to be found in avatar embodiment scenarios. Along with prior work, this suggest that trait assessments are important to contextualize future studies on avatar embodiment. Of course, to confirm this notion, analyses will need to be conducted on much larger samples, with greater variation in embodiment conditions. Further studies may also aim to verify our correlation analysis findings using other kinds of statistical models. Another limitation stems from our use of first person point of view. Recent works have shown that avatars that are customized to look like participants can reduce SoE [GFSBTJ24]. This may also be true of non-human avatars, and future works should apply these kinds of avatars in third person points of view.

One limitation may be drawn from our definition of SoE, as defined by [RL20], whereby we included items for body change instead of questions of self-location. Comparisons with other SoE questionnaires and measurement methodologies would be a useful development on this issue. Also, recent attempts to consolidate guidelines on enhancing SoE revealed an importance for diversifying human avatar presentation to suit participant diversity [FEVEH23]. The generic avatars used for the human condition is one limitation to be considered consequential under this guideline.

A significant limitation of this study would be our distinction between human and non-human avatars. While the two conditions differed significantly in terms of visually salient information, the functional affordances that were offered by the kinematic mapping were the same for both human and non-human embodiment. Future research that investigates whether changing some of those motoric affordances, in a larger or smaller avatar, or else in a quadrupedal avatar, would be of benefit in addressing this limitation. Further studies may also seek to address the general interaction challenges inherent to non-human avatar embodiment, specifically how these motoric affordances may be perceived when a non-human embodiment is combined with relevant haptic and tactile elements in a VE [CFL*23]. Finally, our findings on concept priming may be relevant for any works that seek to aid the transition between real and avatar bodies, or indeed between different avatar bodies, as can be achieved through both active and passive transitions [OGPH*23].

Group	Var. Name	Statement
Ownership	OW 1	*"It felt like the virtual body was my body."*
	OW 2	*"It felt like the virtual body parts were my body parts."*
	OW 3	*"The virtual body felt like a human body."*
	OW 4	*"It felt like the virtual body belonged to me."*
Agency	AG 1	*"The movements of the virtual body felt like they were my movements."*
	AG 2	*"I felt like I was controlling the movements of the virtual body."*
	AG 3	*"I felt like I was causing the movements of the virtual body."*
	AG 4	*"The movements of the virtual body were in sync with my own movements."*
Change	CH 1	*"I felt like the form or appearance of my own body had changed."*
	CH 2	*"I felt like the weight of my own body had changed."*
	CH 3	*"I felt like the size height of my own body had changed."*
	CH 4	*"I felt like the width of my own body had changed."*
Body	SMS 8	*"I clearly physically felt what was going on in my body."*
	SMS 9	*"I changed my body posture and paid attention to the physical process of moving."*
	SMS 13	*"I noticed various sensations caused by my surroundings e.g., heat, coolness, the wind on my face."*
	SMS 14	*"I noticed physical sensations come and go. "*
Mindfulnes	SMS 18	*"I felt in contact with my body"*
	SMS 21	*"I noticed some pleasant and unpleasant physical sensations."*

Table 3: *Questions arranged by group and variable name. Each statement was answered on a scale from 1 – "Not at all" to 7 – "Extremely".*

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