Towards Embodied Identities: Investigating Personalised Avatars with Face Tracking in Social VR

Samuel E. R. Thompson[1], Dominik Lange-Nawka[2] and Burkhard C. Wünsche[2]

[1]*Department of Engineering, University of Cambridge*
[2]*The School of Computer Science, University of Auckland*

Abstract
Social VR has become an increasingly popular and powerful medium of communication. With the emergence of more powerful VR headsets, face tracking and the personalisation of users' avatars has become possible. However, it is unknown how added complexity of face tracking impacts social interactions, and whether these changes are consistent for all users. In this paper we investigate the challenges of face-tracked avatar personalisation, and the effects on embodiment and intrinsic motivation, by conducting an experiment involving a semi-structured interview in social VR. The use of personalised face-tracked avatars resulted in a higher sense of embodiment and intrinsic motivation overall. Results revealed correlations between the extraversion personality trait and embodiment, as well as correlations between embodiment subscales and agreeableness, conscientiousness, and openness. We highlight some key challenges identified in our research that may apply to similar studies in this field. Our findings underscore the importance of personalisation in social VR, empowering developers and researchers to create more effective and engaging social VR experiences.

Keywords
Embodiment, Virtual Reality, Personalisation, Avatars

1. Introduction

Virtual reality (VR) has become an increasingly promising new medium for gaming, human-computer interaction, and social experiences. Social VR experiences have increased in popularity, with many people using social VR as a major source of socialisation [1, 2, 3], partly due to users feeling an increased sense of immersion [4] and body-ownership over their avatars [5]. However, it is not fully understood how dynamic interactions and aspects of the virtual environment or avatars influence the user experience. The use of avatars in social VR has also been found to alter how an individual behaves and views themselves, a concept termed the "Proteus Effect" [5, 6]. Central to this is the concept of embodiment.

Embodiment is the amalgamation of varying diverse sensations that are typically associated with being inside of, and having control of a body [7]. While specific definitions may vary [8], the concept of embodiment can be thought of as three parts; a sense of self presence/self location, a sense of agency/control over the body, and a sense of ownership over the body [9]. Avatars are a user's digital representation of themselves. They are an appropriate way to extend the user's sense of self into the virtual environment (VE), allowing them to interact directly within it [5, 10]. In social VR, typically an avatar becomes the user's entire identity. In popular social VR applications, a users' avatar is often customisable to some extent through in-game customisation options or through third party options [10]. This enables users to choose exactly how they would like to be projected to the world. However, these tools are often limited in customisability, or require an amount of effort so large that some users would rather pay others to create an avatar for them [8].

The fidelity and behavioural realism of face tracking is more significant than body tracking for effective socialising in VR [11]. Current social VR platforms are limited in this aspect as many currently accessible consumer VR headsets do not yet support advanced face or eye tracking [12]. However, this

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sam.thompson.xr@gmail.com (S. E. R. Thompson); dlan133@aucklanduni.ac.nz (D. Lange-Nawka); burkhard@cs.auckland.ac.nz (B. C. Wünsche)
0009-0005-8049-3224 (S. E. R. Thompson); 0009-0004-0888-3490 (D. Lange-Nawka); 0000-0002-8013-4118 (B. C. Wünsche)

is changing, and modern VR headsets are beginning to integrate face and eye tracking technologies [12]. Face-tracked social VR allows a seemingly realistic sense of face-to-face communication [13].

While the role of personalised avatars and face-tracking in social VR has been investigated, it is not understood how combining these two technologies will impact avatar embodiment. Face-tracking is becoming a large part of modern VR headsets and social VR, however modern embodiment research often neglects this technology [14]. Therefore, we seek to answer the following research questions:

RQ1 How is an individual's embodiment impacted by personalised face tracked avatars in a social VR experience?

RQ2 How is an individual's intrinsic motivation impacted by personalised face tracked avatars in a social VR experience?

RQ3 How does an individual's personality impact their sense of embodiment and intrinsic motivation?

While the first research question is the primary research question, the second and third research questions play an important role in understanding the relationship between an individual and their sense of embodiment. It is essential to understand not only how embodiment is impacted by technologies, but also an individual's interests, sense of effort, relatedness, and sense of pressure. Additionally, it's important to understand how different personalities may be influenced by this technology.

To answer these questions we conducted a user study with 39 participants, and we compared the effects of personalised face-tracked avatars with generic non-face-tracked avatars.

2. Related Work

Mottleson et al. conducted a systematic literature review on virtual body ownership in VR, and they found that manipulating visual-motor synchrony correlated the most with body-ownership, while consistent appearance, point of view, avatar abstraction, and visual-tactile stimulus also correlated with body-ownership [15].

Pyasik et al. conducted a systematic literature review on body illusions with a focus on various cognitive domains such as social, perception, personality, and motor functions [16]. They found that despite the large variation in experiments, results showed that the embodiment of an entire fake virtual body typically implied the embodiment of the specific features of the body. Feick et al. found that full body avatars correlated with an increase in embodiment [17].

Personalised avatars are generated to look like the user's real body. Latoschik et al. conducted an experiment where a dyadic social interaction would take place in VR, and the users would either have personalised avatars or a generic mannequin avatar applied [18]. They found that the personalised avatars appeared to be more human-like, and that the other person's avatar impacted the user's own feeling of body-ownership.

Suk and Laine investigated the correlation between an avatar's facial appearance, embodiment and presence [7], showing that embodiment can be enhanced by using a personalised avatar, however the authors did not find the same results for presence.

Overall, there appears to be a lack of research in the area of facial tracking with personalised avatars in VR for dyadic social interactions. Research has been done comparing social interactions in VR to real life, and comparing personalised avatars in dyadic social VR to non-personalised VR, however this was without face tracking. Face tracking is the next step in enhancing avatar fidelity beyond purely graphical fidelity.

3. Design and Implementation

We designed an application to provide an immersive virtual reality experience to facilitate social interaction. An overview of the implementation can be seen in Figure 1.

Figure 1: A dyadic social interaction in the physical world (left) and the corresponding view in the virtual world (right)

To generate the avatars, a personalised virtual head capable of face tracking is generated from a single image using FaceGen Modeler [19], and then is integrated with a pre-constructed 3D avatar body in the Unity game engine, utilising the Facial Action Coding System (FACS). This 3D avatar body is capable of body and hand tracking. An overview of the personalised avatar generation process can be seen in Figure 2. This process would take around 5 to 10 minutes per participant.

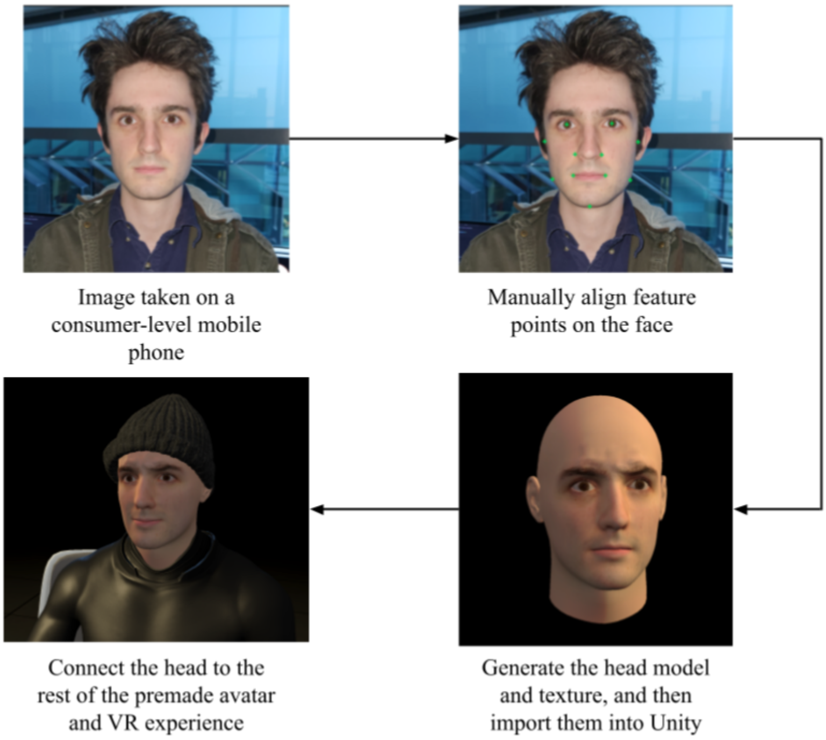

Figure 2: An overview of the personalised avatar generation process used for the user study. First, an image is taken of the participant on a consumer-level mobile phone. Then this image is processed by the FaceGen software, which produces a 3D model of the participant's head. This head model is then imported into the Unity game engine where it is connected to the rest of the avatar.

A generic 3D head model with a similar appearance to people with the expected demographics of the study was also created. This was also done using an image of a face generated with StableDiffusion. We expected most participants to be males in their early 20s, so we generated the genric avatars accordingly. Initially we tried to generate gender-neutral faces, though the results were not satisfactory. A mirror was placed to the side of the user, allowing them to view their avatar. The generic faces can be seen in Figure 3. An overview of the virtual environment can be seen in Figure 4.

Figure 3: The two generic avatar heads for the control condition. The head on the left is the generic head for the interviewer's avatar, and the one on the right is the generic head for the participant's avatar.

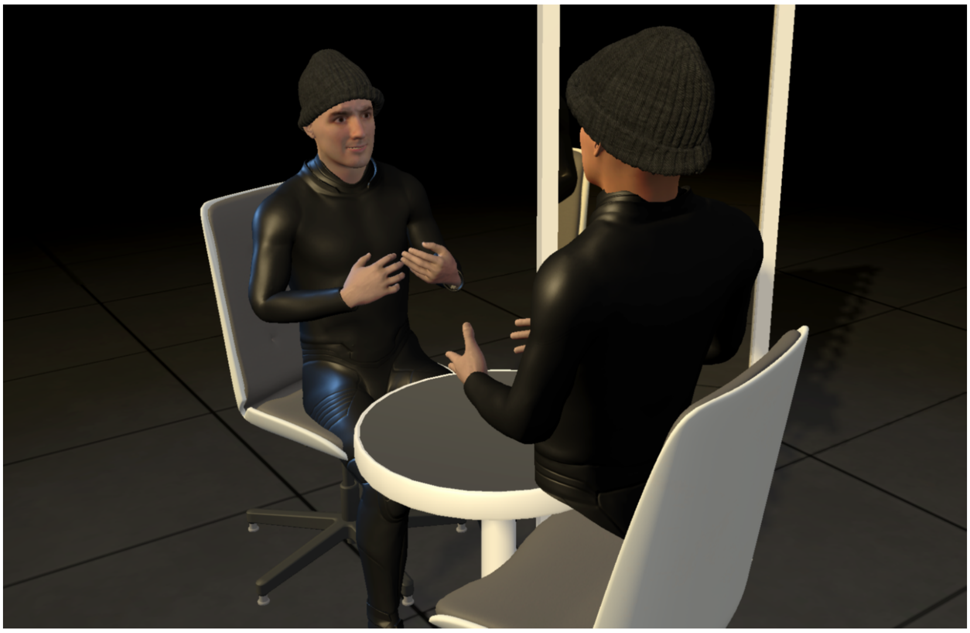

Figure 4: The social VR application. Participants appear to each other in a neurtral space with neurtral clothing. Not captured in this image is the dynamic nature of the facial expressions. On the right is the participant, and on the left is the interviewer. In this image the mirror is being visually obstructed by the participant on the right.

4. Evaluation

4.1. Experiment Methodology

We conducted a user study with 39 participants (36 male, 2 female, and one non-binary). The mean age was 23 years old, with a minimum age of 18 and a maximum of 42. A total of 33 participants had used a VR headset before, while 6 had not. Participants were seated 1 meter apart from the interviewer, facing them while wearing the VR headset. The interviewer was a colleague, but was not involved with the development of the research.

Each participant would complete a control condition and an experimental condition, and the order was counterbalanced using a Latin-square method. In the experimental condition the avatars were personalised and had face-tracking enabled, and in the control condition the avatars were each a generic avatar without face-tracking.

To calculate statistical significance we used both the Wilcoxon rank-sum statistic for two samples and the t-test for two related samples. When displaying results, p_w refers to the p-value obtained from the Wilcoxon rank-sum, and p_t refers to the p-value obtained from the t-test. Previous research has argued that t-test can also be used for Likert scale data [20]. The data is also tested for normality using the Shapiro-Wilk test.

Before the experiment the researcher would take a photo of the participant's face on a Samsung Galaxy S22 camera. Participants completed a pre-test questionnaire which contained a shortened version of the big five personality questionnaire [21].

Finally, we asked participants to write down two positive and two negative experiences that they have faced in their life, and rank how strongly these experiences had made them feel at the time, from Slightly (1) to Extremely (4). The participants were told to only share what they are comfortable to, and that these experiences would form the basis for the conversation with the interviewer. At the beginning of the experiment the interviewer would ask the participant about one of their negative experiences, and then one of their positive experiences, in order to end on a positive note. To ensure that all the results obtained from this experiment were not due to the conversation topics of one condition happening to be more intense than the other, we compared the topics discussed during the experiment. There were no significant differences between how strongly participants felt about the positive experiences in each condition and the negative experiences in each condition ($p_w = .600$, $p_t = .570$) and ($p_w = .300$, $p_t = .378$).

After each VR experience the participants were asked to complete a post-experience questionnaire including questions from the Intrinsic Motivation Inventory (IMI) [22], the standardised embodiment questionnaire [8], and some open-ended questions about the experience.

4.2. RQ1. Embodiment

There was a statistically significant increase in embodiment from the control condition to the experimental condition of 41.6% ($p_w = .190$, $p_t > .001$). There was also a statistically significant increase in response of 16.1% ($p_w = .129$, $p_t > .001$), in agency of 7.5% ($p_w = .147$, $p_t = .036$), and in body ownership of 8.8% ($p_w = .086$, $p_t = .013$). There were non-statistically significant increases in appearance of 5.1% ($p_w = .649$, $p_t = .054$), and multi-sensory of 5% ($p_w = .325$, $p_t = .086$).

It is important to note that while the t-test p-value suggests that these significant results are evidence of a real difference between conditions, the distributions of these groups did not pass the Shapiro-Wilk test for normality, so these p-values may only suggest weak evidence that there was a significant increase in embodiment, response, ownership, and agency from the control to the experimental condition.

It is more surprising that there was no significant difference in appearance between the conditions. This may be due to the fact that the generic and personalised models were generated in the same pipeline with the same technologies. This may suggest that the 3D models used in each condition were of comparable quality. Additionally, as mentioned previously, the generic models were designed to resemble the expected demographic of the user study. This may be partly why there was no significant difference in appearance between the conditions, as overall the quality and appearance of the avatars were similar across both conditions.

There was a significant increase in body ownership in the experimental condition, however this is not surprising. This may be due to the fact that participants recognised their own face in the mirror, and therefore felt that the digital body representation was of themselves. Interestingly, previous studies have found a correlation between including a mirror in experiments and lower reported ownership [15]. The authors suggest that this may be due to the lack of face-tracking in their experiments. Our results suggest that face-tracking has indeed a significant effect on body ownership - especially if users can see themselves in a virtual mirror.

The significant increase of agency in the control condition may be explained by the face-tracking. As participants could control the movements of their avatar, this may have created a stronger sense of control over their entire digital body. During the experimental condition, many participants claimed that their avatar's face matched their own even when they were not trying to test the facial expressions in the mirror. This caught some of them by surprise, in an almost immersive nature.

To answer the first research question, there is a statistically significant increase in embodiment, response, ownership, and agency when using the t-test, but not when using the Wilcoxon rank-sum test. Therefore, we have weak evidence that personalised avatars with face-tracking do enhance embodiment within social VR compared to generic non-face tracked avatars.

4.3. RQ2. Intrinsic Motivation

We measured interest, effort, pressure, and relatedness through the IMI for each condition that participants completed. These results show a statistically significant increase in interest from the control condition to the experimental condition of 6.5% ($p_w = .174$, $p_t = .001$), and a statistically significant increase in relatedness of 12.8% ($p_w = .019$, $p_t = .002$). This suggests weak evidence that there was a real, meaningful difference in interest between conditions, and strong evidence that there was a meaningful difference relatedness between conditions. However, there was a non-statistically significant increase in effort of 3.2% ($p_w = .569$, $p_t = .266$), and a non-statistically significant decrease in perceived pressure of 6.2% ($p_w = .385$, $p_t = .219$).

This may mean that participants felt a stronger sense of social connection in the experimental condition. Perhaps the increased behavioural realism from face-tracking facilitated non-verbal communication within the interaction, making the interviewer appear more relatable. Face-tracking can increase social presence in VR, which has been shown to be a predictor for relatedness and interest [23]. From this, it is not surprising to see that when more dynamic systems are introduced to a social interaction, that these scales appear to increase.

From the post-experiment questionnaire, 32 participants (82.1%) reported that they preferred the experimental condition. Additionally, 26 (66.7%) participants reported that they were more engaged in the experimental condition. This and previous results imply that participants typically found the experimental condition more enjoyable and interesting, and therefore had higher intrinsic motivation to participate compared to the control condition.

When asked about their response, common themes included enjoying the personalisation and face-tracking features, while some participants found the avatars creepy. The most engaging factors seemed to be the face-tracking, conversation topic, and novelty of the experience.

4.4. RQ3. Correlations with Embodiment and Personality Type

As the nature of personalisation is individual-based, we've analysed correlations between personality type and the embodiment/IMI subscales. To measure the relationship between variables we calculated the Spearman's rank correlation coefficient for each pair.

First we investigated any correlations between the embodiment subscales and the big 5 personality types. In the experimental condition there is a significant moderate positive correlation between extraversion and embodiment, with a correlation coefficient of 0.35 ($p = .027$). There is also a significant moderate positive correlation in the experimental condition between extraversion and appearance with a correlation coefficient of 0.38 ($p = .019$), and a significant weak positive correlation in the control condition with a correlation coefficient of 0.34 ($p = .035$). There is a significant weak positive correlation in the experimental condition between extraversion and response with a correlation coefficient of 0.33 ($p = .040$). Finally, there is also a significant moderate positive correlation in the experimental condition between extraversion and agency with a correlation coefficient of 0.40 ($p = .012$).

This is not unexpected, as the experiment is very social, and people who score higher in extraversion are more sociable and assertive [24]. While there is a significant correlation between appearance in the control and experimental conditions and extraversion, there are only significant correlations between extraversion and agency, response, or embodiment in their experimental conditions. The lack of significant correlations of extraversion and agency, response, and embodiment in the control condition may be due to the fact that there is an inherit difference, as suggested in section 4.2.

When analysing the correlations between the Big Five personality types and intrinsic motivation, we found that there is a significant weak correlation between conscientiousness and pressure in the control condition, with a correlation coefficient of 0.33 (p = .038), and a significant moderate negative correlation between openness and pressure in the control condition, with a correlation coefficient of -0.38 (p = .018). There was also a significant weak positive correlation between agreeableness and relatedness in the experimental condition, with a correlation coefficient of 0.34 (p = .033).

The significant positive correlation between agreeableness and relatedness in the experimental condition is not surprising. Individuals with higher scores in agreeableness are more likely to act with empathy [25], so being able to identify and understand the interviewer's emotional responses via facial expressions may be extremely helpful for them to relate to the interviewer.

The positive correlation between pressure and conscientiousness is interesting, as typically neuroticism is the personality trait that is correlated with stress [26]. However, some participants may have thought that the lack of face-tracking was an error. If this was the case, participants who scored highly in conscientiousness may have had the feeling that they were somehow doing something wrong, increasing stress.

There is a significant negative correlation between openness and pressure in the control condition. This could be due to the unsettling nature of the control condition. Participants who score higher in openness may feel less tension from the lack of facial expressions compared to those who score lower in openness.

Overall, these results suggest that intrinsic motivation and embodiment depends on users' personality traits.

5. Key Challenges

When carrying out this study, several key challenges emerged that may also be faced by similar studies.

5.1. Virtual Environment

Despite the personalised nature of this study, it became clear that it was difficult to design an environment that had minimal effects on the outcomes of the experiment. While the environment was designed to be dark and empty in order to remain blank, some participants felt this added a sense of creepiness, as if they were inside of a prison. This was likely further compounded with the blank clothing worn by the avatars. However, while most participants did not mention this, it highlights the limitations of a one-size-fits-all model for other parts of the scene, not just avatars.

Despite this, it is not clear how to best implement the personaliation of virtual environments. Future work should be done to identify the most appropriate metrics to measure for in order to reduce the impact these environments may have on similar experiments.

5.2. Avatar Generation: Automation and Output

Our method of generation relied upon FaceGen, proprietary software. This made it difficult to incorporate into a completely automated generation pipeline. In the future, we encourage personalised avatar software to be made open-source, allowing for easier integration in custom generation pipelines.

As this study focused on personalising an avatar's face, the rest of the virtual body was neglected. This resulted in an overall less personalised result for participants who's body differed from the generic one used for the avatar. These avatars would have benefitted substantially from even basic body personalisation, with minimal measurements, and not requiring images.

5.3. Consistency and Human Variation

This experiment was made possible due to the human interviewer who took part in all experiments. While the interviewer said that he would try his best to remain as consistent as possible throughout each experiment, this is only possible to an extent. Experiments were run throughout different times over multiple days, with participants having a variation of knowledge about the interviewer beforehand. Not only does this increase the risk of potential bias or inconsistency between participants, it also increases the difficulty of running these experiments. As with the avatar generation pipeline, removing the need for a human to constantly be manually involved in the experiment would allow for more consistent, rigorous, and easy to run experiment, which may potentially increase the appeal of these experiments to researchers.

6. Limitations

There was a lack of diversity in the participants of the study. From the experiment, 92.3% of participants were male. The mean age of participants was 23 with a standard deviation of 4.11 years, and the youngest participant was 18 years old, and the oldest was 42 years old. Therefore, despite our sample size of 39 participants, the results may not generalise to the overall population, despite our best efforts to recruit from a diverse population.

Avatars suffered from the uncanny valley effect, as several participants commented that the facial expressions appeared creepy and plastic-like at times. The generation pipeline, while efficient, is not completely automated, and requires human input.

7. Conclusion

We investigated the effects of personalised face-tracked avatars in a dyadic social VR experience on embodiment and intrinsic motivation. To achieve this, we developed a pipeline for generating personalised face-tracked 3D avatars for social VR, from a single image. We conducted an experiment with 39 participants, where they took part in a dyadic social interaction utilising either personalised, face-tracked avatars, or generic, non face-tracked avatars. We found that the use of the personalised face-tracked avatars enhance the user's sense of embodiment, response, ownership, agency, interest, and relatedness.

8. Future Work

One of the main points of this research has been to ensure that the social interactions were conducted in a setting which would achieve minimal bias towards the experience and would ensure the participant's visual focus was always on the interviewer or the mirror. While we believe this has been achieved in this work, it has also had the unintended consequence of appearing unsettling to some participants. Future work should look into repeating similar experiments in differing social settings, such as a relaxing coffee shop, or a large park. It would be interesting to see how changing the environment would impact the results.

We would like to improve upon the clothing of the generated avatars. Our study used basic black clothing to reduce bias from fashion style preferences, but it also appeared unsettling to a few participants. We would like to include more contextually believable and realistic clothing for avatars, or attempt to personalise the clothes that the participant's avatar is wearing based on their own real clothes. Similarly, participants should have the option of hair instead of a beanie, especially hair that has been personalised to the participant. This could be as simple as pre-generating an array of hair styles and colours, and manually matching one based on the participant's appearance. While this system would still not be perfect, it would still be preferable to hiding the participant's hair completely. Clothing has the potential to alter the perceived personality on someone in social VR [27], however it seems to play less of a role in aspects such as team dynamics [28]. Future work should investigate the role of clothing in social VR further.

With the rise of advanced generative AI, it would be interesting to see how this plays a role in personalised avatar generation, face-tracking, or even automating an embodied conversational agent

(ECA). This has the potential to automate the entire avatar generation process, and even automate the semi-structured interviewer role.

Finally, We would lie to improve on the accuracy and fidelity of the personalisation of avatars. In our work, the faces are personalised only by a texture and a 3D model of the participant. The mouth position, beanie position, and facial expression weighing should be personalised for a better “fit” for each participant to ensure that results do not vary too much between participants.

Declaration on Generative AI

The authors have not used any Generative AI tools.

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