The Psychological Impact of the Configuration of Self-Representation in Immersive Virtual Reality

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Abstract

This thesis presents an exploratory examination of *Self-Representation* through the technical configuration of *Embodiment*, meaning the subjective feeling of owning a virtual representation in Virtual Reality (VR). More specifically, it relates to how we prioritise and configure objective attributes of *Embodiment* such as Avatar fidelity and multi-sensory stimuli. This research aims to understand how different technical configurations of *Embodiment* in certain contexts in virtual environments could psychologically impact participants' perceptions of themselves and others. This research hopes to inform the development of successful embodied experiences and social interaction in various VR applications, ranging from training simulations to gaming experiences.

There are three studies conducted in this thesis. Two in-lab studies centre around configurations of synchronicity or *Embodied Consistency*, and the final in-application study focuses on configurations of *Embodied Virtual Perspective-Taking* for practice-based use-cases in VR. A summary of each can be found below.

Study 1 assessed the impact of the configuration of *Agency* in consistent and inconsistent arm movement and lip sync whilst embodied in a full-body *Self-Avatar*. The survey results showed an interaction effect, which suggested that there were higher levels of *Embodiment* in consistent conditions where there was *Agency* and that adding lip sync is not critical to facilitating more elevated levels of *Embodiment*.

Study 2 explored the impact of the configuration of a full-body *Self-Avatar* versus just controllers in a collaborative Embodied Social Virtual Environment (ESVE) and the consistency of Avatar representation between the two players. In the first study, one player was a confederate (*Exp1*), and in the second study, both players were participants (*Exp2*). The level of trust post-VR was measured using a questionnaire and a trust game. *Exp1* suggested that participants were more likely to give higher scores to the confederate (regardless of the confederate's representation) when they had an Avatar. *Exp2* suggested that participants trusted each other more in consistent conditions and that *Consistency* also impacted the pattern of their performance in the collaborative task.

Study 3 consisted of two pilot studies investigating the impact of different configurations of *Embodied Virtual Perspective-Taking* in a medical communication training application on *Self-Evaluation*. Participants were instructed to give bad news to an angry parent (AP) regarding their child's operation whilst embodied in an Avatar of a Doctor in scrubs. We tested whether being able to review the virtual consultation from the AP's perspective versus a third-person perspective could manipulate *Self-Efficacy*. Results suggested no significant influence of perspective; however, there was a slight effect of participant's occupation and personality on how they perceived their performance. Nurses and those with less confidence (nervousness) had a significant shift in their ratings compared to Doctors and more confident participants between their initial consultation in VR and watching their consultation back in VR. This preliminary study suggests this framework may be utilised better by early-stage practitioners who are less confident in their roles. However, more research needs to be done to confirm this effect.

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Licence

A thesis submitted in partial fulfilment of the requirements for the degree of PhD in the INTELLIGENT GAMES AND GAME INTELLIGENCE program at Goldsmiths, University of London.

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CVE	Collaborative Virtual Environment
IVR	Immersive Virtual Reality
VR	Virtual Reality
ESVE	Embodied Social Virtual Environment
EVE	Embodied Virtual Environment
EVPT	Embodied Virtual Perspective Taking
VPT	Virtual Perspective Taking

Chapter 1

Introduction

Examining how we experience ourselves inside a body that is simultaneously interacting with the virtual world is of great interest in the field of Cognitive Science and Virtual Reality (VR), as this helps us to investigate an important question in understanding the multi-dimensional reality of the embodied experience, 'to what extent can we experience a virtual body as our own and how do we utilise our understanding of the psychological impact to configure *Self-Representation* in VR?'

We have reached a point in the evolution of spatial computing where VR has become commonplace for solo exploration and social interaction, increasingly so due to the COVID-19 pandemic, which left most of the populace in isolation at home for increased periods of time. Though this does not exactly reach the reality described in popular pop culture author W. Gibson's Neuromancer (Gibson, 1984), or The Matrix (wac, 1999), the current technical landscape allows developers to create high-fidelity assets and virtual environments to immerse users in a digital world. We are also enabled by tools that add synchronised multi-sensory inputs and visual feedback when embodying an Avatar, a great shift from the 90s, which relied on text-based communication and static Avatar representation. This, in theory and practice, enhances the illusion of *Embodiment* for participants and allows researchers to understand better the extended dynamics of *Self-Perception* and social interaction within virtual worlds. Examples of these sensory integrations are using tactile integrations such as haptics, motor feedback, synchronised body and eye movement, and lip movement with synced audio. But what aspects of *Self-Representation* are specifically relevant in particular contexts of Solo and Social VR? What are the psychological effects of some of these configurations on participants' sense of self and perception of others, and finally, how can we build frameworks around this understanding to make better VR applications?

To address these questions, we must first define the meaning of *Self-Representation* in the context of VR as it stands in this thesis. If we look into the literature, we can see that the concept of '*Self-Representation*' and how it is configured can vary slightly among different schools of thought.

To a Psycho-analyst, the entity of 'Self' differs from the 'Self-Representation'; it refers to a representation or an image in the individual's own mind which can never be completely objective to the original 'Self'. The perception will always be configured through a lens of emotional or psychological factors such as dependency, love, admiration, envy, jealousy, anger or guilt(Milrod, 2002).

To a VR researcher, the role of *Self-Representation* can first be understood under the context of *'Self-Presence'*. In Biocca's work in 1997, they stated that *Self-presence* refers to a user's mental model of themselves or simply the awareness of self-identity inside a virtual world (Biocca, 1997). Lee added to this in 2004 to suggest that it occurs when the technology users, i.e., those wearing a VR headset, do not notice the virtuality of either authentic representations of themselves or artificially constructed alter-selves inside virtual environments but are in a psychological state in which their virtual selves are experienced as the *actual* self (Lee, 2006; Tamborini and Skalski, 2006).

Where the concept of *Self-Presence* refers to the psychological and cognitive connection to the virtual self, the physical and sensory connection is emphasised by the term *Embodiment*; or the feeling of owning

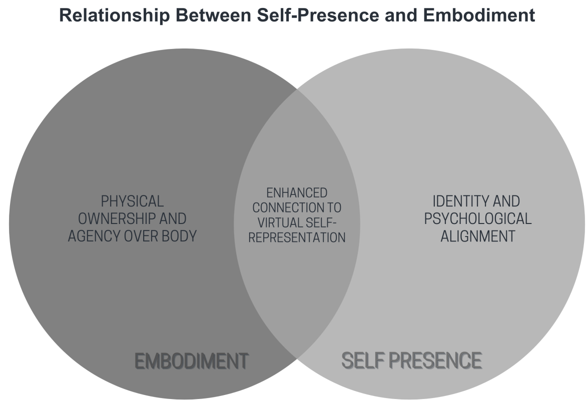


Figure 1.1: Relationship between Self-Presence and Embodiment

a *body* in Virtual Reality (Kilteni et al., 2012a), which is a more recent ideology in the literature around *Self-Representation*.

These dimensions are related concepts and do interact and overlap with one another; a strong sense of *Embodiment* can make users feel more connected to their virtual representations, enhancing *Self-Presence*, whereas feeling psychologically aligned with the virtual representation of a virtual-self can reinforce the sense of physical ownership and *Agency* over that body. However, where they differ is that *Self-Presence* focuses on how much the user feels their virtual representation (Avatar) reflects their real-world self; meanwhile, *Embodiment* extends this by exploring the sensation of owning and controlling a virtual body as if it were your own, regardless of its form, utilising the new possibilities for *Self-Representation* VR creates.

Therefore, in this thesis, we define the configuration of *Self-Representation* as the technical setup of *Embodiment*, both in the realm of visual Avatar factors and tracking attributes.

Through our research, we hope to identify the new (in principle) frameworks for configuring *Self-Representation* in VR by identifying the technical demands in three cases and exploring the *Embodiment* modalities for each task. Those cases will be outlined in the next section, in which we will highlight our research problems.

1.1 First Research Problem

At the nucleus of the issue, several studies have tried to unpack the conditions that need to be met to evoke *Embodiment*. Research suggests general consensus in highlighting important dimensions such as 'Sensory Integration', 'Perspective' and 'Avatar Realism' (Spanlang et al., 2014; Mottelson et al., 2023; Chen et al., 2023). However, there is still a fragmentation within the literature within these dimensions, restricting efforts to fully grasp the impact of certain configurations of *Self-Representation* on subjective paradigms of psychological measurement such as *Body Ownership*, *Agency*, *Social Presence* and more recently, *Self-Efficacy*.

A level of consideration on configuring *Self-Representation* in VR could be hinged on whether the user is immersed in VR alone, with others (humans or *Agents*), or Perspective-Taking in others (humans or Agents), as research denotes contextual attributes (Friedman et al., 2006) could also have an impact on how participants perceive themselves. Arguably, this may also foster different dependencies within how we configure *Self-Representation*.

Our first research problem takes a look into the configuration of *Embodiment* in Solo experiences and addresses sensory integration. In Solo VR, we know that the literature suggests that the removal or interruption of *Visuomotor* feedback may break the illusion of *Body Ownership* - the feeling of owning a virtual body. However, it is also known that participants have been able to adapt to changes in proprioception without disruption to *Body Ownership* and *Agency*, where *Agency* refers to the feeling of having motor control over the virtual body (Kilteni et al., 2012a). Studies also support the notion that multi-sensory integration is important for inducing *Embodiment*; however, other researchers argue these effects may be influenced by participant expectations and suggestibility (Guy et al., 2023) and other influences such as task. Additionally, research informs us that higher fidelity in body tracking, such as full-body Motion Capture, amplifies *Embodiment* by increasing the realism of motor behaviour (Roth et al., 2016). However, restrictions due to devices may mean that some multi-sensory inputs cannot be realised, limiting the amount of body expressions the system captures from the user. Overall, we can say that *Self-Representation* is fluid and can be impacted by attributes other than Bottom-Up (sensory) influences. Though high-fidelity tracking systems can increase *Embodiment*, not all systems can allow it.

Nevertheless, in the literature, we see the argument that even with low thresholds of immersion (the level at which a user can be technically embodied in Virtual Reality), such as in the 'Rubber Hand Illusion' with a static, un-moving projection, can still result in high levels of *Body-Ownership* and *Agency*. (See Chapter 2 for details). As we are becoming advanced in gathering sensory input from users, we must consider the effect of specific configurations of sensory input in displays of *Self-Representation* in VR. One way to do this is to observe the impact of consistency between sensory inputs - i.e., what needs to be present and what does not. Highlighting what consistencies need to be maintained within sensory integration could significantly broaden our awareness of the limitations of manipulating *Self-Representation* in this context.

Research Question 1

We question how the setup of *Visuomotor* congruence in *Self-Representation* can have an impact on the psychological response of *Agency* and *Body Ownership*. This research could prove beneficial to developers and researchers in understanding the thresholds of computational value from different configurations of *Embodiment*. Therefore, we ask:

- RQ1: What amount of sensorimotor inputs and configuration of synchronicity is necessary for *Embodiment*?
- **Hypothesis 1 (H1):** *Synchronised Visuomotor configurations of Arm tracking and Lip-Sync will invoke higher feelings of Embodiment within the dimensions of Agency and Body Ownership.*

1.2 Second Research Problem

The second research problem looks at the configuration of *Self-Representation* in social virtual settings. Social interaction is complex, even in real life. Many aspects can impact the flow of interactions and relationships, most of which have been proven to apply to reality and VR, such as visual representation and verbal and non-verbal communication. Nevertheless, when it comes to VR, these configurations of *Self-Representation* can vary significantly between users in terms of visual and behavioural implementations, as there is a wide breadth of how an Avatar can be constructed outside of what is possible in the real world. This can result in 'uniform' configurations in the setup of *Embodiment* between users, which are consistent, or 'non-uniform', inconsistent configurations where there are significant differences in how users look and behave. Fundamentally, there is still a divide on whether Avatar realism critically affects *Body Ownership* (Mottelson et al., 2023). Additionally, in Social VR, though we know that visual fidelity can have a positive effect on *Social Presence*, we don't know how inconsistent setups of *Self-Representation* between dyads can impact this effect(Pan and Steed, 2017).

It's important to note here that, though inconsistency normally evokes a negative connotation, in this instance, it represents just another intentional setup of configuring an Avatar that can be found in

Figure 1.2: Image of diverse Avatar representations from VRChat

many existing social VR platforms, such as VRChat[1]. On this platform, Avatars can range from Giants to Hobbits, Humans to Anime Characters (see Figure. 1.2). Nevertheless, arguably, in certain contexts, this potentially can impact *Social Presence*.

Social Presence can be defined as the 'sense of being with another' (Biocca et al., 2003) in VR. We already know from previous research that it is possible to feel *Embodiment* with less than a full virtual representation (Tsakiris and Haggard, 2005) and even without one entirely (Murphy, 2017). However, in a social context, it's arguable that one's awareness of oneself is heightened due to the knowledge that someone else is watching. It can be said that *Embodiment* strengthens the loop between perception and action in Social VR, where users' actions are mirrored by their *Self-Avatar* and interpreted by others (See Figure 1.3). Additionally, in the same vein, the participant's perception of the 'other' user is also scrutinised. Therefore, we hypothesise that *Self-Representation* will be impacted.

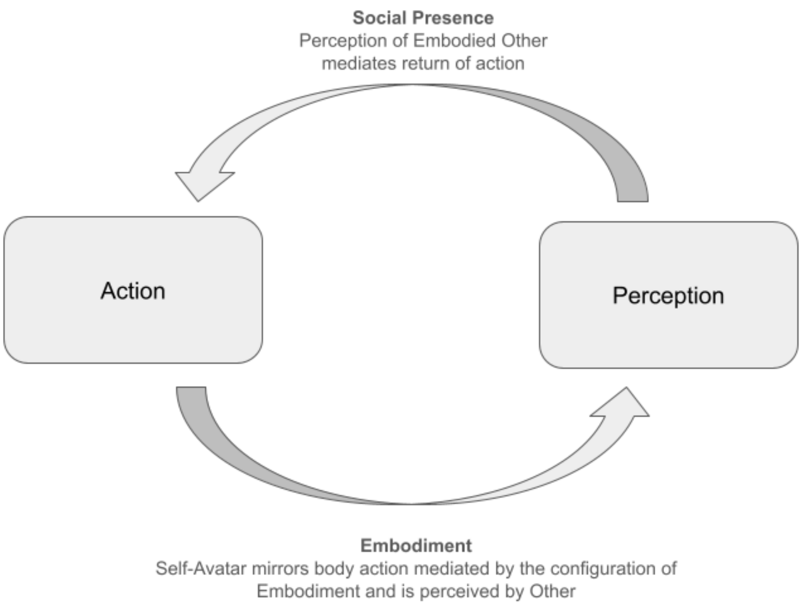


Figure 1.3: Relationship between Social Presence and Embodiment

Understanding the impact of these dynamics can lead to building more informed social experiences in VR. Moreover, in contexts where users need to work with or trust each other, it may become paramount

[1] https://hello.vrchat.com/

to understand how *Social Presence* can be regulated by sensory and visual congruence.

We question how the setup of visual congruence can impact the psychological response of *Social Presence*. Extending the work by Pan (Pan and Steed, 2017), which looks at the impact of 'Self-Avatar' on trust in collaborative VR, the gap identified is the impact of the visual inconsistency in *Self-Avatar* configuration between paired users.

Research Question 2

Exploring how different configurations of *Self-Avatar* representations between multiple users impact social interaction can bring valuable insight into establishing effective frameworks of *Embodiment* in Collaborative Virtual Environments. Therefore, we ask:

- RQ2: How can inconsistent and consistent configurations in *Self-Representation* have varying impacts on *Social Presence*?
- **Hypothesis (H2):** *Inconsistency between Avatar configurations of Embodiment will have negative effects on Social Presence in dimensions of Trust.*

1.3 Third Research Problem

The third research problem focuses on an extended dimension of *Embodiment* in recent VR literature, Perspective-Taking. Perspective-Taking is a powerful tool utilised and studied extensively in Social VR. One popular setup is the *Embodiment* of an Avatar, allowing participants to embody an existing persona or access a change in spatial perspective. We are aware of some of the psychological effects that come from this setup, which research reveals range from temporal reduction of action conformity (Neyret et al., 2020), augmentations to the perceptions of object sizes by becoming children (Banakou et al., 2013) and changes to individual character traits such as self-esteem and intelligence by becoming Einstein (Banakou et al., 2018). These findings have already influenced many virtual experiences, some of which seek to bring awareness and build empathy for medical conditions such as autism and dyslexia. Another way of using Perspective-Taking is to first experience a scenario through *Embodiment* of a *Self-Avatar* (an Avatar representing the Self) and then review the experience through an alternative Avatar perspective. Though this setup is usually utilised to evoke and study empathy, it is not clear how different configurations of *Embodied Perspective-Taking* (first-person Self-Avatar) versus *Disembodied Perspective-Taking* (third-person No-Avatar) can manipulate evaluation, or in particular, *Self-Efficacy*. This can be impactful in scenarios that seek to train communication skills, especially in the medical field. The convergence of healthcare and immersive technologies is ushering in new treatment and training methods, making it vital to investigate how the psychological impact of this utilisation of *Embodiment* can influence learning processes such as *Self-Evaluation* for general practitioners and trainees. There is a need to assess VR systems for non-technical medical training. VR is unique because it's the only platform that can facilitate a full-body perspective switch (or *bodyswap* as it's commercially known) through the process of *Embodiment*, providing a new experience of *Self-Representation.*

Research Question 3

We question how the setup of Perspective-Taking between a *Self-Avatar* and a *Semi-Autonomous Agent* can impact the psychological response of *Self-Efficacy.* Therefore, we ask:

- RQ3: What impact does the configuration of *Embodied Virtual Perspective-Taking* have on learning processes such as *Self-Evaluation?*

- **Hypothesis (H3):** *Configuring Perspective-Taking, an application of Embodiment through a first-person perspective versus no-Avatar third-person perspective will result in a significant negative difference in Self-Evaluation in the dimension of Self-Efficacy.*

1.4 Aim

Our research on the configuration of *Self-Representation* considers the psychological impact through varying modalities in VR.

Through our investigations, we hope to contribute to the literature of configuring *Self-Representation* within three experiential contexts of VR: 'A Solo Training Experience', 'A Social Collaboration Experience' with the use of confederates and Dyads and 'A Social Communication Training Experience' with the use of a *Semi-Autonomous Agent* and Perspective-Taking. We hope the findings will help those developing training and collaboration experiences in VR frame their technical pipeline for *Self-Representation* in these contexts and also create a discussion on how the results align with or contradict the current empirical beliefs around configurations of *Self-representation* and the psychological impacts in VR.

As an additional contribution, this thesis reviews a novel framework of *Embodied Consistency* - see Chapter 2 for definitions. We test this framework in our first two studies.

Overall, this write-up aims to present an informed report of a detailed investigation into the correlative impact of the configurations of *Embodiment* in VR and its potential psychological effects, therefore providing both researchers and developers insights into better designing their experiences for experimental and practical use cases involving *Self-Representation* in VR.

1.5 Overview and Scope of Thesis

Chapter	Study	No. of Participants	Research Question	Hypothesis
3	Lip and Arm Sync	30	RQ1	H1
4	Avatar Consistency (Confed)	17	RQ2	H2
4	Avatar Consistency (Dyad)	18	RQ2	H2
5	Perspective Taking Consultation (Embodied)	6	RQ3	H3
5	Perspective Taking Consultation (Disembodied)	16	RQ3	H3

Table 1.1: Table lists all five studies along with the Research Question (RQ) and Hypothesis (H) they address.

This thesis will start in Chapter 2 with a detailed literature review that will systematically define and depict the technical attributes of *Self-Representation* in lab research and application. This will be accompanied by an explanation of how previous research has informed the investigations presented in this thesis, thoroughly giving the right bases to understand the purpose and importance of the questions being addressed within *Embodiment* and sensory integration, *Social Presence* and Avatar representation and Perspective-Taking and *Self-Efficacy.* We will not delve into the hardware specifics or details on 3D modelling pipelines as this is outside the scope of this thesis, and we utilise pre-existing assets. We wish to highlight the art of the possible available through products currently accessible on the market. Finally, we introduce our additional contribution of the *Embodied Consistency* framework as an alternative lens for constructing *Self-Representation* in Solo and Social VR contexts.

The following three Chapters will explore the results of experiments that answer our research questions; see Table 1.1 for details. Chapter 3, *'Lip and Arm Sync'*, will explore RQ1, the impact of implemented visual sensorimotor input by using the Kinect to Motion Capture arm movement and Oculus's OVR-LipSync plugin to implement simulated lip-syncing. We acknowledge that there are more examples of sensory integration related to *Self-Representation* to explore; however, we chose to focus on lip-sync and arm movement as these are important non-verbal cues for the task of delivering a speech or presentation and within the resource to implement during the time of conception.

Chapter 4, *'Avatar Consistency (Confed/Dyad)'* will address RQ2, *Self-Representation* within social contexts, using the HTC Vive headset and controllers with Inverse Kinematics to capture upper body movement to study the impact of different configurations of *Embodiment* between pairs.

Chapter 5, *'Perspective Taking Consultation (Embodied/Disembodied)'* , will aim to answer RQ3, looking at how Perspective-Taking can impact *Self-Efficacy.* Similar to our study in Chapter 4, we will use Inverse Kinematics to capture upper body movement; however, we will explore two different perspective transitions to investigate the effect of the embodied first-person perspective and disembodied third-person perspective.

Chapter 6 will denote additional work done through internships and partnerships, which have supported and influenced this thesis's work.

Chapter 7 will evaluate the research results gathered, with an overview of its contribution to the grander scope of this field of work in configuration *Self-Representation* and the psychological effects and will detail the notes for future research to be done.

1.6 Associated publications

Portions of the work in this thesis have been presented in national and international scholarly publications, as follows:

- Chapter 3: The Effect of Lip and Arm Synchronization on Embodiment: A Pilot Study:

  T. Collingwoode-Williams, M. Gillies, C. McCall and X. Pan, "The effect of lip and arm synchronization on embodiment: A pilot study," 2017 IEEE Virtual Reality (VR), Los Angeles, CA, USA, 2017, pp. 253-254, doi: 10.1109/VR.2017.7892272.

- Chapter 4: The Impact of Self-Representation and Consistency in Collaborative Virtual Environments:

  Collingwoode-Williams, Tara; O'Shea, Zoe; Gillies, Marco and Pan, Xueni. 2021. "The Impact of Self-Representation and Consistency in Collaborative Virtual Environments". Frontiers in Virtual Reality, 2, 648601. ISSN 2673-4192.[Article]

- Chapter 5: Delivering Bad News: VR Embodiment of *Self-Evaluation* in Medical Communication Training:

  T. Collingwoode-Williams, M. Gillies, P. Nambyiah, C. Fertleman and X. Pan, "Delivering Bad News: VR Embodiment of Self Evaluation in Medical Communication Training," 2024 IEEE 12th International Conference on Serious Games and Applications for Health (SeGAH), Funchal, Portugal, 2024, pp. 1-8, doi: 10.1109/SeGAH61285.2024.10639600.[Article]

1.7 Additional Publications

Listed below is a collection of work completed within the duration of the PhD program. Though not the lead author, there was a significant contribution made that related to the theme and research questions of this thesis. The relevance of this will be discussed in Chapter 6.

- Evaluating Virtual Reality Experiences Through Participant Choices:

  M. Murcia-López, T. Collingwoode-Williams, W. Steptoe, R. Schwartz, T. J. Loving and M. Slater, "Evaluating Virtual Reality Experiences Through Participant Choices," 2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), Atlanta, GA, USA, 2020, pp. 747-755, doi: 10.1109/VR46266.2020.00098.

- A Study of Professional Awareness Using Immersive Virtual Reality: The Responses of General Practitioners to Child Safeguarding Concerns:

  Pan X, Collingwoode-Williams T, Antley A, Brenton H, Congdon B, Drewett O, Gillies MFP, Swapp D, Pleasence P, Fertleman C and Delacroix S (2018) A Study of Professional Awareness Using Immersive Virtual Reality: The Responses of General Practitioners to Child Safeguarding Concerns. Front. Robot. AI 5:80. doi: 10.3389/frobt.2018.00080

Chapter 2

Background

In this Chapter, we present a critical review of the literature to provide a robust theoretical foundation for exploring the psychological impacts of *Self-Representation* inside VR. We begin by examining theories that exist outside of VR. Integrating perspectives from Psychology and Social Sciences on *Embodiment, Social Presence, and Social Identity* theories. We then transition into the context of VR, outlining theories unique to VR and reviewing empirical studies that investigate the technical and psychological aspects of *Embodiment* and the importance of VR integration. This Chapter highlights many interdisciplinary intersections, examining how virtual environments shape *Self-Perception* and social interaction through configurations of *Self-Representation.* Finally, we introduce the *Embodied Consistency Framework*, a novel approach that synthesises existing research to address gaps in understanding and designing experiences for both Solo and Social VR.

2.1 Theoretical Frameworks Relevant to Self-Representation

2.1.1 Embodiment Theory

Even though we don't delve too deeply into nuances of the psychology of *Embodiment* and *Self-Representation*, it's still important to address these theories outside of VR to give a fuller holistic context to the work in this thesis. *Embodiment* in the literature presents the notion that the body is central to how individuals experience the world and is an active participant in perception. Work by Glenberg in 2010 highlighted that knowledge of Embodiment theory could help psychologists understand abstract paradigms such as cognition, social processes and other psychological dysfunctions by unifying schools of thought (Glenberg, 2010).

Merleau-Ponty introduced a philosophical framework emphasising that perception is shaped by bodily engagement with the world; he posits that perception is inherently embodied, meaning that sensory input, motor actions, and environmental contexts are intertwined to provide a unified experience or reality (Merleau-Ponty, 2012). Even in earlier literature, Proffitt highlights the body's role in shaping cognition, suggesting that the perception of physical properties in the environment is influenced by the body's physiological and emotional states, for example, that perhaps wearing a heavy backpack could make hills appear steeper and distances to targets appear greater (Proffitt, 2006). Moreover, we face *Embodiment* daily in what we choose to wear. A study in 2000 by Guy and Banim found that we have a dynamic relationship with what clothes we wear, and this relates to how we view ourselves according to who we hope to be, who we fear to be and how we are most of the time (Guy and Banim, 2000). VR can extend this notion by curating unique circumstances of embodied perception that cannot be facilitated in reality but can have similar effects, going further than clothing to body attributes such as being embodied in a child's body impacting perceptions of the size of objects in the environment (Banakou et al., 2013) or dressing causally in a dark skin Avatar and playing with more vibrancy (Kilteni et al., 2013).

A famous influence of VR *Embodiment* in terms of *Body Ownership* is, evidently, the 'Rubber Hand Technique' (Botvinick and Cohen, 1998). Ten participants were recruited for the study. A life-sized hand was placed on a table in front of the participant and aligned roughly with the participant's concealed real hand. Both the rubber hand and the participant's hands were stroked (in sync or async due to the condition). Participants reported a strong sense of ownership over the rubber hand during the synchronised condition. They also reported that their sense of where their real hand was located shifted towards the rubber hand.

'The Rubber Hand Illusion' is a cornerstone study in *Self-Representation* and *Embodiment* in VR and Psychology research. This experiment showed that synchronising visual and tactile stimuli can create an illusion of ownership over a fake rubber hand, highlighting multisensory integration in body representation. We talk about this more later on in this Chapter. In the next section, we will continue our discussion on *Self-Representation* by addressing theories of how it is curated and mediated, helping us to understand how this pertains to its depiction in VR.

2.1.2 Self-Representation Theory

In our introduction, we broke down some definitions of *Self-Representation* in the field of Psychology; we explained that *Self-Representation* is a perception of 'Self' conformed to the emotional or psychological factors such as dependency, love, admiration, envy, jealousy, anger or guilt (Milrod, 2002). In earlier literature, it is presented that *Self-Representation* is active and dynamic; subject to change due to its centrality or importance; Markus and Wurf posit,

"Some [Self-Representations] are more important and more elaborated with behavioural evidence than others. Some are positive, some negative; some refer to the individual's here-and-now experience, while others refer to past or future experiences. Moreover, some are representations of what the self actually is, while others are of what the self would like to be, could be, ought to be, or is afraid of being..."(Markus and Wurf, 1987).

Self-Representation also differs in whether it has been achieved; some are aspirational but are not possible for the person, which brings an interesting highlight to the unique opportunities of VR, which can graphically curate impossible representations through *Embodiment*, which we can arguably say can mediate perceptions of *Self-Representation.*

Furthermore, Higgins, in 1983, hypothesised that there are three classes of *Self-Representation.* Those that reflect the 'actual self', the 'ideal self' which they would like to possess, or the 'ought self' which represents what a person believes they should possess. When there is a discrepancy between any two of these concepts, this can cause emotional states of discomfort (Higgins, 1987). This arguably could affect measures such as *Self-Efficacy*, which is the belief in one's ability to succeed in a specific task. In Chapter 5, we use *Embodied Virtual Perspective-Taking* as a medium for participants to evaluate themselves in VR. Here, there is a tension between the 'actual self' and the 'ought self', which is mediated by the configuration of *Self-Representation* through embodying a *Self-Avatar.*

Nevertheless, we return to an important question of how *Self-Representation* is formed and functions. Milrod suggested emotional and psychological influences; Markus and Wurf suggest it can be consciously accessible or repressed due to certain defences or desires, but interestingly present the notion that people learn about themselves from others through social comparisons and direct interactions. McGuire and colleagues in 1984 hypothesise that one of the most powerful determinants of currently available *Self-Representation* (or self-concepts as he calls it) is the configuration of the immediate social environment; for example, short children will notice their height when in a classroom of taller children (Suls and Miller, 1977). Ultimately, we can come to a consensus about the fluidity of *Self-Representation*; one can have many 'identities', but the salience and commitment to one seem to pivot on whether it is accessible or desired and how it is potentially mediated by social interactions (Stets and Serpe, 2013; Markus and Wurf, 1987). In the next section, we delve more into the influences of social constructs on *Self-Representation.*

2.1.3 Social Identity and Social Presence Theory

To understand *Self-Representation* holistically, we must also comprehend how it plays a role in interpersonal interactions within VR by going into its theoretical history in Social Psychology.

Social Identity Theory (SIT), and *Social Presence* together shed light on the complex aspects of *Self-Representation*. SIT can be defined as a person's knowledge that he or she belongs to a social category or group and therefore incorporates characteristics or ideologies of the in-group into their self-concept (Stets and Burke, 2000). As discussed in the previous section, the salience and commitment to *Self-Representation* can be mediated by group settings and social interactions. Furthermore, if we think about technical mediums for facilitating these social interactions, this conversation becomes pertinent to the configuration of *Self-Representation* in VR, as it can enable a higher fidelity of multisensory interaction than others.

In a book by Short, Williams and Christie, they discuss previous ideologies on social interaction by Douglas in 1957, suggesting a person and another Person (Other) think of both acting out a certain role and maintaining some personal relationship during an interaction - defined them as *interparty* and *interpersonal* exchange respectively. They argue Morley and Stephenson took it a step further, suggesting that the relationship between these two terms can be affected by the medium of communication in which it is being used; for example, in VR, there would be a greater emphasis on *interpersonal* exchange as each party would be more concerned with how they appear to the other in comparison to a telephone call where there is no visibility. However, the authors alternatively proposed that the 'degree of salience' of the other person in the interaction and the 'consequential salience' of interpersonal relationships could be an important hypothetical construct that can be applied more generally. They coined this theory, *Social Presence* (Short et al., 1976), which focused on the capacity of a medium to transmit information about non-verbal cues, the direction of looking and aesthetics during an exchange. They argued that the weight given to these factors is dependent on the Person and their mental state towards the medium and its configuration, further refining this definition to be a subjective quality of the medium. They note that it's not the objectivity of these factors available in the medium but the awareness of them to the user which is more impactful, creating a continuum where mediated others could be more or less 'present'.

Off the back of this notion, VR researchers began to explore the dimension of *Social Presence* in IVR, stretching its definition to include the sense of 'being with others' in a virtual space.

The interconnected frameworks of *Social Identity Theory (SIT)* and *Social Presence* collectively highlight the complex characteristics of *Self-Representation*. SIT underscores the role of group memberships in shaping an individual's self-concept, demonstrating how categorisation into in-groups and out-groups drives behaviours such as bias and status-related responses. These foundational perspectives converge in revealing that *Self-Representation* can be intricately tied to social structures (Stets and Burke, 2000). Furthermore, insights from the review of *Social Presence* theories extend these ideas to technology-mediated contexts, showing how virtual and physical environments amplify or constrain the ability to express and perceive social and emotional cues (Short et al., 1976; Stets and Burke, 2000; Biocca et al., 2003). Together, these theories propose that *Self-Representation* is a dynamic construct shaped by societal, psychological, and technological dimensions, and therefore, how we are configured through *Embodiment* within VR can mediate these effects. In the next section, we will outline the core theories proposed through the literature on VR that are fundamental to the unique experience this medium provides. We use this to justify the use of the technology and introduce the main psychological effects we hope to measure and address within this thesis.

2.2 Introduction to the Psychology of VR

2.2.1 Perceiving the world through Illusions of IVR

Immersive Virtual Reality (IVR) is the construction of a 360-degree virtual environment in which a fully immersed user can explore multisensory, 3D computer-generated content. Immersion usually occurs when a user wears a standard head-mounted display that occludes the outside world, allowing total isolation into a virtual environment. Depending on the Immersion level - the objective capabilities of the system - users may interact with their surroundings using a paired device, such as a controller or wand, giving them 3DoF (position data) or 6DoF (position and rotation) of movement.

We decided to use this technology as a testbed for this thesis as it provides the unique opportunity to create 3D environments and experiences that would be difficult, unsafe or impossible to replicate in real life. For example, encouraging bystander behaviour in a violent incident (Rovira and Slater, 2022).

Additionally, three fundamental illusions can be evoked which are unique to VR: *Embodiment* and two orthogonal illusions of *Presence*: *Place Illusion* and *Plausibility Illusion* (Slater, 2009). Witmer defines *Presence* as the feeling of being 'present' in VR (Witmer and Singer, 1998). In the next section, we will go into more detail about the illusions and their role in the VR experience.

Plausibility Illusion

According to (Slater et al., 2022), *Plausibility Illusion* centres around three requirements:

- The virtual environment must respond to the participant's actions, for example, the participant turning to look to their left and the system responding with an update to the virtual camera's pose.
- The events must in the environment contingently refer to and acknowledge the participant, for example, an *Agent* turning to face a participant due to a programmed condition of interaction based on proximity.
- The virtual events must meet the expectations of the participants. This is contingent on the individual and their expertise and familiarity with the subject. For example, a doctor noticed they could read the computer screen during their consultation within a VR CAVE setup. Something which they should be able to do in real life (Pan et al., 2016).

In summary, it relies on the events and actions, building the credibility of the experience. And there is research that suggests there are correlations of effect between Slater's illusions. In Skarbez's experiment (Skarbez et al., 2017), the team investigated the components of *Plausibility Illusion* using subjective matching techniques similar to those used in colour science. Twenty-one participants experienced a scenario with the highest coherence level (the extent to which a scenario matches user expectations and is internally consistent). They chose transitions from lower-coherence to higher-coherence scenarios in eight different trials to match the plausibility level they felt in the highest-coherence scenario. In this example, there were three conditions of the *Self-Avatar*: Feet-Only (VB0), Static Arms and Torso Avatar (VB1), and Fully Tracked (VB2). Their results showed that participants tended to choose improvements to their virtual body before any other improvements to the environment, suggesting that having an ideal *Self-Representation* of oneself in the virtual environment contributed most to the *Plausibility Illusion*, suggesting the correlative relationship between *Embodiment* and *Plausibility.*

Place Illusion

Place Illusion relies heavily on the technical setup of the virtual environment. This involves fundamentally occluding the participants' field of view (FOV) of the real world to be fully immersed in another location painted by the 3D graphical interface. This is commonly accomplished using a stereo head-mounted display (HMD) with a wide field of view. Where the *Plausibility Illusion* requires more dynamic provocation, building the *Place Illusion* is quite static; a participant can still feel this effect even when no events occur. However, there are other ways of establishing this illusion besides using an HMD, which can be seen in Garau's experiment using the Cave Automatic Virtual Environment, also known as CAVE (Garau et al., 2005). In this experiment, the virtual space's visual has been projected on the four walls, the ceiling and the floor surrounding the participant (Cruz-Neira et al., 1993). The participant's location within that virtual space is tracked using gyroscope head-tracking shutter glasses, allowing the room's projection to shift according to the participant's perspective and make the room appear 3D. The only drawback of using CAVE is that it does not completely occlude the real world; the participant can still see their own body. Therefore, as this thesis centres around a spectrum of *Embodiment* within Avatars, CAVE was eliminated as a testbed for these studies. In the next section, we will discuss further challenges of various implementations of *Embodiment* and how this has influenced the chosen setup of immersive VR for this research. Still, first, we will introduce the concept.

Embodiment in Virtual Reality

There are many parallels across bodies of literature that help to frame our present understanding of Embodiment Theory; however, as we addressed earlier, the starting point for these fragmented notions is that there is a belief that psychological processes are influenced by the body; this includes body morphism, sensory systems, and motor systems - in VR, these body manipulations are processed through an Avatar - a virtual body.

To explore VR scenarios, there needs to be a vessel which participants can use to feel 'present' in the environment. The solution employed in many cases is to use a virtual body (*Self-Avatar*), which allows for the first-person exploration of the 3D world with a digital representation of themselves, which can come in various shapes, sizes and depictions of identity (Morris et al., 2023; Freeman et al., 2022). The subjective feeling of ownership a participant may have over this virtual body is what we refer to as *Embodiment* (Kilteni et al., 2012a). Research has investigated the most important factors that precede this illusion. We discuss these later on in this Chapter.

In Kilteni's work, she breaks *Embodiment* into three dimensions of measure: *Sense of Location*, feeling self-located inside a body; *Sense of Body Ownership*, one's self-attribution of a body; and *Sense of Agency*, having control and an experience of will in a body (Kilteni et al., 2012a). This was established to allow for more detailed research in measuring the impact of having a virtual body whilst having a continuous presence in one's own body in VR. Methods for setting up a VR experience to manipulate the Body Schema can range from simple *Visuomotor* correlations provided through real-time Motion Capture, such as in the 'Rubber Hand Illusion', where participants take partial *Body Ownership* of a single limb (Botvinick and Cohen, 1998) to experiences that cannot be replicated in the physical world, such as taking *Body Ownership* of a giant Abtahi et al. (2019). These studies led researchers to acknowledge the psychological influence that manipulation of *Self-Representation* can have on attitudes and behaviours in VR, one of which is The Proteus Effect.

2.2.2 The Proteus Effect Theory

The Proteus Effect is the theory that the look and movement of a virtual body's representation can affect how embodied users behave online. More recently, it has been shown that it is also possible to a degree offline (Banakou and Slater, 2014).

The theory is based upon the idea that our mind has learned to attribute certain behaviour patterns to certain types of bodies and groups of people based on race, contextual background or status. It is like playing the word association game and asking players to act out the word they hear. This happens on a subconscious level when embodied in a *Self-Avatar*. For example, a study examined how an Avatar's body size (stereotypically within weight, obese) influenced physical activity among men playing an exergame in VR. Results showed that participants portrayed decreased physical activity when their *Self-Avatar* was perceived as more obese than the opponent character (Peña et al., 2016). *The Proteus Effect* is important in discussing the impact of configuring *Embodiment* as it deals with VR's unique ability to *transform* a user's *Self-Representation.* More examples will be discussed later on in this Chapter.

2.2.3 Social Presence in VR

The second research question looks at the configuration of *Embodiment* in social virtual settings. When considering *Embodiment* in social contexts, we must also consider *Social Presence*. *Social Presence* can be defined as the 'sense of being with another' (Biocca et al., 2003) in VR. Biocca's research frames the discussion within three core dimensions in VR: *Co-Presence* - the feeling of being *present* with others; behavioural interaction - references levels of behavioural engagement; and psychological connection - the phenomenal state of judging the nature and course of interaction. These attributes of *Social Presence* have been depicted to be impacted by the configuration of *Self-Representation* in VR (Steed and Drga, 2023), as you will see in our study in Chapter 4.

Co-presence, though similar to *Social Presence*, should not be confused as being one and the same. Biocca positions *Co-presence* as a precursor to stronger *Social Presence* but suggests that it doesn't inherently lead to social connection. This is similar to Short's own perspective that highlights *Social Presence* to be about the medium's ability to facilitate connection and enable emotional intimacy. In contrast, *Co-presence* is more about spatial and temporal attributes.

With the empirical belief that higher induction of *Social Presence* precedes successful virtual communication, researchers and practitioners are interested in the impact of this phenomenon in varied social virtual contexts. The ongoing debate within this research pocket is how to surmise which objective attributes of *Social Presence* play a dominant role in provoking the illusion. In a 2006 review, researchers broke down the key predictors into three segments: the influence of immersive qualities such as realism and interaction, contextual differences, and individual psychological traits (Friedman et al., 2006). However, though research is done individually in these areas, little research has been done to build a consensus on how these factors relate and correlate. In Chapter 4, we add to the first dimension of immersive qualities with a look at the representation of the *Self-Avatar.*

2.3 Technical Configurations of Self-Representation in VR

In this section, we will lay out a structured review of the technical setup of *Self-Representation* in VR as well as its impact by looking at the factors of *Embodiment* literature highlights as the main domains for configuration in the context of this thesis. This will provide the history of the types of technical configuration and environment design used to manipulate *Self-Representation* in VR.

2.3.1 Projection Vs Headset

The first and most well-known *Body Ownership* experiment is the *'Rubber Hand Illusion'*, which was first conducted outside of VR using a fake rubber hand as explored earlier on in this Chapter. (Botvinick and Cohen, 1998). In Armel's study, (Armel and Ramachandran, 2003), the rubber hand was aligned with the participant's shoulder whilst their own hand was hidden out of view. The fake hand and the real hand were then synchronously stroked to generate *Body Ownership*, and then the fake hand was threatened. The results showed that most users reacted to the threat realistically as if trying to protect their real hand by moving away from the danger. This depicted the successful *Body Ownership* of that rubber hand.

This methodology was later attempted to compare the original version with mixed and full Semi-Immersive VR (IJsselsteijn et al., 2006). In this setup, the VR condition consisted of a projected 2D hand on a table, and the Mixed Reality condition followed the same setup; however, unmediated stimulation was applied to this projection. The questionnaire's results showed more feelings of *Embodiment* with the condition of the real rubber hand, followed by VR and then Mixed Reality.

Slater's setup is similar to Ijesselsteijn, with the user's real arm hidden behind a standing screen; the virtual arm is projected on a widescreen but is seen through passive stereo glasses as protruding from the user's shoulder. The results supported the conclusions found in the original experiment; when the virtual arm was threatened, participants reacted as though it was their own arm and the measurement of subjective *Embodiment* reflected high *Body Ownership*.

In early setups of *Embodiment* such as this, the use of projections was effective. It provided a non-invasive method of eliciting *Embodiment* without *Visuomotor* mechanics. Both Ijsselsteijn and Slater (IJsselsteijn et al., 2006; Slater et al., 2008) use projection in a coined 'virtual' revision of the 'Rubber Hand Illusion'; however, the only difference is that Slater utilises a 3D representation of the hand on a power screen whereas, in Ijsselsteijn's setup, he used a 2D projection of a hand on a table.

While both were successful in provoking the illusion of ownership, Slater claims that by using this Top-Down method of a 3D model (see section 2.4), he could produce a stronger *Body Ownership Illusion*, which can be presumed to be due to the stronger *Plausibility Illusion*. We will speak more about the attributes for creating a stronger illusion in the next section.

This kind of technical setup can be labelled as Semi-Immersive Virtual Reality (SIVR) as it does not completely rely on a VR headset to occlude the real world, but instead a projector. The limitation is that it is unable to support research and applications that look at full-body ownership, as this consists of the physical body being completely hidden from view.

When trying to create a VR system for *Embodiment*, especially when using a full-body Avatar, it has been made evident through various studies that the critical outcome is to have a spatially coincident virtual body to replace the users' own (Gonzalez-Franco et al., 2010). This is only possible if the user's body is out of sight. A stereo headset provides the occlusion of the real world.

Though limited studies compare the effectiveness of fully Immersive Virtual Reality (IVR) *Embodiment* over SIVR, as mentioned above, the limitations of just using projection prohibit more advanced research on *Body Ownership*. The following studies all use a IVR 6DoF headset to harness the VR System.

2.3.2 Inverse Kinematics VS Motion Capture

There are many different tools utilised in VR to track the body. Presently, there are two frequently used methods: Inverse Kinematics and Motion Capture. Inverse Kinematics (IK) is a computational technique widely used in Virtual Reality (VR) to enable accurate and natural body tracking. It calculates the joint positions and angles required for a virtual *Self-Avatar* to achieve a specific pose based on a limited number of tracked points, such as the head (via a headset) and hands (via controllers or additional sensors). By leveraging human skeletal constraints, IK algorithms estimate the positions of untracked joints, such as elbows, shoulders, hips, and knees, ensuring that the resulting movements are biomechanically accurate and as natural as possible.

The most popular method to use within lab studies is still Motion Capture due to its high fidelity of tracking (Roth et al., 2016; Kilteni et al., 2012a; Peck et al., 2013; Latoschik et al., 2017; Maselli and Slater, 2014; Banakou et al., 2016; Spanlang et al., 2014). Motion Capture is a widely used technology for recording human motion and translating it into digital data for use in animation. Though most would be familiar with this method used in creating believable characters in Film and Games, this is also used in real-time to animate the *Self-Avatar* in VR. This process involves tracking specific points on the body using marker-based systems, where reflective markers are placed on key joints and tracked by multiple cameras or markerless systems that rely on computer vision algorithms and depth-sensing cameras. High-fidelity options can consist of a 12-camera Opti-track system, but lower-fidelity options can consist of more lightweight options such as using Mircosoft's Kinect (Perez-Marcos et al., 2012).

Though a handful of studies have looked into the fidelity of Inverse Kinematics in VR, only a few focus on the implementation of the *Self-Avatar* (Eubanks et al., 2020; Ma and Pan, 2022; Parger et al., 2018; Caserman et al., 2019). Nevertheless, research has depicted the success of *Body Ownership* utilising configurations of the basic IK triad: The head (with headset) and arms (with controllers) in a few studies (Eubanks et al., 2020; Pan et al., 2016) and other studies have looked into increasing it's impact by heightening it's fidelity with more sensors positioned on the pelvis and feet (Eubanks et al., 2020; Caserman et al., 2019). This does not always bring better results, which may be because of prevailing unresolved technical limitations in capturing the realistic movement of the upper body. Caserman's study in 2019 utilised some of the most popular IK methods of the time to estimate the full body pose and found in the results that participants felt higher *Body Ownership* over the legs of the *Self-Avatar* than the arms; they suggested that the overall sense of *Body Ownership* arose from the fact that the reconstruction of the upper body sometimes would fail whilst the lower body was very consistently accurate (Caserman et al., 2019).

There is limited research comparing body tracking fidelity and its impact on *Embodiment*. However, one study by Roth (Roth et al., 2016) compared a five-point tracking solution (head, hands and feet) using inverse kinematics (IK) to a full-body Motion Capture system. The findings revealed no significant differences between the two tracking methods in terms of *Agency* and *Body Ownership*. In contrast, a study by Fribourg (Fribourg et al., 2020) reported that users significantly preferred full-body Motion Capture over a six-point IK tracking solution. Nevertheless, both configurations of IK relied on an inertial motion tracking system, which is susceptible to drift and could leave space for error. Using IK with an HMD and controllers can, in some instances, provide more reliable tracking. Additionally, it supports research being delivered off-site (remotely).

In a recent study by Eubanks, he compared three configurations of IK for *Self-Avatar Embodiment*. He created the IK Avatar by using RootMotion FinalIK and VRIK components, a commercially available full-body solver designed for consumer VR. He also used an HTC Vive Pro HMD, controllers, and three additional trackers to provide the head, hand, feet, and pelvis tracking for the solver. The three conditions were as follows: Complete (head, hands, feet, and pelvis tracking), Head-and-Extremities (head, hands, and feet tracking), Head-and-Hands (head and hands tracking), and No-Avatar (head and hands tracking but only controllers are visible) See Figure. 2.1. Participants were asked to complete two tasks: calibrate the *Self-Avatar* to their liking and then complete a coin-collecting task in the scene. The results of the subjective questionnaires suggest that the head, hands and feet significantly impact *Body Ownership* when embodying an inverse kinematic *Self-Avatar* for male participants (Eubanks et al., 2020). It's important to note, however, that the interaction and context of the applications also impact the necessity of the tracking modules, as this was a practical task that required hand (controller) interaction and locomotion.

Researchers have explored various tracking issues in VR, including latency, noise, and errors, and comparing IK tracking with full-body Motion Capture. Koilias (Koilias et al., 2019) observed that tracking issues such as latency and motion jumps significantly reduced *Agency* during self-observations and Mirror-based observations. However, these effects were not observed during locomotion. Similarly, Jeunet (Jeunet et al., 2018) reported that inducing tracking latency led to a significant decrease in *Agency* scores. Roth and Latoschik (Roth and Latoschik, 2020) demonstrated that increased latency not only reduces *Agency* but also diminishes *Body Ownership*. Furthermore, Toothman and Neff (Toothman and Neff, 2019) found that latencies exceeding 300 ms notably reduced *Embodiment*, although tracking errors did not show significant effects.

This research highlighted the importance of VR developers and researchers implementing higher body tracking fidelity when attempting to evoke stronger *Embodiment*. Currently, the recommended choice is Motion Capture, as it is the popular choice for research in getting full body tracking; however, when there are limited resources, IK still proves to be an accessible option as there is evidence of similar results - as long as there are additional sensors available for more complex body movement (Eubanks et al., 2020). We utilise both technical pipelines within this thesis. We utilise Motion Capture with the Kinect version 1 for our *Embodiment* setup in the '*Lip and Arm Sync*' study in Chapter 3, we also use it to create

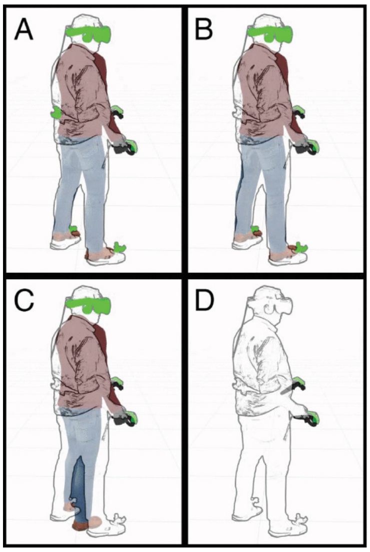


Figure 2.1: The four body tracking conditions investigated in Eubank's research: A) Complete, B) Head-and-Extremities, C) Head-and-Hands, and D) No-Avatar. Active IK trackers are highlighted in green (Eubanks et al., 2020).

a believable *Semi-Autonomous Agent* in the '*Perspective Taking Consultation (Embodied/Disembodied)*' studies in Chapter 5. However, *Embodiment* in Chapter 3 and in *'Avatar Consistency (Confed/Dyad)'* studies in Chapter 4 use the three-point IK setup.

Research suggests that other factors can influence the illusion of *Embodiment*. In the next section, we will explore the alternative factors of eliciting *Embodiment* and their psychological impacts on participants.

2.4 Manipulations of Self-Representation in VR

2.4.1 Top-Down versus Bottom-Up Design

In this section, we will discuss the manipulations within implementing *Embodiment* for *Self-Representation*, beginning with Top-Down and Bottom-Up design mechanics. *Embodiment* has been proposed to emerge from combining Bottom-Up and Top-Down influences (Tsakiris and Haggard, 2005). Bottom-Up consists of sensory information; this involves mechanisms that focus on fast reactions and quick visual identification. In this, the body signals and visual information affect the illusion of ownership of an Avatar. An example would be sensory input that resembles human likeness, an example being the first-person perspective. Another example is implementing synchronised *Agency*, which is the subjective feeling of having control over a virtual body in VR.

Top-Down refers to processes that are more goal-orientated and are influenced by the users' understanding; this can be instant or mediated over time. It may modulate sensory information. i.e., the human likeness of a body part for it to even be considered one's own body, or the tasks that utilise motor control and directed attention. To summarise, Top-Down is from the brain, and Bottom-Up is from the body.

This research places particular significance on the diverse configurations of *Embodiment*. These configurations entail integrating both Top-Down and Bottom-Up processes and how their interplay can either enhance or balance each other, ultimately influencing the strength and impact of the illusion of *Body Ownership*. Previous studies (Slater et al., 2010) express findings that Bottom-Up mechanics could temporarily override Top-Down mechanics, causing a stronger sense of *Body Ownership*. Slater's 2010 investigation found that using the first person to embody male participants in a female virtual Avatar and seeing this virtual body aligning with their own was enough to generate the illusion of *Body Own-*

ership. This data was collected subjectively through a questionnaire and physiologically through heart rate acceleration when the virtual body was threatened. Examples like this underscore the malleability of our sense of self, particularly when the representation closely resembles a humanoid body. Importantly, experiencing this phenomenon from a first-person perspective intensifies its effects, further demonstrated by how our self-identification evolves with age. Nevertheless, given the current limitations of consumer-grade immersive VR technology, embodying a complete humanoid Avatar with full body tracking is rare outside of a few Social VR applications. This necessitates creative approaches to the configurations of *Self-Representation.* Thankfully, research has shown that it is possible to feel ownership of a digital representation that deviates from the human form (Murphy, 2017) or disappearing human forms (Steed and Drga, 2023). In a recent study at the University College London, they addressed the phenomena of *'Tomato presence'*, which refers to the effect coined by Owlchemy Labs of feeling hand presence over an object that is not their hand. Using the context of the 'Job Simulator Game' [1] in VR, they ran a hand ownership experiment where participants were tasked with scanning items at a store at the till. They either had a virtual hand, a disappearing hand or a robot hand. Results support the notion that users still feel ownership over a virtual hand even though it periodically disappears. Additionally, participants did not report that their hands had disappeared. However, where the virtual hand did not disappear, there was seen to be less *Body Ownership.* One radical hypothesis suggested that Top-Down mechanics were at fault, that the hand occluded the object (fruit) that was the target of the interaction, affecting task orientation. There can be both positive and negative outcomes in these settings. Therefore, it is crucial to grasp the implications of such trade-offs on *Self-Perception* and the dynamics of social interaction. This understanding will contextualise the *Embodiment* settings in our five forthcoming studies.

Avatars have provided excellent conditions to test different aspects of interaction with the virtual world. This is important to note when deciding on tasks for experiments. The context could also be essential to the process of embodying a person into a body and their behaviour as a result. Just as others' perceptions can influence acceptance of the *Self-Avatar*, Top-Down mechanics such as task and believable storytelling could have an impact. In our first study in Chapter 3, we had participants deliver an interview in a Mirror in order to have them see their arms and lips in a realistic scenario. In our second study in Chapter 4, we had our participants play a collaborative game, which gave us a credible scenario to observe the development of trust. Finally, in our third study in Chapter 5, participants delivered bad news about the cancellation of a child's surgery, which is frequent and plausible in a pediatric ward.

Examples of both Top-Down and Bottom-Up processes can be found in Table 2.1. Top-Down engages cognitive practices such as completing a goal, identifying human likeness, and assessing a different perspective on behaviour. Bottom-Up engages sensory practices such as having control of a virtual body, real-world perspective point and having the body aligned to their own. We speak more about these Bottom-Up mechanics in the next section.

Top-Down	**Bottom-Up**
Stress-induced Tasks	First Person Perspective
Human Likeliness	Agency
Perspective-taking	Body Alignment

Table 2.1: Examples of Top-Down and Bottom-Up processes

2.4.2 Visuomotor, Visuotactile and Visuo-proprioception

Three techniques are commonly utilised when trying to evoke and manipulate *Embodiment* using multi-sensory stimulation. The one we have already encountered is *Visuomotor* processes, which is when the participant sees a virtual body and can also move it. Second is *Visuotactile* processes, which can be

[1] https://jobsimulatorgame.com/

understood from literature as receiving visual feedback of tactile stimulation (Kokkinara, 2015), allowing participants to translate their tactile sensation and perception onto a virtual representation (Tsakiris and Haggard, 2005). The last is *Visuo-proprioception*, which involves the spatial alignment of where a participant's body is in reality to where the participants see the placement of the Avatar body they embody.

An example that uses all three is Yuan and Steed's study, which also used the 'Rubber Hand Illusion' in IVR. However, even though they tested for limb ownership, they used a full-body virtual Avatar and set the user to do specific tasks in VR (Yuan and Steed, 2010). They found in their study that participants in an HMD-based IVR who saw a virtual body could experience similar responses to threats as those in comparable 'Rubber Hand Illusion' experiments and also that the *Body Ownership Illusion* was stable even under some gradual forced distortion of tracker space so that proprioceptive and visual information was not matched. This suggests, as we mentioned in Chapter 3 that the mind is flexible to adapt to shifts in the mapping of body schema.

In one particular setup, (Petkova and Ehrsson, 2008) demonstrated evidence of multisensory stimulation principles to provoke the illusion of ownership over a mannequin body when seen from the first-person perspective. In this experiment, they used two CCTV cameras on the mannequin to show the body displayed on a head-mounted display worn by the user. The user was told to look down so that the mannequin was where they would normally see their own body. A rod was used to provide synchronous tactile stimulation to the body. Here, the importance of *Visuo-proprioception* is evident, as well as spatial awareness, making sure that the body is where it is expected to be as with a mannequin, there is no movement possible; therefore, no *Visuomotor* contingencies are mapped.

Tactile stimulation has been delivered in various different ways; in the original 'Rubber Hand Illusion' experiment, the tactile stimulation was delivered with touch (Botvinick and Cohen, 1998). Then, as it was moved into VR, experimenters used a wand or a ball (Kokkinara et al., 2015). However, tactile stimulation doesn't have to be done through human intervention. In one experiment, the *Visuotactile* stimulation was provided with a fan. The fan was placed facing the participant from the same position it was placed within the virtual environment (Christou and Michael, 2014) so that when they heard and saw signs of the wind blowing in VR, they felt a synchronous physical wind from the fan. Another example by Durgin is the use of a light beam to stimulate touch (Durgin et al., 2007). One could question whether the source of the tactile stimulation could be a critical contributor to the effect of *Embodiment*; however, though this was the initial belief (Kilteni et al., 2012a; Kokkinara, 2015), other studies have shown that when a highly realistic spatially coincident virtual body is used, synchronous or asynchronous *Visoutactile* stimulation is not critical to inducing feelings of ownership (Carey et al., 2021), and can be elicited with just *Visuomotor* contingencies (Kilteni et al., 2013; Tsakiris et al., 2006) and even can be a tool for modifying the allocentric memory of the body (Slater et al., 2010). Slater emphasized this in his work 'Inducing Illusory Ownership of a Virtual Body' in 2009:

"The very act of looking down, changing head orientation to gaze in a certain direction, with the visual images changing as they would, in reality, is already a powerful clue that you are located in the virtual place you perceive". (Slater et al., 2009).

With this knowledge, in our studies, we utilise *Visuomotor* stimulation and *Visuo-proprioception* to induce *Embodiment* as it requires less human intervention. Nevertheless, it's been shown to be sufficient in evoking *Embodiment* (Tsakiris et al., 2006).

2.4.3 Perspective

Another manipulation in VR is that of perspective. The first thing that donning a VR headset will do that is different than with other mediums is give you dynamic control of viewpoint. In a *Self-Avatar*, you can experience this through a first-person perspective. This fundamental Bottom-Up feature has been proven in the literature to be a crucial factor for eliciting *Embodiment.*

As mentioned above, early research by Slater looked at the impact of perspective (Slater et al., 2010) showing that the first-person perspective of a life-sized virtual human body was sufficient enough to elicit *Embodiment*. This finding supports other similar results in the literature (Kokkinara and Slater, 2014; Petkova et al., 2011).

Additionally, when it pertains to dynamically customising a *Self-Avatar*, research shows that customising Avatars from a first-person perspective enhances the sense of *Embodiment*, whereas a third-person perspective decreases the illusion, suggesting first-person perspective can facilitate more profound body transformations in VR (Gonzalez-Franco et al., 2024).

Recent literature, however, argues that it is possible to feel high or comparable *Embodiment* in both first-person and third-person perspective conditions, indicating that *Body Ownership* can be induced from both perspectives (Liou et al., 2024). In a recent in 2024 by Liou and his colleagues, they configured a third-person perspective to be located at the right-front side (45°) and about 45 cm away from the initial embodied *Self-Avatar*. To strengthen the chance of higher results, they added sync *Visuotactile* feedback in a novel system that simultaneously vibrated when the user kicked a ball. They suggest this configuration as one of the contributing factors to the result of high *Embodiment*.

When it comes to alternating between the two perspectives, research shows that giving the ability to alternative between first and third person perspective did not impact *Embodiment*, and results were still comparable to first-person perspective alone (Galvan Debarba et al., 2017). The transition from one perspective to another was configured by a very fast (200 ms) straight-line translation of the camera. This setup avoided motion sickness as the visual during motion was blurred to avoid participants perceiving interpenetration with their *Self-Avatar*, giving a pipeline for a novel approach to fluid perspective taking. Nevertheless, in line with previous research, the sense of *Body Ownership* and reactions to virtual threats were generally stronger in first person perspective (Slater et al., 2010).

In our research studies discussed in Chapter 3 and 4, we utilise the first-person perspective to alienate the effects of sensory and visual coherence. In the study presented in Chapter 5, we add to this discussion the impact of perspective by comparing the impact of body swap; first and third perspective on *Self-Efficacy*. In the next section, we discuss the environmental integrations involved in evoking *Embodiment*; this presents an important background for our first study, *'Lip and Arm Sync'* in Chapter 3.

2.4.4 Mirrors and Self-Representation in VR

Mirrors, also known as looking glass, are quite remarkable tools; they reflect to the viewer a perspective they cannot see with their own naked eyes. An allocentric perspective on how they look outside of their own egocentric field of view. From perceived non-verbal communication to visual aesthetics, they can see themselves as others do. The ability to recognise the reflected image of one's own body is called, in Psychology, '*Mirror-Self Recognition*', and the only species to date known to be able to achieve this are humans and primates (Keenan et al., 2004). Many cultures view mirrors as a symbolic device for self-recognition and self-understanding, and neurological evidence is consistent with the proposition that *Mirror Self-Recognition* is a robust indicator of having a fundamental sense of Self (Keenan et al., 2004). Therefore, research shows us that the use of Mirrors in the real world can be tied to processing one's physical *Self-Representation*. With this understanding, it comes as no surprise that virtual Mirrors can play similar roles in VR in provoking the illusion of *Embodiment* over a digital *Self-Avatar*.

Mirrors as a Primer to Embodiment

There are several cases in VR literature focusing on *Embodiment* that utilise mirrors (Gonzalez-Franco et al., 2010; Neyret et al., 2020; Banakou et al., 2013, 2016; Banakou and Slater, 2014; Tajadura-Jiménez et al., 2017; Hamilton-Giachritsis et al., 2018). In VR, mirrors allow the user to visualise the *Self-Avatar* in detail, and due to *Mirror Self-Recognition* - a person's cognitive ability to associate the reflected image as themselves - they can identify the *Self-Avatar*'s mirrored appearance as their own even if it doesn't look like their true reflection. Spanlang argues that mirrors are a critical piece in establishing the illusion of *Body Ownership, Self-Location and Agency,* enhancing the perception of *Embodiment* by displaying the real-time movements of a *Self-Avatar* that cannot be fully understood in the context of the 3D virtual environment otherwise (Spanlang et al., 2014). Early research shows that this synchronicity or *Visuomotor* contingencies reinforce the illusion of inhabiting a virtual body (Gonzalez-Franco et al., 2010).

But it's important first to understand if this effect is unique to a user's explicit knowledge of a Mirror present over the isolated visual of a mirrored synchronised *Self-Avatar.* Outside of VR, Preston found in their study that compared a mirrored, non-mirrored and third-person perspective of a viewed mannequin; the mirrored condition outperformed in terms of eliciting *Body Ownership* (Preston et al., 2015). A study by Bertamini showed that the 'Rubber Hand Illusion' was successfully induced even when participants viewed a fake hand only via a mirror. Moreover, in a follow-up experiment where they compared Mirror views to the third-person perspective of another individual, they found that the illusion of *Body Ownership* was weaker or absent in the latter experience (Bertamini et al., 2011). These two studies highlight the importance of not only the presence but also the awareness of the Mirror in evoking *Body Ownership.* We see that in VR literature, though there is no exact comparison similar to the work of Preston, there is evidence to suggest that subjective *Body Ownership* and reactions to threats are generally stronger in the first-person perspective than in the third-person (Galvan Debarba et al., 2017), and, that it could even cause alternative effects such as the illusion of drifting (Pomés and Slater, 2013).

We have established the impact of the acknowledgement of the Mirror in the space for invoking *Mirror-Self Recognition.* Still, after this, we must also understand that for a stronger body illusion to take place, it must also carry the attributes of a Mirror, meaning providing a horizontally flipped view of the user and applying real-time synchronous movement and visual feedback. Objects have material properties – in particular, in ways in which they reflect light. When the participant looks into a virtual Mirror in the scene, they expect to see a reflection of their virtual body. It is also important to take into consideration that studies with Mirrors might utilise tasks that involve activity or movement of body parts that are not visible without a virtual Mirror present.

In a study by Gonzales-Franco, they examined how real-time Mirror reflections of participants' upper-body movements affected their sense of ownership over a virtual body. In one condition, they had synchronised *Visuomotor* movement with the reflected Avatar, and in the other, they had asynchronous *Visuomotor* movement. Results suggested that synchronised Mirror reflections elicited stronger feelings of *Body Ownership* and response to threat (Gonzalez-Franco et al., 2010). This effect is also found in Augmented Reality (AR); a study by Nimcharoen in 2016, which utilised an AR Mirror to reflect a synchronised *Self-Avatar* of the user, also found that this enhanced the sense of *Body Ownership* (Nimcharoen et al., 2018).

There are recent studies that contradict this notion, expressing that the impact of Mirrors is inconclusive and not always positive. In a study by Dolliger (Döllinger et al., 2023), they found that Mirrors diminished bodily awareness, mediated by the sense of *Embodiment* in a *Self-Avatar.* Other literature also reflects this; in Mottelson's systematic review of *Body Ownership*, he found that the presence of virtual Mirrors has a limited to negative effect on *Body Ownership* compared to studies without any Mirror (Mottelson et al., 2023). This suggests that more research needs to be done to validate their use and elicit a stronger impact.

Nevertheless, there is a benefit to the use of a virtual Mirror that cannot be replicated in the real world, and that is in application to manipulate body perceptions without hindering *Body Ownership.* This is prevalent in therapeutic-related literature. For example, Heinrich looked at VR as a technological medium to deliver Mirror therapy interventions to people after a stroke (Heinrich et al., 2022). Ito and colleagues looked at whether it was possible to elicit *Body-Ownership* over a *Self-Avatar* with a tail, even when the *Visuomotor* feedback given from a Mirror is interrupted or reduced and found that even when reduced, the illusion is still evoked (Ito et al., 2019). Dunn's literary review of Virtual and Augmented

Reality (AR) studies on Phantom Limb Pain (PLP) also presents evidence that VR and AR Mirror therapy has the potential to be effective in reducing PLP (Dunn et al., 2017). However, we'll refrain from delving deeper into this literature as this topic is outside the scope of this thesis. Instead, we will give a broader overview of modifications of Body Schema in section 2.4.5.

Overall, the studies in this section demonstrate that the use of virtual Mirrors has the capacity to significantly aid in the setup of *Embodiment*, which can lead to profound psychological impacts such as an enhanced sense of *Agency*, sense of *Self-Location* and sense of *Body-ownership*. Our research in Chapter 3 and 5 capitalises on the *Mirror-Self Recognition* theory and the brain's ability to adapt to modified body schema to help create immersive experiences that can reshape how individuals perceive and relate to their *Self-Avatars* in VR, curating new experiences of *Self-Representation*.

2.4.5 Avatar Realism

Defining the types of Avatars used in Virtual Reality

Before we move on to the next section, we will define the usage of Avatar terminology in this thesis. Avatars are essential in numerous forms of mainstream media, such as games, CGI films, therapy and even advertisements and websites. They have progressed from static background aesthetics to fully functioning, dynamically controlled, or embodied digital vessels.

Avatars in VR consist of two groups: there are *Self-Avatars* that participants embody and control via *Visuomotor* contingencies and immersion, and there are *Agents*, programmed to respond in a certain temperament and manner, either using AI or controlled responses of animation and dialogue in real-time. We will use this duo terminology to specify the type of Avatars utilised within the referenced studies, and will use Avatars to refer to virtual characters as a whole.

When we think about Avatar realism, we can split it into two sections: behaviour realism - which deals with animation and fidelity of movement, and visual realism - which pertains to visibility and aesthetics.

Visual Realism - Self-Avatar

When we discuss Avatar realism, this pertains to human-likeness. In terms of appearance, developers are continuously striving to find ways of making Avatars more realistic; it is now possible to create a virtual replica of a person in a virtual environment using 3D scanning systems, though for detailed scans, this process is expensive and not yet available for consumer use (Tong et al., 2012).

Studies on Avatar realism have yielded mixed results. For instance, while highly realistic *Self-Avatars* have been shown to amplify *Social Presence*, emotional engagement (Volante et al., 2016) and *Embodiment* (Banakou et al., 2013), others argue that stylised or abstract representations can achieve comparable outcomes (Armel and Ramachandran, 2003; Ma and Pan, 2022). Some suggest it may be reliant on context and environment (Lin and Latoschik, 2022), research from Fang Ma and colleagues suggested a 'first trial effect' wherein a within-study experimental design with a cartoon-like character and high fidelity character, participants felt higher *Embodiment* with whichever *Self-Avatar* they had experienced first. This was evident in their first study, where the *Self-Avatars* were created based on images of the participants and the second study, which used generic *Self-Avatars* (Ma and Pan, 2022).

Armel's team sowed support for non-human likeness in their experiment (Armel and Ramachandran, 2003), which suggested it was possible to provoke the ownership illusion from participants embodying external objects. In this instance, they used a table and stroked the table and the participants' hands both synchronously and asynchronously to build *Visuotactile* stimulation. When the table was stroked or threatened, participants displayed a strong skin conductance response (SCR), suggesting that they felt *Body Ownership* over the table. However, in Yuan's study (Yuan and Steed, 2010), we see an attempt to try and embody an arrowhead, which resulted in overall low *Body Ownership Illusion* results. Though not consistent, there is still evidence that more research needs to be done to understand the impact of non-human Avatar representation.

Behavioural Realism - Self-Avatar

When considering behaviour realism, we'll focus on virtual social interaction. We could say that verbal and non-verbal communication plays a vital role when trying to evoke *Social Presence*. Non-verbal communication is a fundamental human trait and can be taken as a more honest reaction in a discussion than verbal responses, as verbal responses are goal-oriented, whilst non-verbal can be both a conscious and subconscious behavioural response (Vinayagamoorthy et al., 2006a).

Steed has also looked at the effect of the *Self-Avatar* in Social VR environments, specifically the social applications that include models of hands enabling gesturing (Steed et al., 2016). The participants were asked to complete three tasks:(T1) memorisation of letter sequence, (T2) mental rotation of figures and (T3) recollection of letter sequence.

The results revealed that (T3) performance was lowered without a *Self-Avatar*, and there was less hand movement without a *Self-Avatar*, but also that (T3) performance was lowered when *Self-Avatar* gestures were disallowed.

Overall, the paper suggested that a *Self-Avatar* is important for motor-related tasks and general interaction with the virtual environment. Interestingly, this supports the notion that the *Self-Avatar* appearance could affect social interaction within a negotiation or collaborative task where much of the success relies on trusting each other. Many people gesture when explaining things; Hostetter showed in his experiment, where participants needed to describe ambiguous dots, they used more complex hand gestures to help them convey complex shapes (Hostetter and Alibali, 2007). Gestures play a role in conceptualising information and views and, therefore, arguably are important in social interaction. If this ability is inconsistent between interacting participants, research implies that this could negatively affect the feeling of *Social Presence*.

When it comes to gaze behaviour Steptoe's study indicated a high quality of communication in co-located VR could be achieved without using extended gaze behaviour models besides small, rapid eye movement simulation (Steptoe et al., 2010). He suggests users might have to gain more experience with VR technology before noticing subtle details in gaze animation (Seele et al., 2017). Nevertheless, (Garau et al., 2001) argued that higher realism in an Avatar's appearance might heighten expectations for behavioural realism. Their study discovered that when comparing using random eyes or inferred eye movement on configurations of both a photo-realistic model with gender match and a basic 'match-stick' model with no gender, higher realism in a high-fidelity model boosts performance. In contrast, a low-fidelity model had adverse effects. These results were also supported in similar previous research (Tromp et al., 1998).

Visual Realism - Agent

With a few exceptions, (Qiu and Benbasat, 2005; Kim and Sundar, 2012) research suggests that people feel higher levels of *Social Presence* when an Avatar is present. A study by Feng (Feng et al., 2016) found that participants felt higher *Social Presence* toward online support-seekers (*Agents*) who provided a profile picture compared to those who did not. In Chaturvedi's (Volante et al., 2016) experiment, they look at the human-likeness of virtual *Agents*. The experiment investigates the extent to which a realistic human-like appearance of an Avatar versus two levels of a non-photorealistic appearance impacts participants' emotional investment within a scenario. The participants looked at three virtual *Agent* models in a hospital operating room environment: realistic, cartoon and sketch. This virtual *Agent* went through 4 stages of deterioration expressed through vital signs, verbal feedback, and non-verbal behaviour. The participant then took a (PANAS) Positive and Negative Affect Schedule questionnaire. Overall, the subjective and physiological results showed little positive effect due to the *Agent's* lack of realism but a significant negative effect. However, most participants in the realistic condition seem to elicit significantly higher levels of positive emotion in many of the timestamps (four conditions of deterioration). This suggests that *Agents* must hold a certain level of realism to elicit an emotional response and be considered believable (Murcia-Lopez et al., 2020). Evidence depicts that paying closer attention to the interactive virtual *Agents'* visual realism can have a strong impact on the participants' emotional reaction to their performance.

Behavioural Realism - Agent

Mimicry is a very subtle way, whilst interacting with someone, of showing that they are engaging (Forbes et al., 2016) and relating with each other, even resulting in social influence (Yee and Bailenson, 2007). Recently, gaze has been found to be a significant non-verbal cue. Normally, gaze aversion has many negative connotations within a discussion between a group of people; however, Andrist and his team (Andrist et al., 2014) theorised that gaze aversion could be used to signal cognitive effort, modulate intimacy and regulate turn-taking (Wei, 2023). Their research showed evidence that mutual gaze significantly interferes with production and spontaneous speech.

Lopez ran a study in 2020 which looked at what attributes of configuring an *Agent* make them more 'believable.' They gave participants a budget to spend on the use and fidelity of Mouth Animation (MA), Eye Gaze (EG), Eye Blinking (EB) and Micro Expression (ME). 55 participants experienced an *Agent* delivering a presentation in VR. At fixed times, participants had the opportunity to spend a virtual budget to modify the factors to incrementally improve their experience of how believable the *Agent* was. They could stop making transitions when they felt further changes would make no further difference. From these transitions, a Markov matrix was built, along with probabilities of a factor being present at a given level on participants' final configurations of the *Agent.* Most participants did not spend the full budget, suggesting that there was a point of equilibrium which did not require maximising all factor levels. Overall, the group's most likely final configuration was EG (2), EB (1), MA (1), and ME (1). MA, followed by EB, were accepted overall at a minimum of level 1, but there was less agreement in what was the optimal level for EG and ME. This means that not all sensory integrations were required for the *Agent* to feel believable, but more work needs to be done on understanding how gaze and micro-expressions impact *Social Presence.* Read more on this study in Chapter 6 and Appendix D.

Here, we see from these examples that there are many different configurations of an Avatar, from visual appearance to non-verbal communication. Evidently, not all need to be implemented at once to evoke *Embodiment* or *Social Presence*, but there is here a narrative around the balance of motion fidelity and visual fidelity, as we will also come to see tested in Chapters 3 and 4 respectively.

Modified Avatar Body Schema

It's understood that there is an initial body image with prior cues that is accepted as it is experienced through life, and then there are current multisensory cues that we experience at the moment (Tsakiris, 2010). What is interesting is that the brain can modulate both these cues to such a degree that it can take ownership of modified body representations. This, perhaps, is due to the mind's ability to adapt and learn. In (Kilteni et al., 2012b), the 'Rubber Hand Illusion' is revisited; the length of the virtual arm is extended from its original size in each of the four conditions by double the size each time. The subjective and objective results, similar to (Davies et al., 2013; Lloyd, 2007) when exploring the limitations of proprioceptive drift, were that the illusion of *Body Ownership* was established, but there was a decline in strength as the length of the arm grew. Interestingly, in the first condition, where the arm was double the length of the original, there was no change in the strength of the illusion. In (Won et al., 2015), they test this theory in two experiments to explore the implications of *Embodiment* in novel bodies. In the first experiment, there are three conditions; 'Normal', where the user and the *Self-Avatar* movements correspond with each other; 'Switched Limb', where the leg movement controls the arm movement but they still had their original ranges, so a waist high kick would be equivalent to arms reaching over the shoulders. Then, there is the 'Switched Range' where the limb's movement is the same, but their ranges are switched such that a small kick in the real world would give a bigger kick in the virtual world. The participant was given the task of popping balloons. The amount they popped and by which appendage was noted. The results revealed that most participants could adapt to their new conditions in less than 10 minutes and move their bodies in such a way that they could adapt to the movement in the virtual world. However, their performance was not compared to that of a non-human body. In experiment two, Stevenson adds an appendage, another longer arm. There were two conditions: with the extra arm and without. Once again, participants were given a task to touch three arrays of cubes at different distances, the longest distance matching the length of the extra arm. The hypothesis was that participants should surpass their performance in the normal condition using the extra appendage. What was interesting about their setup was that when each of the experiments first began, participants were given approximately two minutes to get used to the movement in front of a virtual Mirror, which was then removed once the task began. The Mirror was used as a tool to help the participant get used to the movement of their body. It could be said that it was also used to provoke *Agency* and perhaps ownership over the limbs before the task began. This gave the participant time to acquire the necessary spatial transformations to complete the complex movements to control the extra limb or re-adapt to the movement of the *Self-Avatar* (Preston et al., 2015). However, there was no condition without the Mirror to strengthen this notion.

Nevertheless, the results of the second experiment showed no significant difference in ownership. Perhaps, like in (Kilteni et al., 2012b), the length of the arm was too long, or maybe removing the Mirror prohibited the mind from updating the body representation once distracted by the tasks. This highlights that there is more to be explored regarding the limitations of this area, but this is out of the scope of the research questions in this thesis.

2.5 Summary of the Psychological Impact of Configurations of Self-Representation in VR

2.5.1 Psychological Outcomes: The Proteus Effect

In these next three sections, we will discuss how different configurations of *Embodiment* influence psychological outcomes on *Self-Representation*.

Earlier on in this chapter, we discussed the theories in VR literature, and one of them was *The Proteus Effect* - the transformed self.

Literature has shown that even being embodied in a different skin tone can shift both cognitive thinking and behaviour(Kilteni et al., 2013; Slater and Sanchez-Vives, 2014). In an experiment involving playing the drums, Kilteni investigates the effect of *Embodiment* on motor actions in IVR. The 17 participants were placed into two groups: 'Casual Dark-Skinned' and casually dressed and another where the virtual *Self-Avatar* was 'Formal Light-Skinned' and was dressed formally in a suit. The participants were asked to play the drums whilst embodied in these two different *Self-Avatars*. The baseline motor behaviour was retrieved first, whilst untextured white hands represented the users. To measure the movement, they used a Principal Components Analysis (PCA) to compute the dimensions needed to capture 95% of the total variance in the complete data. Overall, the data showed that those in the 'Casual Dark-Skinned' *Self-Avatar* showed significantly higher upper body movement than those embodied in the 'Formal Light-Skinned' *Self-Avatar*. Therefore, it shows that the aesthetics of the *Self-Avatar* affected the way the participants chose to behave.

Another recent study examined whether embodying a well-known famous character, such as Leonardo da Vinci, could enhance participants' creative performance (Gorisse et al., 2023). 40 participants took part in the experiment either embodied in a *Self-Avatar* or Leonardo da Vinci. They were given three tasks to complete; the first task assessed participants' divergent abilities, the second test evaluated convergent abilities, and the last task consisted of designing alternative use cases of objects in the 3D environment using a 3D sketching tool. Results suggested that Participants embodying Leonardo da Vinci depict significantly higher levels of divergent thinking than those in the *Self-Avatar* condition.

This experiment showed that it is possible to change participants' behaviour whilst inside the virtual space, but there is also evidence in other studies of real-world changes - that *Embodiment* can cause changes in racial bias (Peck et al., 2013). In Slater's experiment, 60 female light-skinned participants were put in the body of a female dark-skinned *Self-Avatar* – 'Embodied Dark'. In this scenario, an even split of black and white *Agents* walked past the participants whilst they were embodied and looked at them. The participants were given an Implicit Association Test (IAT) a few days before the experiment and then immediately after the experiment. In this test, participants were asked to associate negative and positive words with black and white faces, and the response time was recorded to reveal any bias. There were two other conditions: a light skin Avatar- 'Embodied Light', an alien *Self-Avatar*- 'Embodied Alien' and a non-embodied dark-skinned *Self-Avatar* which moved independently to the participant but could still be seen- 'Non-Embodied Dark'. After the experiment, the results showed significantly lower racial bias in the 'Embodied Dark' condition than in the 'Embodied Light' condition. The 'Embodied Alien' results showed no significant difference in IAT results or subjective embodiment results; there were only notable results in the asynchronous condition of 'Non-Embodied Dark', where the feeling of *Body Ownership* was lower. The results show that there can be lasting effects after coming out of VR. It could also be argued that there was no change in the 'Embodied Alien' condition because there was no bias on the body type initially. We can see from previous research how the representation of an *Avatar* could affect relationship dynamics like trust in VR (George et al., 2018).

Proteus Effect in Gaming

Games that require users to choose their own *Self-Avatar* provoke the question of what impact *Self-Representation* has on a gameplay experience. Looking over what we have already discussed in this review, it is possible that it could; however, most studies involving an 'alien' *Self-Avatar* and behaviour changes are inconclusive in the results (Peck et al., 2013). In Christou's study, (Christou and Michael, 2014), this issue is addressed. A first-person video game was created to see if the visual characteristics of the *Self-Avatar* affected gameplay. The two gender-matched *Self-Avatar* conditions were a normal humanoid and a tougher-looking alien. The participants were asked to block incoming projectiles, and the number they hit and the force used were recorded. Christou used an Oculus Rift to provide the first-person perspective and Kinect to track body movement. He also used a Unity plugin to provide data on the force that the participants used to hit the projectiles away. They hypothesised that due to research in both *Body Ownership Illusion* and the *Proteus Effect*, the players' movement or behaviour would be more aggressive in the tougher-looking body, similar to the results of another study by Despina Michael-Grigoriou (Michael-Grigoriou and Slater, 2012). The subjective results showed that overall, participants felt the same amount of *Body Ownership Illusion* with humanoid and alien representations. They also found that participants in the alien condition suffered fewer blows than when playing with a humanoid *Self-Avatar*. This could result from the *Proteus Effect* because the alien *Self-Avatar* seemed more protected in armour. Another thing to note is that the alien *Self-Avatar* still had a humanoid body structure; therefore, a Top-Down effect may have been in play. This example successfully provides evidence of non-verbal behavioural differences in performance based on the *Self-Avatar* aesthetics, just like in previous studies, (Kilteni et al., 2013). This example also supports evidence that suggests the strength of Top-Down processes.

The opportunity to change the perspective of the user in terms of size and space awareness is also another powerful tool offered. Banakou et al. (2013); Slater and Sanchez-Vives (2014) completed research looking at the effect virtual *Embodiment* could have on attitudes of self and the participants' idea of object sizes in a virtual child body or in an adult body that is the size of a child (roughly 4 years old). These were the two conditions experienced through a first-person perspective, and they tested 30 adults. Participants were asked before and after to show with their arms how big they thought the objects were. The results supported the *Proteus Effect* and participants overestimated the sizes of objects; however, the child estimations were almost double the adult estimations. Additionally, the participants took an IAT test, which revealed a greater implicit self-association towards childlike categories than in the adult condition. There was a strong illusion of *Body Ownership* in both conditions, but there wasn't any significant difference between them. In this experiment, a Mirror is used to show the reflection of a child and an adult. The Mirror serves a unique purpose here, as though the size of the *Self-Avatar* does not change, and the details of the body change, which is what would change the perception of how the participants perceive the world. This would not be so strongly shown and acknowledged unless the user sees the change in a Mirror. The Mirror gives the visual update that though they are a smaller size, they are still an adult. This once again shows the flexibility of the brain to adapt not only to body form but size.)

What's interesting is what (Slater and Sanchez-Vives, 2014; Slater et al., 2010; Kilteni et al., 2013) highlight in their paper, which is the idea that the mind generates an idea of the behavioural traits of the virtual *Self-Avatar* they embody, whether it is due to social expectation (Stets and Burke, 2000) or a subconscious mental estimation of capabilities due to an intrinsic property of the brain. It is a question of where the mind derives it from. In the psychology literature, there is a debate about whether the action precedes self-attribution and behaviour or vice versa (Bem, 1972). Presently, this is still an unresolved issue. In terms of *Embodiment*, self-association precedes behaviour, and it is yet to be confirmed whether this reflects how we perceive ourselves and behave accordingly. (Vala et al., 2012) suggests that whatever we view as intelligent is always compliant with the physical and social rules of the environment and exploits these rules to create diverse behaviour. Since our bodies define how we interact with the environment, we cannot dissociate intelligence from our bodies as a whole. This highlights once again the relationship between *Self-Representation* and the environment, similar to the theories of Merleau-Ponty (Merleau-Ponty, 2012). More research needs to be done in this area to solidify this understanding.

2.5.2 Psychological Outcomes: Social Presence, Collaboration and Interaction

With Social Virtual Interaction, we can see many examples through the decades, stemming from strictly text desktop-based social forums to video-based communication platforms such as Skype, and now, immersed, embodied interaction within a virtual space. Research has shown that a sense of *Embodiment* can be provoked through the 2D persona that users create in chatrooms and role-playing games (McCreery et al., 2012). This belief is within the framework of the Social Information Processing theory, which states that online communication void of non-verbal cues (i.e. without any intimacies of embodied 3D interaction) can still demonstrate qualities of face-to-face communication (Walther, 1992). However, theories such as the Social Presence Theory and Media Richness theory (Dennis and Valacich, 1999) incline us to believe that for successful Interaction, the more we can keep the face-to-face and motor contingencies of social interaction in place, the richer the experience will be and therefore the more *Social Presence* can be felt.

We can see in this Chapter that *Self-Representation* in terms of Avatar Realism has been depicted to impact *Social Presence* in many ways. Studies have shown that the configuration of high or low fidelity does not always predict enhanced *Social Presence* (Bente et al., 2008; Clayes and Anderson, 2007), but configuring behavioural realism, such as mutual gaze or dynamic interaction, can enhance the phenomenon (Bailenson et al., 2001; Garau et al., 2003). Garau showed that the balance of Avatar realism and behavioural realism was effective. Pan in her 2008 study, depicted how *Avatar* blushing and behavioural cues increase interaction duration, highlighting the role of potential nuanced *Self-Representation* in engaging communication (Pan et al., 2008). Research also shows that participants who believed to have interacted with a human reported a stronger feeling of *Social Presence* than participants who believed to interact with an artificial entity (Appel et al., 2012). These studies, however, were not conducted in IVR but still give evidence of the implications of Avatar configuration in virtual environments.

In this section, we specifically look into the impact on trust and collaboration, as is the focus of 4, but the literature we find is limited. First, we look at behavioural implications. In line with *Visuotactile* feedback in social interaction, research has shown that haptic force feedback significantly improved perceived virtual presence, perceived *Social Presence* and perceived performance in a collaborative experiment that tasked participants to pass an object between each other with and without feedback (Sallnäs, 2010). A higher fidelity of *Visuotactile* feedback increased *Social Presence* and collaboration effort.

When it comes to visual coherence, a study in 2021 showed that participants interacting with highly expressive *Self-Avatars* felt more *Social Presence* and attraction and exhibited better *task performance* than those interacting with partners represented using low-expressive *Self-Avatars* in a collaborative game of Charades (Wu et al., 2021). A similar study found that *Self-Avatars* with facial expressions were more effective in influencing the participants' trust levels and decision-making behaviours than those without facial expressions (Luo et al., 2023). Moreover, the authors found that the participants were generally less trusting of the *Self-Avatars* with negative expressions. In contrast, the *Self-Avatars* with positive expressions made the participants feel comfortable and thus increased their willingness to cooperate in the trust task.

Another study tested the impact of Avatar similarity (to their real self) on measures of trust (Tang and Bashir, 2023). They measured trust as behaviour that persisted over time during cooperation. They played the 'Coin Entrustment Game', where players entrusted their coins to each other in order to earn more coins. The results, however, did not support their hypothesis that *Self-Avatar* similarity moderated trust, but the authors highlight the limitation of sample size, which could mean meaningful differences in the data were not detected. This leaves room for more research to be explored in this area to come to a conclusive understanding. Another dimension is the similarity between the configuration of others and the participant. Recent studies have highlighted the positive effect that Avatar visibility has on *Social Presence*, especially when dealing with multiple embodied entities in a shared virtual environment (Pan and de C. Hamilton, 2018). Though a more accessible configuration, Croes believes that reducing Avatar visibility in social interactions will make participants feel less self-aware, more anonymous, and more inclined to stick to a task-oriented conversation (Croes et al., 2016). This can potentially inhibit deeper connections, such as building trust, and it raises the question of whether this could be manipulated by synchronicity between users. Nonetheless, there is still research to suggest that even with less visibility of body parts, it is still possible to provoke the illusion of *Body Ownership* (Steed and Drga, 2023). We look at this dimension and other related literature examples in more detail in Chapter 4.

2.5.3 Psychological Outcomes: Evaluation and Perspective-Taking

Believable Agents in Medical Training

The final study of this thesis gives discourse to the third research question: What impact does the configuration of *Embodied Virtual Perspective-Taking* (EVPT) have on learning processes such as *Self-Evaluation*? In this case, we decided to focus on Medical Training as a use-case. VR has already been credited as an effective tool for training in the Medical Field. One of the many advantages of using VR is that it offers the developers the freedom to control the virtual world's conditions and constraints and practice without real-world implications, which could be detrimental otherwise. What makes these scenarios effective is evoking realistic stress feedback through Top-Down mechanics that enable participants to react as they would in a real-life scenario. This is partly due to the successful implementation of the *Plausibility Illusion* (as mentioned above) and believable *Agents*.

Using *Agents* and *Semi-Autonomous Agents* in Medical Training is a thoroughly researched and validated practice. For example, Pawar (Pawar et al., 2018) found that they were able to successfully evaluate the relative cognitive load of the participants' experience and their emotional state using a simulated clinical scenario. Additionally, it has been argued that using *Agents* can elicit the same information from Medical students as a real human, however, with less reported engagement and sincerity (Raij et al., 2007). This was argued to be due to the lack of expressive behavioural realism in the Avatars. However, this study is dated and was not conducted in IVR; instead, it used projection. More recent studies, like Pan's 2016 investigation (Pan et al., 2016, 2018), depict how the evolution of *Agents* and *Semi-Autonomous Agents* has aided the effectiveness of training with simulated consultations. However, participants thought the people were still slightly robotic without facial expressions in some cases (Pan et al., 2016), which lessened the impact. Nevertheless, the Top-Down devices (consultation task) were enough to plausibly cause them to feel it was real once participants were immersed in the scenario.

In an environment where healthcare professionals, including Doctors and Nurses, engage with patients from diverse backgrounds, each with their unique perspectives and coping strategies, it's crucial to offer them a secure platform to assess and refine their communication skills thoroughly. This platform should allow for repeated practice without introducing any behavioural bias. VR is particularly adept at meeting these requirements, which is why we've selected this domain as the testing ground for our investigation into *Self-Representation*, focusing on the configuration of *Embodied Virtual Perspective-Taking* (EVPT).

Embodied Virtual Perspective-Taking for Medical Training

Embodiment plays an important part in building plausibility for skill transfer, as we've seen earlier in this chapter (Skarbez et al., 2017). To foster an active construction of knowledge, junior practitioners should be encouraged to take on a self-regulating role in the learning process (Lok et al., 2006). This approach is emphasised in many educational mission statements, as exemplified by the assertion that "the self-regulated learner must have a healthy self-concept with a strong understanding that they, alone, are in control of their learning, mastery of tasks, and attainment of goals". (Sandford and Richardson, 1997). Techniques such as *Embodiment* and EVPT in VR could provide avenues for junior and senior practitioners in training to establish personal ownership of their growth and assessment.

EVPT can be viewed as a single or double-tiered embodied experience within the role that is usually observed. This would result in an experiment where participants would embody an initial role 'A'. They would switch to another perspective, role 'B', to either continue the experience (Ke and Xu, 2020) or re-watch the experience (Raij et al., 2009).

Examining different viewpoints or immersing oneself in another person's perspective has been associated with various positive outcomes. (Kohlberg, 1976) connected it with moral development, while (Cialdini et al., 1997) linked it to increased empathy and altruism, as well as enhanced prosocial behaviour (Batson, 1995). Researchers have also shown that adopting different perspectives can also play a role in reducing biases in social thinking and mitigating intergroup conflicts (Galinsky and Moskowitz, 2000).

Furthermore, recent studies have shown EVPT could reduce negative stereotyping (Yee and Bailenson, 2006) and increase cognitive empathy in immersive VR (Van Loon et al., 2018). In a study in which researchers compared online and Virtual Reality perspectives for gender bias in STEM hiring decisions, results depicted EVPT resulted in significant changes to participant behaviour following exposure to a gender-incongruent *Agent* such that men showed a preference for the female candidate, and women showed a preference for the male candidate (Crone and Kallen, 2022). However, can this method also manipulate self-assessment of performance in a communication training simulation?

Though there isn't much literature on the potential impact of EVPT on *Self-Evaluation*, there is enough empirical evidence to make some inferences about the possibilities. In a study that looked at a virtual *Body Ownership* paradigm for self-counselling, participants were asked to engage in a conversation with Sigmund Freud embodied in a *Self-Avatar* that looks like themselves. Then, they were asked to respond to themselves from the embodied perspective of Sigmund Freud. Results suggested that "this form of embodied perspective taking can lead to sufficient detachment from habitual ways of thinking about personal problems to improve the outcome."(Osimo et al., 2015) Participants also recorded that they felt their mood improved overall. These results demonstrate the power of virtual *Body Ownership* to effect cognitive changes. Therefore, we believe that participants in our study watching their performance from an embodied perspective will express more of a cognitive impact, i.e. in this case, due to the nature of the task, more criticism of their performance (Raij et al., 2009).

To conclude, Perspective-Taking in VR has demonstrated significant potential in enhancing empathy, *Self-Perception*, and behavioural change. It allows users to inhabit another *Self-Representation* and experience scenarios from another's viewpoint, fostering understanding and reducing implicit biases, such as those related to race or gender (Peck et al., 2013). Studies have also shown that embodying a *Self-Avatar* with different attributes and identities can influence users' self-confidence and cognitive performance, as seen in applications like embodying Einstein to boost self-esteem (Banakou et al., 2018). Furthermore, VR's ability to facilitate shifts between first-person and third-person perspectives enhances spatial awareness and cognitive interpretation of environments. Despite these findings, several gaps remain. The variability in its effectiveness, influenced by factors like Avatar realism and perspective, is not fully understood.

Consequently, we will utilise EVPT in our research in Chapter 5 as a means of self-reflection as we hypothesise it may significantly impact *Self-Efficacy.*

2.6 Embodied Consistency Framework

While the primary focus of this thesis lies in *Self-Representation,* the concept of *Embodied Consistency* offers an additional lens to understand how certain consistent and inconsistent configurations of *Embodiment* within Solo and Social VR can impact the psychological and practical experience in VR. The framework has three dimensions in research, though we will only discuss the first two in this thesis.

Context	Embodied Consistency	Consistent example	Studies	Inconsistent example	Studies
Solo	**Sensory Consistency**	I see my body/body parts; it moves in sync	(Slater et al., 2010)	I see my body/body parts it moves async or no movement	(Pan et al., 2016)
Social	**Co-Visual Consistency**	I see my body and their body	(Steed et al., 2016)	I see my body; I don't see their body	(Collingwoode-Williams et al., 2021)
Social	*Co-Percieved Consistency**	*I see my body, and they see my body*		*I don't see my body, they see my body*	*(Steptoe et al., 2010)*

Table 2.2: Examples of dimensions of Embodied Consistency. (*) Co-Perceived Consistency, though a part of the framework, is out of scope. Only those in Bold will be tested in this thesis.

This framework refers to the alignment of sensory and representational attributes in virtual environments, ensuring sensory inputs (e.g. *Visuomotor* synchronisation) and Avatar representations are congruent. This alignment has been shown to influence user experiences of *Self-Representation*, including *Embodiment* and *Social Interaction.* In the sections below, we briefly detail the dimensions and where they will appear in this thesis.

Sensory Consistency

Sensory Consistency regards visual synchronicity (accurate movement alignment) or congruence (switching on or off) of user input modalities to the virtual body of the *Self-Avatar* (i.e. control of hands, arms, etc). An example of *Sensory Consistency* is *Visuomotor* synchronicity. Slater showed that *Visuomotor* synchronicity versus asynchrony leads to high *Embodiment* (Slater et al., 2010) when viewing your *Self-Avatar* in a Mirror. A lot of research supports the role of synchronised *Visuomotor* and *Visuotactile* integration in eliciting strong ownership over the *Self-Avatar* (Kilteni et al., 2012a; Kokkinara et al., 2015), findings also reveal that asynchronous or partial sensory input can significantly undermine the illusion of *Embodiment*, hindering *Self-Representation* (Botvinick and Cohen, 1998; Roth et al., 2016). However, as we highlight in R1, little is known about the thresholds of acceptable asynchrony and how varying levels of *Sensory Consistency* may differentially affect Solo VR experiences. As it aligns with our first research question and hypothesis for this thesis, we will touch upon *Sensory Consistency* in Chapter 3.

Co-Visual Consistency

Co-Visual Consistency regards visual synchronicity or congruence of Avatar realism. This can be visual attributes of the virtual body of the *Self-Avatars* - such as Avatar type and fidelity, between pairs. Fidelity can pertain to a *spectrum* of human likeness (i.e. humanoid robot, human or augmented human) or realism (cartoon fidelity, photorealistic fidelity). Avatar type can range a bit more contextually but is more *binary*, covering whether the Avatar is visible or invisible, short or tall, etc. This is observed in both multiplayer and *Agent*-facing contexts, as arguably, these both account for Social VR.

In the literature, we have seen in Pan and Steed's study that within the consistent configuration of *Co-Visual Consistency*, having both participants with *Self-Avatars* results in higher subjective feelings of trust over having both participants with controllers (Pan and Steed, 2017). Furthermore, a recent study examining *Co-Visual Inconsistencies* in the realism of Avatars and virtual others in VR found that the incongruence between a stylised *Self-Avatar* and a group of realistic virtual others resulted in diminished ratings of *Self-Location* and *Self-Identification*. This suggests that higher-order incongruent visual cues that are not within the ego-central referential frame of one's (virtual) body can have an adverse effect on the relationship between one's *Self-Representation* (Mal et al., 2024). Nevertheless, there is a paucity of research exploring how inconsistencies between Avatar realism affect group dynamics in VR. As this aligns with our second research question and hypothesis, we will touch on *Co-Visual Consistency* in Chapter 4.

In summary, the contribution of this novel framework is to highlight the impact of congruence in sensory inputs, Avatar realism, and environmental factors, complementing established theories on *Embodiment* and *Self-Representation*, see Table 2.3.

2.7 Conclusion

Overall, through this review, we can identify the importance of utilising a *Self-Avatar* in VR and how the different configurations of *Self-Representation* can have a significant psychological impact on participants. Various issues have been raised throughout this Chapter regarding the gaps in the literature that we try to fill with our research. These issues raised can help form the building blocks for solidifying a framework for *Self-Representation* in Solo and Social VR. In the next three Chapters, we will begin our investigations into our research questions. We introduce an experimental study, where we investigated whether lip-sync and arm *Visuomotor* synchronicity increased subjective feelings of *Body Ownership* and *Agency*, and we will discuss the results. We hypothesise that congruence in sensory integration will invoke higher feelings of *Embodiment*. The results of this investigation can be found in Chapter 3.

Framework	Core Components	Overlay	Difference
Embodied Consistency Framework (2025)	Sensory Consistency, Co-Visual Consistency	N/A	N/A
Sensorimotor Integration (2010)	Visuomotor, Visuotactile, Visuoproprioception	Sensory Integration and Embodiment	ECF incorporates consideration of Avatar Appearance and contextual differences (Solo, Social)
Presence and Embodiment (2005)	Place Illusion, Plausibility Illusion, Embodiment illusion	Highlights Embodiment and Plausibility	ECF explicitly investigates Consistency over the broader Presence Model
Proteus Effect (2007)	Avatar Appearance, Behaviour, Self-Perception	Both focus on Avatar Appearance causing Psychological Impact	PF is about behaviour change, ECF emphasises broader impact of sensory and visual consistency
Sense of Embodiment (2012)	Self-Location, Agency, Ownership	Sensory Integration and Embodiment	ECF integrates Avatar realism and contextual differences (Solo, Social)

Table 2.3: Table comparing existing theories with Embodied Consistency Framework (ECF)

In Chapter 4, we introduce an experimental study where we investigate the impact of inconsistent representations between pairs (just controllers vs *full Self-Avatar*) in comparison to consistent representations and discuss the results. We hypothesise that visual inconsistency between *Self-Representations* will have negative effects on *Social Presence* in scenarios which involve collaboration.

Finally, we will look at how *Embodied Virtual Perspective-Taking* in communication training can impact learning (See Chapter 5). We hypothesise that utilising the first-person perspective will result in participants experiencing changes in *Self-Efficacy* towards their communication skills in delivering bad news.

Chapter 3

The Effect of Lip and Arm Synchronisation on Embodiment: A Pilot Study

In Chapter 2, we reviewed studies demonstrating the success of specific configurations in eliciting *Embodiment* during Solo VR experiences. For instance, combining sensory integration with Mirrors and *Visuomotor* synchronicity has been shown to enhance *Body Ownership*. However, gaps remain in validating these setups due to variations in design and technical resources.

We investigated in this Chapter the impact of manipulating *Visuomotor* configurations of lip-sync and arm movement whilst embodied in a *Self-Avatar*. Specifically, we tested whether consistency between these sensory inputs enhances *Body Ownership* and *Agency*. A 2x2 experimental design was implemented, where participants experienced conditions with either full or no control over the *Self-Avatar's* lip and arm movements, addressing the first thesis research question:

- *What level of sensorimotor inputs and synchronicity configuration is necessary for Embodiment?*

Drawing from previous findings on the role of gestures and *Self-Representation* in presentations (Murcia-Lopez et al., 2020; Steed et al., 2016), we hypothesized that:

- Congruent *Visuomotor* configurations of lip-sync and arm movement would invoke greater *Body Ownership* and *Agency*.

This highlights the potential importance of aligning these factors to enable effective *Self-Representation* in Solo VR tasks.

To ensure accessibility and repeatability, we introduced an economy-friendly technical pipeline using Kinect version 1 integrated with the Oculus PC SDK. Participants presented while wearing an HMD and viewed a gender-matched *Self-Avatar* in a virtual Mirror. The *Self-Avatar* mirrored their arm and lip movements under synchronous and asynchronous conditions. Post-experiment questionnaires assessed participants' experiences. Results revealed an interaction effect: congruent conditions elicited higher levels of *Embodiment*, particularly for *Body Ownership* and *Agency*, compared to incongruent setups.

These findings have implications for developers designing Solo VR embodied experiences, emphasising the need to balance context, accessibility, and computational efficiency. Researchers may also adopt this methodology to further investigate *Agency* and *Self-Representation* in VR under limited technical conditions, expanding the understanding of embodied interactions.

3.1 Introduction

The popularity of HMD devices and real-time optical motion tracking devices (e.g., Kinect, Leap Motion, Vive Face Tracker) has enabled a novel way for users to control their *Self-Avatar*; they can embody it and achieve motor synchronicity. Implementing *Visuomotor* contingencies has been proven to provoke higher levels of *Embodiment* in *Self-Avatars* (Marini and Casile, 2022). That being said, various methods could be used in the technical implementation of *Embodiment*. In most cases, due to resource restrictions from the devices in use, only a subset of body expressions will be captured to animate the *Self-Avatar*. The question we ask and investigate in this experiment is whether these technical restrictions can harbour the illusion of *Embodiment* or inhibit the flexibility with which the mind accepts its mobility in VR - as has been proven with body image (Banakou et al., 2013).

3.2 Background

Head-mounted displays and real-time optical motion tracking devices have enabled users to be placed in the body of a *Self-Avatar*, whose movements are synced to theirs in VR (Kim et al., 2023). Indeed, several studies suggested that the ownership of another person's body, or *Embodiment*, can be induced via multi-sensory correlation (Maister et al., 2015) and could have a direct impact on users' behaviour (Kilteni et al., 2012a), the user's cognitive ability (Banakou et al., 2018) and feeling of *Agency* over the virtual *Self-Avatar* (Kokkinara, 2015; Gonzalez-Franco et al., 2010). Existing literature suggests that by taking advantage of the unique affordances in VR, it is possible to have a sense of ownership over a body part or even a voice that is not your own (Botvinick and Cohen, 1998; Bolt et al., 2021; Banakou et al., 2016; Tajadura-Jiménez et al., 2017). *Body Ownership Illusion*, or responses to this illusion, can be measured subjectively through questionnaires or objectively through physiological data (Seinfeld et al., 2022).

With the introduction of these sensory controllers, it is important to investigate such anatomical control systems in more depth, particularly the potential link between their functionalities and *Embodiment*, in this case, in the first person. In a previous setup where the participant faced a reflection of their *Self-Avatar* representation, they were head-tracked by Fakespace Labs Wide5 HMD and gesture-tracked by a 12-camera Optitrack (Gonzalez-Franco et al., 2010). It was found that participants' upper body movement being mirrored alone was a provocation for the illusion of both *Agency* and *Body Ownership* towards the virtual body, even without full-body tracking or lipsync.

There are not many literature papers that look at the impact of lip-sync on *Embodiment*. However, a study in 2020 by Gonzalez-Franco and colleagues (Gonzalez-Franco et al., 2020), looked at the effect of a static *Self-Avatar* (no animation or lipsync), a *Self-Avatar* with lip-sync and a *Self-Avatar* with lip-sync and idle facial animations (lip pursing, eye blink and gaze, nose flare to simulate breathing). Participants were asked to give a pep talk, looking into a virtual Mirror that reflected their *Self-Avatars* with *Visuomotor* contingencies implemented. The cognitive load was lifted due to the fact that the researcher gave participants lines to repeat, making the presentation a performance and provoking the use of more body language. Though inverse kinematics was implemented to capture upper body language, arm movement wasn't a variable controlled in this experiment. The results suggested that participants felt more *Embodiment* in conditions with lip-sync and idle facial animation as well as with just lip-sync over a static *Self-Avatar*, though there was no significant difference between these two conditions. This experiment also included a self-recognition task and found adding lip-synchronisation significantly enhanced users' self-identification with the *Self-Avatars*; participants experienced a stronger *Enfacement Illusion* (perceiving the *Self-Avatar's* face as their own) when the *Self-Avatars* exhibited both lip-sync and idle animations compared to static faces or those with only lip-sync. These findings emphasise the role of including multi-sensory mapping of facial animations for higher *Embodiment* but also support previous research that advocates the unique role VR plays in curating new *Self-Representation* experiences, as

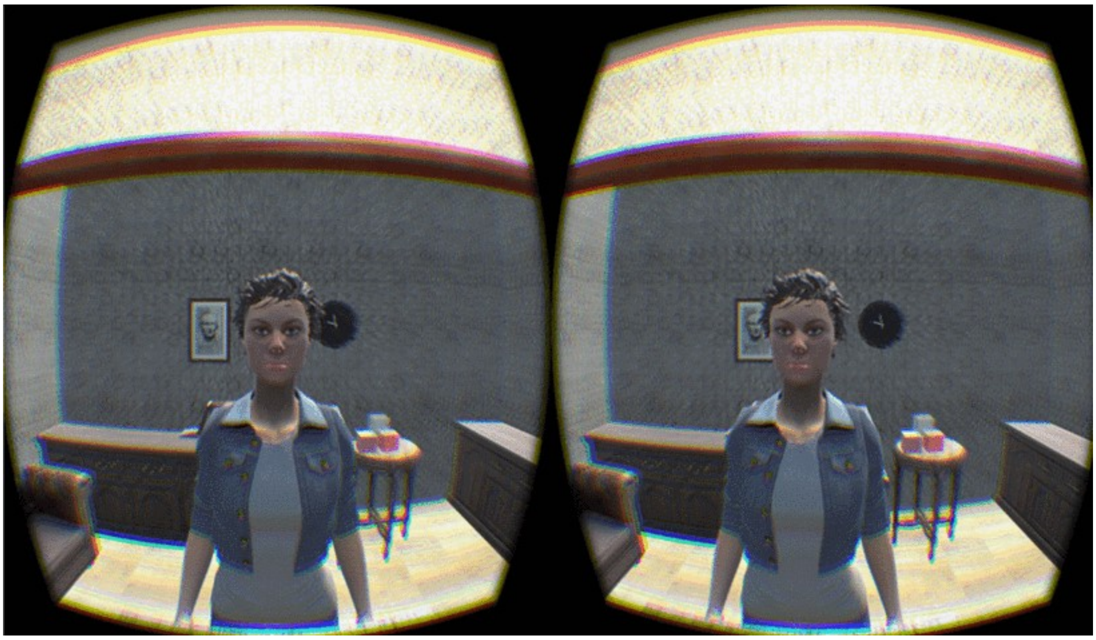


Figure 3.1: Shows the virtual room and female Avatar used in the experiment.

the Avatars used in the study were not look-alikes of the participants. Yet, they achieved significant levels of *Embodiment* and self-identification through animations. However, this study does not look at the configurations between layers of real-time facial Motion Capture and body Motion Capture, which could potentially impact the results.

This pilot study explores the extent to which lip-sync and arm movement influence *Embodiment* and the relationship between these two features. We hypothesised that there would be a stronger effect on *Embodiment* when both lip and arm are synchronised due to enabling more access to control the body; we also hypothesise, as a result, that the level of *Embodiment* would reduce when only one variable or none were synchronised.

This is important as using VR with *Embodiment* can lead to a deeper understanding of human behaviour and social interactions. As it is such a broad field, many applications can take advantage of this research, such as training applications, immersive games that involve users taking on an Avatar persona, and even educational experiences and serious games.

3.3 Technical Implementation

VR Core Module - The Platform

The Virtual Environment (VE) was created using Unity3D 5.3.4p1 patch as it was the most compatible version at the time of development with the current VR Headsets. It was made to resemble a room in a home to support the scenario. The participants were told that they were testing VR to practise and improve their speeches. The room consisted of a table in the centre holding a Mirror which reflected from the waist up. The virtual characters were purchased from the Unity Asset Store; both the male and female Avatars were Caucasian and chosen to look very generic and casually dressed. They were placed a few feet from the Mirror. The walls held picture frames and a clock. There were two long tables, one with books atop and another with three cubes. These were positioned to be visible in the Mirror's reflected view from the Avatar's point of view.

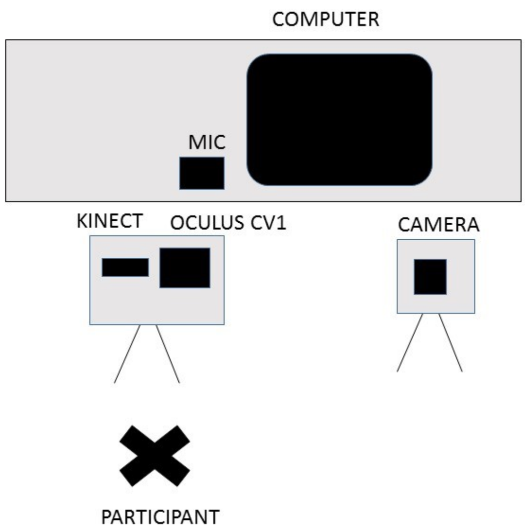


Figure 3.2: Figure shows the diagram of the layout of the experiment in the Virtual Lab

VR Core Module - The Display

The environment was viewed via Oculus Rift 1.3 Consumer Version 1, which has a field of view of 110 degrees with a 2160 x 1200 resolution. It was integrated into Unity3D with the Oculus SDK.

VR Core Module - The Avatar

The *Self-Avatar* used was taken from the asset package 'Morph3D'. As they did not include facial blend shapes, I arranged for the model to be edited. Maya 3D modelling tool was used to edit the Avatar and implement the blend shapes so that it would work with the OculusLipsync plugin.

User Input Module

Lipsync was integrated using the OculusLipsync plugin for Unity, which took in live stream audio from the mic. The head movement was applied using the position and rotation data collected from the Oculus Rift and the Oculus PC SDK 1.17. The setup allowed for real-time tracking of the participant's upper body movement and the mirroring of the movement by the Avatar in the Virtual Environment. A standard plug-in microphone captured voice, and a script was written to handle the audio input.

Technical Contribution

The prominent contribution to this application is Motion Capture. During the implementation of this project, there was little documentation on how to utilise the Kinect Version 1 in Unity3D with the Oculus; therefore, I had to work with different existing libraries to find a solution to integrate this Motion Capture into the project. I initially began with the Leap Motion SDK for Motion Capture but found the limitation of the field of view (field-of-view of 150 degrees in a horizontal arc and 120 degrees in a vertical arc, with a range of approximately 25 cm to 60 cm (10 inches to 24 inches)) as the Leap Motion could only be placed on a table in front or on the headset, minimising the capture of certain arm movements. We settled on the Kinect version 1. The integration into Unity3D was made possible by utilising a collaboration of libraries and SDKs:

- Kinect SDK 2.0

- This SDK allowed us to access tracking data and interaction functionality from the Kinect within Unity3D

- Zigfu for Windows with Open Natural Integration (OpenNI) bundle (2016)
  - OpenNI is an open-source framework that provides a standard API for accessing and processing data from 3D depth-sensing devices like the Microsoft Kinect. Zigfu is a middleware library that simplifies the development of gesture-based applications using 3D sensing technology. Zigfu acts as middleware that builds upon OpenNI, providing higher-level APIs and pre-built features that make it easier to create natural user interfaces on Windows.

- Zigfu Development Kit 4.f1 (ZDK) package for Unity
  - This tool provides Unity-compatible Scripts and Components for natural user interface features. Most importantly, it supports the mapping of body movements to 3D characters in Unity3D.

The inverse kinematics was implemented using the position data from infrared tracking collected by Kinect Version 1 and the ZDK for Unity. I modified parameters on the Zigfu Skeleton Script for mapping the skeleton rig for my Morph3D Avatar, which collected this data and fed the tracking method parameters to move the position and rotation of the Avatar arms. However, there was a conflict between tracking the head orientation with the ZDK and Oculus PC SDK. As this was an immersive experience in VR, I disabled the tracking for the head within the ZDK. In order to prevent a conflict between the two API's I created an Empty GameObject to offset the Head position from within the Oculus Camera Rig so that the position of the head remained relative to the movement configured by the ZDK. This resulted in a relatively non-disrupted full-body Motion Capture setup in VR from a first-person view. A full diagram of the technical pipeline is shown in Figure 3.3.

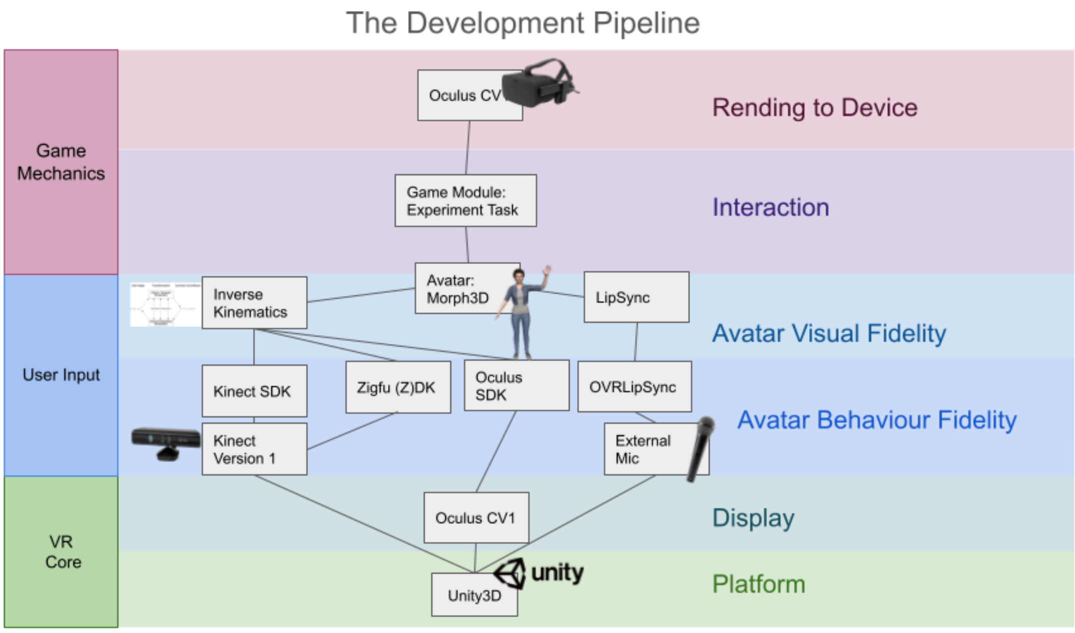


Figure 3.3: The figure shows the technical pipeline of the project.

3.4 Experimental Design

Sample

Thirty participants took part in this experiment. The breakdown came to twelve female and eighteen male participants with an average age of twenty-nine. Each participant was paid 5 pounds for their involvement. The payment was given to them upon the completion of the experiment. The participants were recruited from Goldsmiths University by word of mouth and through ads on social media.

Methodology

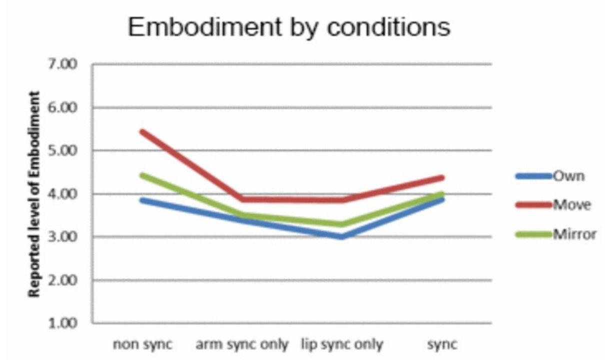
It was a between-group experiment where each participant experienced only one of the four conditions: (1) lip-sync/arm-sync, (2)lip-sync/non-sync arm, (3)non-sync-lip/arm-sync, (4)non-sync lip/non-sync arm). Therefore, it has a 2x2 factorial design. The head movement provided by the Oculus CV1 was constant in all four conditions.

- (1) In this condition, there was a 1:1 mapping of arm movement between the *Self-Avatar* and the participant. There was canned lip-sync that was triggered in real-time by audio detection.
- (2) In this condition, there was canned lip-sync that was triggered in real-time by audio detection but no tracking of the body by the Kinect.
- (3) In this condition, there was a 1:1 mapping of arm movement between the *Self-Avatar* and the participant, but there was no lip-sync.
- (4) In this condition, there was no tracking of the body by the Kinect and no lipsync.

Procedure

On entering the lab room, the participant was given two documents to read and sign and a brief questionnaire for demographic purposes. One document was a consent form, and the other was an information sheet that described the experiment and procedures to be expected. They were advised that they could withdraw at any moment without reason. After this was completed, they were then advised by the experimenter that the experiment was completely voluntary and were asked whether they had any questions and if they understood what was to be expected of them for the duration of the experiment. They were then informed that their data would remain anonymous and the process would be filmed. They were also shown a quiet place where they could recuperate and drink water at any point during or after the experiment. They were then notified that the experiment results would be shared with them if requested after the data had been evaluated. The examiner explained to the participants that this virtual simulation was a scenario to practice their speech for an interview to teach English (or a subject more comfortable to them) in Ghana for a year.

The participant was then helped to put on the Oculus CV1 and told to keep their body still and only move their arms and head. They were able to adjust the headset until they felt comfortable. They were told to close their eyes, and when they opened them again, they saw either the reflection of a male Avatar or a female one, depending on the gender they identified with. Participants could now try different movements and become familiar with their environment and capabilities for 30 seconds. The participant was informed before starting the condition what movement was available to them. Following the test run, the participant was then asked to deliver a prepared speech to the Mirror for 2 minutes - a brief was given to them upon sign-up. After this period, the participant was asked to close their eyes and answer a verbal questionnaire read out to them by the examiner. Upon completing the questionnaire, the participant would be asked to open their eyes, and they would once again be facing the reflection of a gender-matched Avatar.



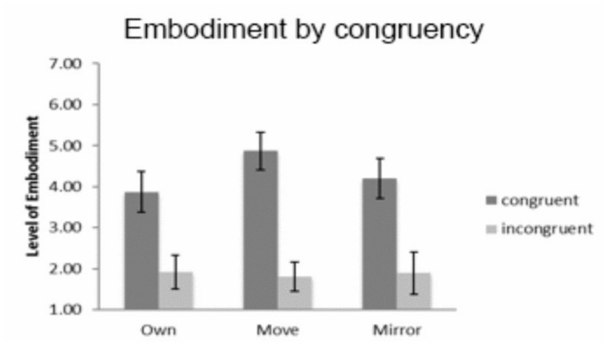


Figure 3.4: (Left) Means of questionnaire results arranged by conditions, (Right)Means arranged by Congruence (i.e. Consistency)

Finally, participants were paid and thanked for their time. The Goldsmiths Research Ethics Committee had approved the experiment.

3.4.1 Measurement

The independent variables of this experiment were: *Lip-Sync* (the *Self-Avatar*'s mouth moved to the participant's speech, based on audio from a microphone) and *Gesturing* (the *Self-Avatar's* arm movements imitated those of the participant, as tracked by a Kinect). We measured the effect of each condition with verbal questionnaires. The *Embodiment* questions asked were to find out; (1) How much the user felt the Avatar body was their own (*OWN*); (2) How much control they felt over the body (*MOVE*); and (3) How much they felt that the reflection was their own reflection (*MIRROR*).

These questions were based on the 'Body Ownership and Agency Questionnaire' with a 1-7 Likert scale where 1 indicates *completely disagree*, and 7 *completely agree* (Osimo et al., 2015).

Though we did conduct a semi-structured interview at the end of the experience, this was in line with another research question that is out of the scope of the focus of this review. This experimental design addresses the first research question of the two explored within this work, which addresses *Agency*. The second research question explored Change Blindness. The abstract of this can be found in the Appendix A.

3.5 Results and Discussion

We performed a two-way ANOVA test with SPSS, setting lip (sync, a-sync) and arm (sync, a-sync) as the two dependent variables and questionnaire results (*MOVE, ANOTHER, OWN*) as the dependent variables. There was a significant interaction effect ($p = 0.048$) between the arm and lip on MOVE, as shown in Figure 3.4(right). The results depicted that in the consistent conditions where both the lip and arm were synced or a-synced, the participants felt a higher *Agency* over the *Self-Avatar* than in inconsistent conditions.

Figure 3.4 also shows the mean of the average score of all participants for the three questionnaire factors (*MOVE, ANOTHER, OWN*), filtered by *Consistency*. Although this result was not statistically significant, the same pattern of higher results due to *Consistency* was evident in all three measurements. This indicates that maintaining congruence between arm movement and lip-sync input could be important in the level of *Embodiment*.

In this research, we aim to investigate whether manipulating the *Visuomotor* synchronicity of both lip and arm movement between the participant and the virtual character will impact the *Body Ownership Illusion*. We ran four conditions where each participant was invited to present in an HMD while seeing in a virtual Mirror a gender-matched *Self-Avatar* who copied their arm and lip movements in sync and

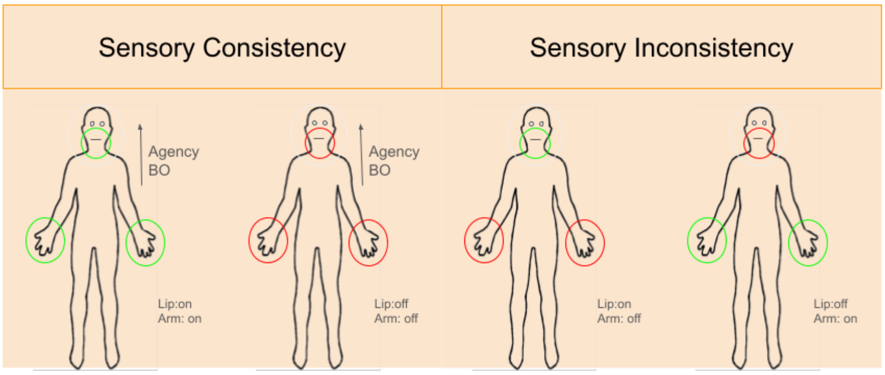


Figure 3.5: The figure shows the summary of the impact of *Sensory Consistency* in configuring the *Self-Avatar.*

a-sync states. The result suggested an interaction effect of arm and lip, showing reports of a higher level of *Embodiment* with the consistent than in the inconsistent conditions. Our hypothesis was supported by the verbal questionnaire's subjective results, which pointed out the effect of congruence over synchronicity.

It is also interesting to see that participants felt higher *Agency* in the consistent non-sync condition, where they had very little actual control over the *Self-Avatar* (only head movement) than they did when they controlled lips or arms (but not both). This is perhaps due to the familiarity of being only able to visually immerse themselves in different realities with little to no movement (i.e. cinema, TV, early VR mobile devices). Also, we know from previous studies mentioned that even just the sight of having a virtually aligned body can provoke ownership (Kokkinara, 2015) and humans, in general, have shown to be quick to accept the new limitations in 3D worlds without it breaking *Presence* or *Embodiment* (Murphy, 2017). There is evidence to support that there can be high *Embodiment* in conditions where there is just head orientation and voice (Pan et al., 2016). Still, arguably, context and Top-Down mechanics come into play in regulating user expectations. For example, this result may be due to the setup being a solo experience. Social Virtual Reality contexts would potentially demand more non-verbal cues, heightening the expectancy of the *Agency* (Pan et al., 2018). This research is important as it implies that using VR with *Embodiment* can lead to a deeper understanding of human behaviour and social interactions (de Melo et al., 2010). In future research, we hope to explore this effect further with a broader participant pool and a full-body high-fidelity Motion Capture system.

In this Chapter, we explored the impact of *Visuomotor* lip-sync and arm movement on an embodied *Self-Avatar* - curating a configuration suitable for the resources at hand with guidance from present research (see 3.3). The results conflict with some bodies of literature that highlight high fidelity *Visuomotor* synchronicity as a crucial step for provoking the psychological illusion of *Embodiment.* In the context of building a Solo VR embodied *Self-Avatar* experience where the user can see their reflection, results suggest that the need for arm movement and lip-sync isn't mandatory for configuring *Self-Representation.* Instead, congruency in the sense of *Sensory Consistency* enabled a stronger result, overriding the potential limitation of an inexpensive technical setup (see Figure. 3.5). This aligns with the *Embodied Consistency* framework, which emphasises the importance of congruence in sensory and representational elements of *Self-Representation.* It's also important to acknowledge that in this context, there is no explicit prompt given to participants to use their hands, unlike in the work of Gonzalez-Franco (Gonzalez-Franco et al., 2020), as research also suggests interaction and Top-down influences such as tasks can also influence the psychological effects of the configuration of *Self-representation.*

To return back to our first hypothesis for this thesis, we can see that the results of this study did not support it - *Visuo-proprioception* was enough to elicit not just *Body-Ownership* but *Agency* and *Mirror Self-recognition.* In terms of our research question (R1), this study gave informative results which can help build on our understanding of what is possible in fundamentally configuring *Self-Representation* in solo embodied contexts with an accessible mid-fidelity implementation. Some attributes to the threshold of provoking *Embodiment* lie within the congruence of multi-sensory integrations for *Self-Avatar Embodiment*, but more research needs to be done to validate if this is applicable over diverse configurations of multi-sensory integrations.

In the next study in Chapter 4, we will pivot from the behavioural aspect of *Self-Representation* to investigate the gaps in research around visual *Self-Representation* of dyad *Self-Avatars*. We will investigate whether the congruence in the visual configuration of *Self-Avatars* between pairs can have a psychological impact on how participants trust each other during a collaborative task.

Chapter 4

The Impact of Self-Representation and Consistency in Collaborative Virtual Environments

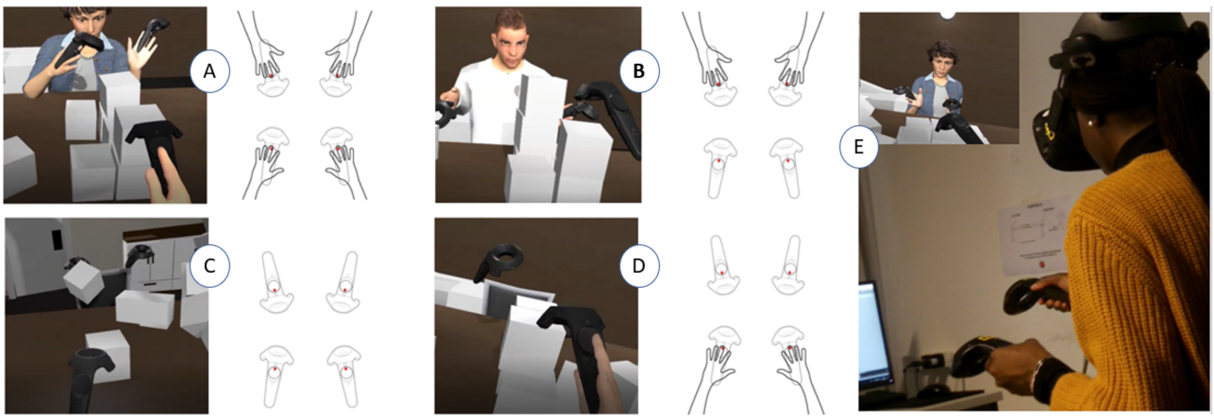


Figure 4.1: Four Conditions. A) Avatar/Avatar, B) Just Controllers/Avatar, C) Just Controller/Just Controller, D) Avatar/Just Controllers. E) Participant in playing the 'Build the Block' game in condition B.

Following the pilot study in Chapter 3, we concluded that *Visuomotor* congruency in the configuration of *Self-Representation* when embodied in a *Self-Avatar* has a positive effect on the psychological illusion of *Body-Ownership* and *Agency*. However, in this Chapter, we moved our investigation into a social virtual space with the intention of testing how different configurations of *Self-Representation* - in this case, visibility of *Self-Avatars* between pairs, can have an impact on social interaction and the psychological illusion of *Social Presence* in collaborative environments.

The *Self-Avatar* in Social VR has crucial implications in addition to its function in a Solo VR experience; early research highlights that it may have a social interactional role (Bowers et al., 1996). For example, Bowers found that in a virtual meeting environment, users would actively turn their *Self-Avatars* to face each other when talking. There was ambient stereo sound in the environment, deeming the notion practically unnecessary but socially important.

So far in the literature, we have evidence to suggest three interconnected theories: 1) On a psychological level, one's *Self-Representation* can be impacted by social and societal constructs (Stets and Burke, 2000), and many of these biases and stereotypes (skin tone, height, attractiveness, seniority) can translate into virtual social interactions and spaces. 2) How one is perceived within a virtual environment roots itself majorly in how they are visually presented. 3) How one is configured to be presented both in visual attributes and supported sensorimotor can affect participants on a cognitive and behavioural level (Peck et al., 2013; Kilteni et al., 2013; Banakou et al., 2018; Yee and Bailenson, 2007).

However, most of the examples of literature to date predominantly assess these dynamics within an equally calibrated multiplayer Avatar system. The reality is that most platforms for Social VR allow for diversely configured embodied social interaction due to a focus on accessibility. Our second research question (R2) for this thesis looked at the configuration of the *Self-Representation* in social virtual settings. We question:

- *How can inconsistent and consistent configurations in Self-Representation have varying impacts on Social Presence?.*

We hypothesised that:

- Inconsistency between Avatar configurations of *Embodiment* will have negative effects on *Social Presence* in dimensions of *Trust.*

This is important as non-verbal communication is a fundamental human trait that is critical to having natural and responsive communication and takes more time to be taken as an honest reaction in a discussion than verbal responses, as verbal is goal-oriented whilst non-verbal is a behavioural response (Vinayagamoorthy et al., 2006b).

We ran two studies for this investigation, one in the United States with a confederate and the other within the UK using dyad pairs. As the research states below, there can be unforeseen consequences when using a confederate in an unbalanced way. However, we also measure whether productivity is affected by the congruency of *Embodiment* in each condition. In both studies, participants were asked to play a collaborative game, and we investigated the effect on trust with a questionnaire, money invested in a trust game, and performance data. Study 1 suggested that having a *Self Avatar* made the participant give more positive marks to the confederate and that when the confederate was without a *Self-Avatar*, they received more trust (measured by money). Study 2 showed that consistency led to more trust and better productivity. We discuss these results against our framework of *Embodied Consistency* and other related present research.

If we aim to keep the aspects of face-to-face communication outlining the framework of Social Virtual Interaction, we must understand how the configuration of *Self-Representation* in this domain-specific context, being embodied in a *Self-Avatar* different from the participant's appearance, impacts the perception of *Self* and others. Therefore, this study helps developers and researchers comprehend how the *Self-Avatar* alters collaborative outcomes in VR.

4.1 Introduction

Collaborate Virtual Environments (CVE) can be used effectively in many industries; more commonly applicable are those that utilise VR for training, education and entertainment. The advantage of a CVE is that it allows for interactions and controlled conditions that would not be possible in real life. For example, the ability to be virtually present in the same environment as someone who lives across the world is the fundamental feature that many social VR applications offer (such as *Alt Space* [1]). Another example is to be able to collaboratively build a structure and explore and manipulate it in real-time in 3D (like with *Tilt Brush* [2] and *Oculus Medium* [3]). In order to effectively complete tasks via negotiation and collaboration, a significant level of trust is necessary between users. In this Chapter, we are interested in how different configurations of *Self-Avatar* representations can have an impact on user experience. More specifically, by exploring how different configurations of *Self-Avatar* representations between multiple

[1] https://altvr.com/
[2] https://www.tiltbrush.com/
[3] https://www.oculus.com/medium/

users impact social interaction, we hope to bring valuable insight into establishing effective setups of *Self-Avatar* representation in CVE. In particular, we are interested in two aspects: self-presentation (whether to render a *Self-Avatar* or not) and *Consistency* (whether to maintain the same setup of *Self-Representation* between users in the CVE or not).

Previous research suggested that the use of a *Self-Avatar* can be a powerful tool in facilitating trust. Pan and Steed investigated the impact of the *Self-Avatar* on collaborative and competitive tasks (Pan and Steed, 2017) in an immersive Virtual Reality (VR) system and found that both the *Self-Avatar* condition and the face-to-face condition led to higher trust scores than the no *Self-Avatar* condition. A similar study in Augmented Reality (AR) investigating the effects of Avatar representation on *Social Presence* found that a realistic full-body *Self-Avatar* was perceived as being the best for remote collaboration, but an upper body or artistic cartoon style could be considered as a substitute depending on the collaboration context (Yoon et al., 2019). However, in these studies, each dyad (pairing) had consistent *Self-Representations.* In this Chapter, we explore the impact that consistency or co-representation may have on trust within a collaborative setting. We ask whether *Consistency* in *Self-Representation* could improve trust as well as the productivity between pairs in a CVE.

Another dynamic we examine is how results may vary when using a confederate (Study 1) compared to paired participants (Study 2). The purpose of Study 1 was to validate the virtual test-bed and see whether the theory of consistency could be tested using a confederate, as it is a common practice in analysing participant responses to others due to the ease of preparation and recruitment. In Study 2, we developed the experimental design to include paired participants, giving us the opportunity to see whether organic social dynamics also matter when observing trust between a group. To investigate this, we developed a CVE where two players can meet and play a collaborative game. Each participant will have either a *Self-Avatar* or just controllers in a consistent or inconsistent condition (see Figure 4.1). They will wear a Head-Mounted Display (HMD), which will allow them to see each other in VR, and paired controllers will allow them to interact with the virtual objects in VR.

4.2 Background

4.2.1 The Self-Avatar in CVE

The accessibility of consumer-friendly Head-Mounted Displays (HMDs), like the Meta Quest 2, HTC Vive, and PlayStation VR 2, has made socialising and collaborating within VR a routine practice. This transition is particularly noticeable at international conferences, which increasingly adopt online formats. In these digital conferences, attendees can engage in exploration, conversation, and collaborative tasks that necessitate well-executed and effective implementations of Avatar-mediated communication. (see Figure 4.2).

In these virtual spaces, there are varied displays of the *Self-Avatar.* A good example of this variation is *Alt space* [4]. In this CVE, users can be represented by full-body humanoid Avatars or robots without arms and just hands. In other CVE such as *RecRoom* [5], as well as having no arms, *Self-Avatar*s are depicted only from the torso up. Studies have shown that the display of the *Self-Avatar* can have a strong impact on social dynamics in CVE (Pan et al., 2018; Wei, 2023). In some of these studies, participants were embodied as a full-body *Self-Avatar*, and we can reasonably suggest that the full-body *Self-Avatar* generates a positive outcome to the sense of *Presence*, interaction tasks and perceptual judgement.

However, research also confirmed that using only visual hands and feet was sufficient to induce illusory *Body Ownership*, and this effect was observed as being just as strong as using a whole-body *Self-Avatar* (Kondo et al., 2018). Moreover, studies have found that Avatars with a strong visual presence are not required in situations where accomplishing the collaborative task is prioritised over social interaction(Yoon

[4] https://altvr.com/
[5] https://recroom.com/

Figure 4.2: First two columns: images of Avatars from Rec Room. Last column: top image is Avatars from Altspace, and the bottom is Avatars from Engage

et al., 2023).

We can see that with varied levels of complexity and demand, both the visual representation and the setup of immersion can have a psychological impact on how participants complete tasks (Banakou et al., 2018; Pan and Steed, 2017). For this study, we chose to use full-body, gender-matched models holding controllers as users' *Self-Avatars*. In comparison, the Avatar rendering was turned off during our control condition, leaving only the pair of disembodied controllers as the sole representation of the user. This allowed us to moderate how the participants would interact with the environment but helped isolate the impact that each representation condition may have. We chose to investigate the impact inconsistent *Self-Avatar* representations may have on social interaction with collaborative tasks as it is a likely scenario to be affected by this conditioning.

4.2.2 Confederate versus Participant

The use of confederates is a common occurrence in VR psychology studies, even though there is debate on how this may hinder a study's re-productivity (Doyen et al., 2012), or if participants may behave differently with confederates than another participant. Early research (Martin, 1970a) suggests the possibility that the use of confederates to manipulate independent variables in small group experiments is compromised if the confederates arouse suspicion and imply 'deceived' and 'undeceived' subjects do not behave alike. Though this predates the establishment and use of CVE, it probes whether these social dynamics can carry over into a virtual space. It is still a common practice to utilise confederates in CVE studies; however, research shows there are certain contexts in which their use could introduce unknown factors into data, such as when taking up the addressee role (if they know more than is warranted by the experimental task and if their non-verbal behaviour is uncontrolled (Kuhlen and Brennan, 2013a). On account of this, we hypothesise that the use of a *Self-Avatar* can become a potential hindrance when a confederate is utilised. We look deeper into this investigation by running two studies, one that used a confederate and the other paired participants.

4.2.3 Consistency in Collaborative Virtual Environments

Consistency in Avatar representation has been a topic of research for many years in VR. A branch of this research focuses on whether consistency in representation can have an impact on trust.

Presently, there is no consensus on this research question as there are various studies that depict results favouring either end of the debate. For example, Gong looked at how trust and judgement could be affected by Avatar representation (Gong and Nass, 2007b). Here, the consistency was pairing a human face with a human voice or a humanoid (artificial human) face with a humanoid voice, and the inconsistency was the async of both these conditions. They found that in the inconsistent conditions, making judgements of the *Agents* took a longer processing time, and the participants felt less trust in them. Here, we see evidence in favour of this hypothesis. On the other hand, Latoschik compared paired interactions with abstract Avatar representations based on a wooden mannequin with high-fidelity *Self-Avatars* generated from photogrammetry 3D scan methods. Participants were assigned one or the other and alternated between different representations of the virtual *Agent* in dyadic social encounters (Latoschik et al., 2017).

This created a 2x2 factorial design where two conditions were consistent (both the participant and the virtual *Agent* had the same Avatar) or inconsistent (the participant and *Agent* had different Avatars). An interesting result found that the appearance of the virtual *Agent*'s Avatar had an impact on the *Self-Perception* of the participant's own virtual representation. A more realistic-looking *Agent* Avatar seemed to increase the impressions of the changed *Self-Avatar* and therefore helped to increase the suspension of disbelief for the respective Avatar owners. However, they did not find any significant result regarding trust between the conditions.

There is also research that revealed equal trust levels towards both categories of human and robot Avatars. Nevertheless, participants still felt a significant sense of 'togetherness' with the human-like Avatar compared to the robot even though the participant could only see their human hands and the confederate had a full body (George et al., 2018). In this condition, another perspective could still be considered inconsistent; however, the fact that the participant could still see their hands may have played a role in the positive result (Kondo et al., 2018).

Additionally, research has also shown that how the virtual environment is set up can affect the emotional states of participants (Dey et al., 2017) as well as the choice of the task that is to be completed (Kim et al., 2012; Regenbrecht et al., 2006). Fundamentally, it is important to be able to successfully immerse the participant into both the virtual world and the scenario of the scene; the susceptibility to these effects is mediated by two illusions of *Presence*, *Place Illusion* and *Plausibility Illusion*. Different communication scenarios may influence online trust (Feng et al., 2004). In Latokchik *et al.*'s experiment, they used only basic non-verbal communication (hand wave) as the form of interaction, but other more complex scenarios could be considered.

4.2.4 Measuring Trust

Trust is difficult to measure as it is a subjective construct. There are many different approaches to evaluating the development of trust, both objective and subjective. The most commonly used method to collect subjective data is questionnaires, giving self-reports, but this is still a method under constant controversy regarding its validity. For example, Bailenson gave evidence in his research that objective measures such as behavioural data (heart-rate, average movement) could be sensitive enough to pick up on responses that self-reports could not (Bailenson et al., 2005b).

Behavioural tasks are another method used to gather objective data. Hale created a virtual maze as a behavioural tool for measuring trust. They manipulated *Agents*' trustworthiness during an interview stage with the participant and then measured how often they approached and followed advice from each character (Hale, 2017). In this study, they compared their behavioural tool with using a Social Dilemma game called 'The Investment Game'. The investor was given 10 US dollars (different amounts have been used in subsequent studies, (D.Johnson and A.Mislin, 2011) and had to decide how much of their 10 US dollars to send to the trustee, knowing that the amount they sent would be tripled before it was given to the trustee. Then, the trustee had to decide how much of the tripled amount to return to the investor.

The game measures trust behaviour in terms of the percentage of money the investor is willing to send to the trustee. They found that where the maze picked up on specific trust, 'The Investment Game' picked up on trust felt by participants.

Due to the results above, we have decided to use both subjective and objective methods to collect data in this experiment with the intent to make our findings more robust. In the subjective questionnaire, we also focus on the *Liked* score as research suggests that people who are liked more by others are also more likely to win their trust (Feng et al., 2004).

We are motivated by the research questions above to investigate the potential impact of *Self-Representation* and *Consistency* in Collaborative Virtual Environments, paying close attention to the effect on *Trust* and *Liked* as well as the possible influence on collaborative productivity between participants.

4.3 Technical Implementation

VR Core Module - The Platform

The virtual environment and game were created using Unity 3D version 2017.2.0f3. To enable the tracking data from the HTC Vive, we used the SteamVR Unity plugin, and to allow for the 1:1 mapping of arm movement, we used the Inverse-Kinematics plugin. Networking was provided by the Photon Unity plugin.

The experiment in Study 1 was held in the lab office of George Mason's Virginia Serious Games Institute (VSGI). The two users were placed facing each other in the centre of the room. The HMDs were connected to two separate VR-ready desktops at opposite ends of the room. The Vive HMDs shared the same lighthouse sensors but were set up in SteamVR to face the direction of the centre of the room. In study 2, the experiment was held in the Virtual and Augmented Reality Lab at Goldsmiths University of London, which consisted of two separate rooms. The paired participants were allocated one individual in each room. The HTC Vives were connected to two separate Virtual Reality-ready desktops at opposite ends of each room to maximise distance and prevent any noise from carrying through the walls.

VR Core Module - The Display

Two HTC Vive HMDs were used to capture the head position and rotation of participants. The HTC Vive Virtual Reality headset features a per-eye resolution of 1080 x 1200 pixels, totalling 2160 x 1200 pixels combined. It offers an estimated horizontal field of view (FOV) of 108 degrees. Additionally, position and rotation tracking data from the VIVE controllers were utilised to control the arm movements of the Avatar, allowing for 6DOF. This was captured by the SteamVR SDK with the OpenVR library. OpenVR is an API developed by Valve that provides an abstraction layer for interfacing with VR hardware in Unity3D. SteamVR is the runtime and ecosystem built on top of OpenVR. It provides the software and tools required to run and manage VR experiences on Steam-compatible hardware such as the HTC Vive.

VR Core Module - The Avatar

The *Self-Avatar* used (MORPH3D) was downloaded from the Unity Asset Store. Using high-fidelity models has been seen to provoke more acceptance, especially if they are perceived as attractive (Latoschik et al., 2017). These models were given small face masks to limit this effect, as well as hide the (static) mouth from view. Avatars were also given Vive Controllers identical to the Just Controller condition, as research shows virtual hand representations can significantly influence users' perception of action possibilities in VR. Notably, simpler, non-graspable hand models led to quicker action planning (Joy et al., 2022). Full-body *Self-Avatars* were edited to remove the head when in an embodied condition, as we could not cull the mesh to hide the back of the facial rendering from the XR-rig camera. Consequently, we avoided the use of Mirrors in this experiment.

User Input Module

Inverse kinematics (IK) was utilised to simulate realistic body movement and was implemented through the InstantVR plugin. This plugin facilitated the seamless integration of a full-body Morph3D Avatar and was fully compatible with tracking systems such as SteamVR. Tracking data for the head and hands was captured using the Camera Rig provided by the SteamVR plugin, ensuring an accurate representation of upper body movements in the virtual environment. As the experience was designed to be seated, leg movement was intentionally disabled to maintain focus on the seated posture and avoid unnecessary complexity in the IK setup. The combination of InstantVR and SteamVR provided an efficient framework for full-body Avatar representation, enhancing the immersive quality of the experience.

Networking

The networking functionality for the multiplayer game was implemented using Photon Unity Networking (PUN), a robust and widely used framework for developing real-time networked applications in Unity. PUN provides seamless integration with Unity, enabling synchronisation of game objects, real-time communication, and server management. The framework's core component, PhotonView, was utilised to synchronise object states, such as player positions and in-game interactions, across the two clients (MasterClient and Client). Remote Procedure Calls (RPCs) were employed to handle event-driven actions, ensuring consistent gameplay mechanics. Additionally, Photon's cloud-based infrastructure eliminated the need for custom server development, offering a reliable backend to manage player connections and game sessions.

Technical Contribution

My contribution to the project was creating the collaborative VR Game that the participants played. This included creating scripts to manage the game foundations (i.e. timer, start and end clause) and swapping the models for each round by creating a button participants can press to enable and disable the right game state.

Though the main setup of the server was outsourced, to support the implementation of networking, I utilised and customised the Photon Unity Networking (PUN) framework to enable online multiplayer functionality, which was one of the most complex and critical aspects of the project. PUN provided the backbone for real-time communication and synchronisation between clients, utilising its core PhotonView component to manage networked objects. Each object requiring movement or interaction, such as blocks, needed to be updated consistently across all connected clients to ensure the MasterClient and additional players observed the same scene layout. This involved maintaining synchronisation of the object's orientation, state, and ownership. PUN offers native support for state synchronisation using components like PhotonTransformView and PhotonAnimatorView, which streamline the process of synchronising object properties like position and rotation. However, additional functionality was required to enable dynamic interactions, which I achieved by implementing Remote Procedure Calls (RPCs). RPCs allowed for efficient communication between clients, enabling method calls on networked objects to handle events such as state changes, interactions, and gameplay triggers.

During development, a significant challenge emerged when two participants attempted to interact with the same block simultaneously. This scenario created conflicts in the ownership protocol, as PUN's real-time synchronisation struggled to determine control per frame, resulting in jittery and erratic block movements due to physics inconsistencies. To resolve this issue, I implemented a robust solution by modifying the ownership transfer mechanism. When ownership of a block was transferred to a new client, I used PUN's ownership transfer methods to ensure proper reassignment and temporarily put the block's Rigidbody (which enables and controls the physics simulation on an object) into a sleep state for at least one frame. This prevented conflicting physics calculations during the transition, effectively eliminating jitter and ensuring smoother gameplay interactions. By leveraging PUN's native capabilities

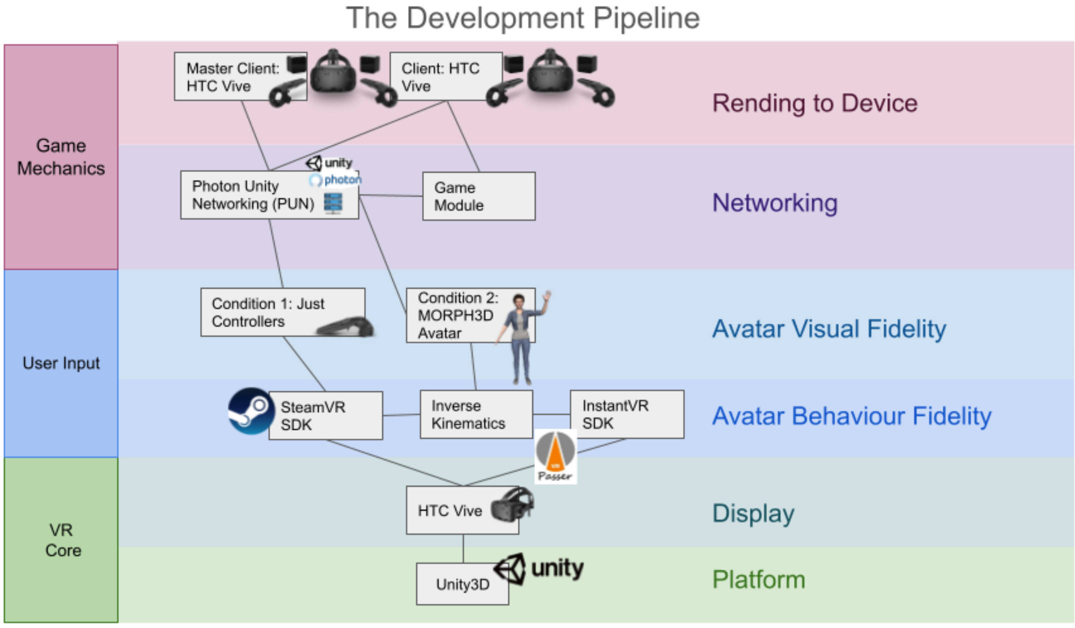


Figure 4.3: The figure shows the technical pipeline of the project.

and extending them with custom solutions, I was able to create a responsive and consistent multiplayer experience while addressing complex real-time synchronisation challenges. A full diagram of the technical pipeline is shown in Figure 4.3.

4.4 Study 1: Collaborative Virtual Environments with a Confederate

In this study, we looked at the effect of two factors on Collaborative Virtual Environments: the *Self-Representation* of a *Self-Avatar* and the *Consistency* of representation between players. The participant was asked to play a collaborative game in Virtual Reality with a confederate, followed by a trust exercise, before completing a questionnaire. Our goal was to investigate how different configurations of *Self-Avatar* representations between multiple users impact social interaction. Our hypothesis for Study 1 is as follows:

H1 Participants in consistent conditions (C1 & C3, see Table 4.1) will have a higher level of *Place Illusion*, *Plausibility*, and *Co-Presence*. As is consistent in previous literature (Pan and Steed, 2017).

H2 Participants in consistent conditions will feel more trust towards the confederate, reflected in both their subjective trust score and offering a higher amount of money in the trust game, and will, in turn, report more positive feelings towards the confederate (measured by *Liked*).

H3a Participants in consistent conditions will perform faster in the collaborative game. **H3b** Those in conditions where they both have a *Self-Avatar* (C1) will have the fastest times.

H4a Participants with a *Self-Avatar* (C1 & C2) will report higher levels of *Place Illusion*, *Plausibility*, and *Co-Presence*, **H4b** as well as a higher level of trust and more positive feelings towards the confederate.

There is evidence to suggest embodying a *Self-Avatar* has a positive impact on subjective experiences such as *Presence* (Skarbez et al., 2017); however, we propose that even when participants do not have a *Self-Avatar* - but are in a consistent condition - they will feel higher *Presence* than in inconsistent conditions. Previous research by Slater has been done on aspects which can prevent or interrupt the flow of *Presence* (Slater and Steed, 2000). It could be that inconsistency in Avatar representation between pairs could act as a 'break in *Presence*', causing both the loss in plausibility and the feeling of being present in the virtual environment. If Avatar realism is believed to be a balance of visuals and behaviour (Oh et al., 2018), then if there is a mismatch of expectation on both sides, this may create a negative impact. We know from previous studies that there may be a correlation between how much a person is liked and trusted (Feng et al., 2004). We also know that successful non-verbal communication is positively impacted by the use of gestures as it helps to reduce cognitive load and makes conceptualising ideas easier (Steed et al., 2016). However, it may be that consistent Avatar representation allows for mutually shared social cues which can be grasped and understood more quickly, therefore impacting play faster. In both conditions, the controller is available to suggest hand orientation. Following on from H3 we can further argue that with better communication established, participants may be able to act more efficiently. Research has shown that the *Self-Avatar* can positively impact the experience of interacting with the virtual world (Steed et al., 1999; Kilteni et al., 2013), so we anticipate that, regardless of condition, the *Self-Avatar* will have a stronger effect overall on trust.

4.4.1 Experimental Design

Sample

A total of seventeen participants were recruited for this experiment from George Mason University in North Virginia. Among them were six females and eleven males, with a mean age 27±6.4. All participants were unacquainted with the confederate before the study and never interacted with each other except via their particular experimental condition. Participants were not allowed to exchange social information either before or during the game. This study was approved by the ethics board of George Mason University.

Methodology

As shown in Figure 4.1 and Table 4.1, the experiment had a between-subject 2 x 2 factorial design with each participant taking part in only one of the four conditions. The two factors are *Self-Representation* (*Self-Avatar/Just Controllers*) and *Consistency* (*Consistent/Inconsistent*). Participants either had high fidelity, gender-matched *Self-Avatar* holding controllers or *Just Controllers* without a *Self-Avatar*. The confederate they interacted with either had the same consistent setting or an inconsistent one. We did not manipulate the perceived representation and kept it consistent across conditions for both studies (i.e., if user A perceived themselves to have a *Self-Avatar*, user B also perceived A to have a *Self-Avatar* and vice versa). In the following, we refer to having a *Self-Avatar* as AV, and just-controllers as JC.

Self-representation	Consistent	Inconsistent
Avatar	**C1**: Self - AV; Other - AV	**C2**: Self - AV; Other - JC
Just controllers	**C3**: Self - JC; Other - JC	**C4**: Self - JC; Other - AV

Table 4.1: The four conditions. AV stands for Avatar, JC for Just Controllers.

Collaborative Game

Using the collaborative framework provided by Unity3D we created a short gaming experience for the experiment. The game, 'Build the Block' was designed to be simple and enjoyable, with a timer included to add an element of game challenge. The participant would appear seated at a table with a confederate and be shown a series of sequences, which they would have to imitate with the blocks provided to them on the table. There were ten possible models to replicate, but we were only concerned with the first three sequences for data collection. This is because not all groups could finish within the time limit, but they had enough time to manage at least three sets and experienced a range of difficulties. The players could pick up and place the blocks in stacks using the Vive controller, where they would either see a virtual body with controllers or just a pair of controllers in the environment, depending on the conditions. According to Game Theory (Myerson, 1992), interactive tasks are where one player's action directly influences the others. The mechanics of the game encouraged the participants to verbally and physically collaborate with each other in order to make progress. With this setup, we hoped to highlight the effect of having consistent and inconsistent Avatar representations between pairs whilst playing a collaborative game. This game was pilot-tested in real life using Jenga blocks with two participants. They were asked to play with a confederate and then filled out a questionnaire on gamer experience (IJsselsteijn et al., 2013) , and their feelings towards the other player, including questions such as: *I thought it was fun*, *I thought it was hard*, and *I was good at it*. These were rated on a Likert scale from 1 to 5, 5 being fully agreed. The results were used to validate the choice of game and its design. Overall, they found the game enjoyable and engaging, but not really challenging. In response, we made the block models slightly more complex and grow in complexity as they are completed. Based on existing literature (Pan and Steed, 2017), we hypothesise that in consistent conditions (conditions 1 & 3), participants will be faster when both players have a *Self-Avatar*. Times for completion will be collected from the three sequences and analysed using a Two-Way ANOVA.

The Investment Game

The experiment had two phases. The participants were first asked to complete a game of Build The Block with a confederate. They had to work together to lift the cubes and stack them on top of each other, mimicking the sequence shown to them. The participant, depending on the condition, would have a different immersion setup, which was either consistent or inconsistent with the confederate player.

To analyze the level of trust the participant feels towards the confederate, once the player finishes the game, they will take part in an exercise called 'The Investment Game.'

The participant is rewarded with 100 points. They will be offered a chance to share some, all or nothing of this amount with the confederate. Every time points are sent to another player, it is doubled by the experimenter. The confederate will then be given the same option. The amount the participant gives will be recorded. The goal was to get as many points as possible; however, there was no real-world gain related to this exercise, which we acknowledge as a potential limitation.

Example:

1. A decides to share 20 of the 100 points with B. (A= 80, B= 20)
2. This is doubled and given to B. (A= 80, B= 40)
3. B can then send back an amount of their points to A. B sends 20. (A= 80, B= 20)
4. This is doubled and given to A. (A= 120, B= 20)

In this scenario, B can also choose to keep all the points given, e.g. (A= 80, B= 40). This exercise tests the amount of trust A has in B. This was developed based on the Investment Game in Hale's study (Hale, 2017) and Glaeser's Trust Game (Glaeser et al., 2000). There was only one turn to share and potentially increase the initial amount of participants. We observed the number of participants who decided to share with the other player, as a representative of the amount of trust they felt towards them. The more money given, the more the participant 'trusts' that the other will reciprocate so that they both benefit.

Procedure

First, participants were given a brief and asked to sign a consent form and a short questionnaire to collect demographic information. Participants were then informed that they would take part in a game in which they would have to stack blocks according to the sequence shown to them for an undetermined period of time while seated. Once finished, they would take part in the investment game. After completing the game, participants were asked to fill out a questionnaire survey which gathered subjective data on their experience. At the end of the experiment, participants were paid for their time and debriefed (if desired). The whole process took approximately 30 minutes.

4.4.2 Measurements & Data Analysis

The level of trust was measured with both Questionnaire data (*Subjective Trust*) and behaviour data (*Trust Money*) collected in 'The Investment Game,' as described in section 4.4.1. We also measured the extent to which participants *Liked* the other person (in this case, always the confederate) with a questionnaire (Pan et al., 2015). We also collected participants' performance data in the Collaborative Game in VR (three sets) and other related questionnaire data (*Place Illusion*, *Plausibility* (Slater, 2009) and *Co-Presence* (Bailenson et al., 2005a)). All data analysis was performed with IBM SPSS Statistics version 23 (see Appendix B).

We first conducted a two-way ANOVA test regardless of the normality of data distribution because ANOVAs are considered to be fairly 'robust' to deviations from normality (see (Maxwell et al., 2004) for a review), although no specific research has been conducted into the two-way ANOVA. In the instances where there has been a significant difference found in the data, which were not normally distributed, we also ran a non-parametric test (Mann-Whitney U) for further analysis to validate the result.

4.4.3 Results - Behavioural

Investment Money

A two-way ANOVA was conducted on the *Investment Money* given, with the two between-group factors (*Consistency* and *Self-Representation*). There was no statistically significant effect for *Self-Representation*, ($F(1, 13) = 0.97, p = .343, \eta^2 = 0.07$), nor for *Consistency* ($F(1, 13) = 0.61, p = .45, \eta^2 = 0.05$). However, there was a significant **interaction effect** ($F(1, 13) = 9.22, p = .01, \eta^2 = 0.42$), suggesting a 'Confederate Avatar Effect': when the confederate did *not* have a *Self-Avatar*, more money was shared by the participant, indicating higher levels of trust (confederate with a *Self-Avatar* mean and standard error: 50.4 ± 8.8; confederate without a *Self-Avatar*: 86.3 ± 8.1).

The Shapiro-Wilk's test revealed that *Investment Money* was not normally distributed ($p = .001$). To verify the results from ANOVA, we ran a two-tail Mann-Whitney U test on *Investment Money* between participants who interacted with a confederate with a *Self-Avatar* and with those without. The result remained significant ($U = 12.5, p = .027$), confirming our findings from the ANOVA analysis.

Mean Game Time

A two-way ANOVA was conducted on *Mean Game Time* from collected timestamps from each of the 3 rounds played. There was no significant difference found in *Consistency*, ($F(1, 13) = 0.00, p = .982, \eta^2 = 0.00$) and *Self-Representation*, ($F(1, 13) = 0.37, p = .556, \eta^2 = 0.03$). There was also no significance found for (*Consistency* $\times$*Self-Representation*), (F(1, 13) = 0.40, p = .536, $\eta^2 = 0.03$). We also tested the game time of the three sets separately, and again, no effect was found. We have also performed tests for each round, and no significant results were found.

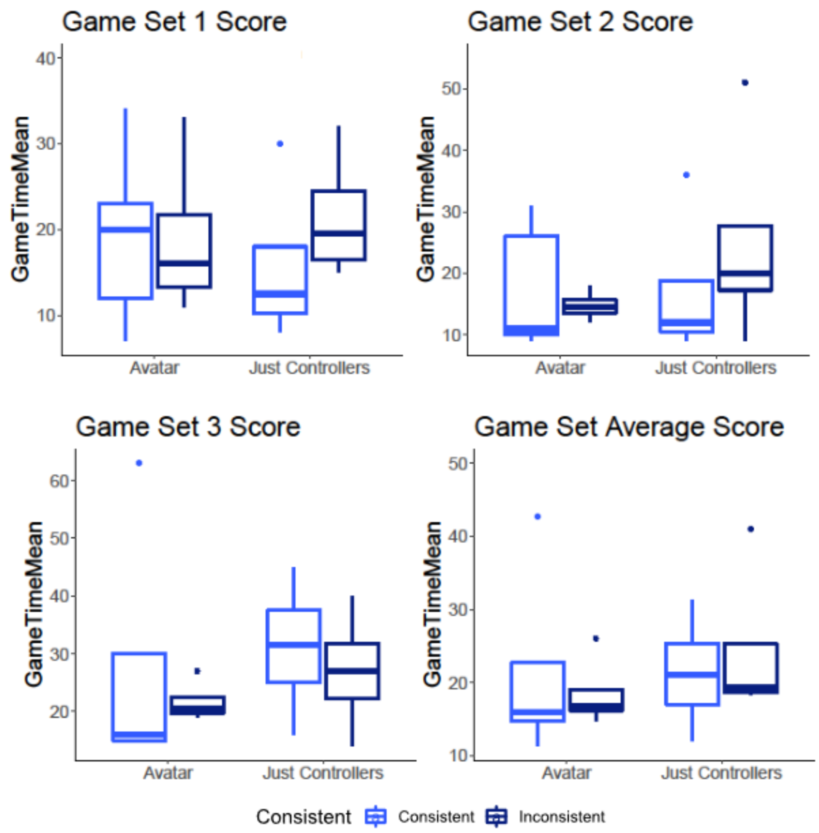


Figure 4.4: Boxplot of 'Build the Block' Mean Game Time Results

4.4.4 Results - Questionnaire

Subjective Trust

A two-way ANOVA was conducted on *Subjective Trust* with the factors (*Consistency* and *Self-Representation*). No statistically significant difference was found for *Consistency* ($F(1, 13) = 1.3, p = .27, \eta^2 = 0.09$). However, for *Self-representation*, there is some evidence indicating a ' *Self-Avatar*' effect ($F(1, 13) = 4.4, p = .056, \eta^2 = 0.25$), indicating that participants who had a *Self-Avatar* were more likely to give a higher rating on trust to the confederate. This is inline with **H4b**. There is also some evidence suggesting an interaction effect, indicating that the confederate gained more trust when without a *Self-Avatar* ($F(1, 13) = 1.2, p = .07, \eta^2 = 0.23$). Although not significant, these results are inline with our behavioural results from *Investment Money*.

A Shapiro-Wilk's test reveals that data was not normally distributed ($p = .001$). We ran a Mann-Whitney U test on *Subjective Trust* to see if there was a difference in score between participants with a *Self-Avatar* (AV) and without (JC). Though there was a higher *Subjective Trust* scores for AV ($meanrank = 10.78$) than JC ($meanrank = 7.00$), they were not statistically significantly different ($U = 20, p = .139$).

Liked

A two-way ANOVA was conducted on *Liked* from the questionnaires, with the factors (*Consistency* and *Self-Representation*). There was no statistically significant main effect of *Consistency* ($F(1, 13) = 0.3, p = .579, \eta^2 = 0.02$). However, there was a statistically significant main effect of ***Self-Representation***

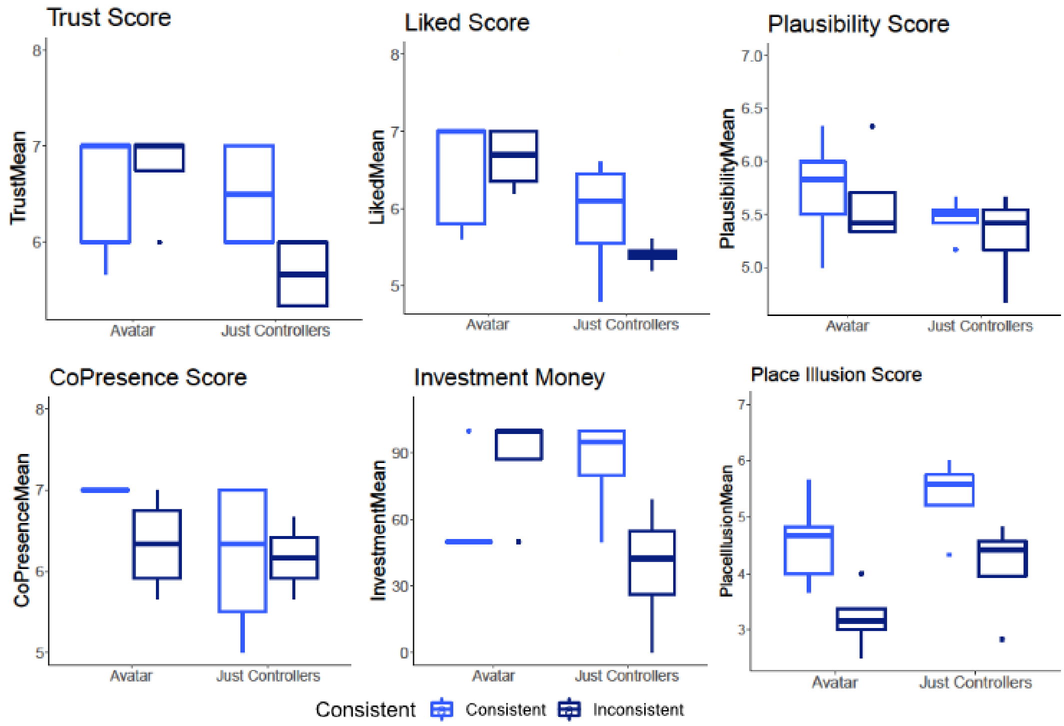


Figure 4.5: Boxplots of the Social Presence questionnaire components and Investment Game

$(F(1,13) = 1.0, p = .008, \eta^2 = 0.43)$. There was no interaction effect $(F(1,13) = 1.3, p = .269, \eta^2 = 0.09)$. Data was normally distributed as assessed by Shapiro-Wilk's test $(p > 0.5)$.

The significant *Self-Representation* effect revealed here indicates that participants with a *Self-Avatar* (AV) were more likely than JC to give more positive marks to the confederate (AV: 6.6±0.2; JC: 5.7±0.2), regardless of the confederate having a *Self-Avatar* or not. This is inline with findings on *Subjective Trust* presented in section 4.4.4, and inline with **H4b**.

Place Illusion

A two-way ANOVA was conducted on *Place Illusion* from the questionnaires, with factors *Consistency* and *Self-Representation*. We found a significant difference in both ***Consistency*** $(F(1,13) = 5.0, p = .004, \eta^2 = 0.27)$, and ***Self-Representation***, $(F(1,13) = 11.83, p = .036, \eta^2 = 0.48)$. No interaction effect was found $(F(1,13) = 0.07, p = .886, \eta^2 = 0.005)$. Data was normally distributed, as assessed by Shapiro-Wilk's test $(p > .05)$.

As shown on the Boxplot (see Figure 4.5), participants in the consistent condition reported a higher level of *Presence* (consistent: 5.0 ± 0.3; inconsistent: 3.7 ± 0.3), supporting **H1**. However, contrary to **H4a**, participants without a *Self-Avatar* (JC) seem to have reported a higher level of *Place Illusion* than AV (AV: 3.9 ± 0.3; JC: 4.8 ± 0.3).

Plausibility

A two-way ANOVA was conducted on *Plausibility* with *Consistency* and *Self-Representation*. No statistically significant was found for *Consistency* $(F(1,13) = 0.43, p = .525, \eta^2 = 0.32)$ or *Self-Representation* $(F(1,13) = 2.09, p = .17, \eta^2 = 0.14)$. Neither was there an interaction effect $(F(1,13) = 0.19, p = .892, \eta^2 = 0.001)$.

Co-Presence

A two-way ANOVA was conducted on *Co-Presence* with *Consistency* and *Self-Representation.* No significant effect was found for *Consistency* ($F(1, 13) = 0.274, p = .09, \eta^2 = 0.91$), or *Self-Representation* ($F(1, 13) = 2.93, p = .111, \eta^2 = 0.18$). Neither was there an interaction effect ($F(1, 13) = 1.30, p = .274, \eta^2 = 0.91$).

4.4.5 Discussion

The results from the questionnaire revealed a significant difference in mean Liked score when participants had AV than when they had JC, regardless of the condition of the confederate. Though not significant, this pattern is almost mirrored in the results for the mean *Subjective Trust* score. Both these results suggest support for **H4b**. This could be due to the fact that the participants were able to express themselves through non-verbal cues, such as gesturing or looking at the confederate. This could have resulted in the confederate being able to better coordinate with the participants and provide appropriate verbal and non-verbal feedback. There are many studies demonstrating the importance and effect of gesturing, an example being that the mimicry of gestures and body language could be an indicator of trust (Verberne et al., 2013). Another recent discovery is the potential ability to reduce cognitive load whilst completing a task (Steed et al., 2016). An alternative reasoning is that the confederate was perhaps able to respond to the participant's gaze - suggested by the movement and rotation of the *Self-Avatar's* head in a more appropriate way. There have been many investigations on the positive impact of eye gaze on Avatar-mediated communication (Garau et al., 2001).

There was a significant interaction effect between the factors *Consistency* x *Self-Representation* on *Investment Money.* When we observe the mean data from the Investment Game, we can see that overall, more money was shared by the participant when the confederate did not have a *Self-Avatar*, suggesting that when the confederate had JC, they were better at gaining trust. The 3D models utilised in the experiment were from the high-fidelity Morph3D package from the Unity asset store. Using high-fidelity models has been seen to provoke more acceptance, especially if they are considered 'attractive' (Latoschik et al., 2017). These models were given small face masks to moderate this effect as well as hide the non-animated mouth from view, which may have hindered trust. It could be seen from the Boxplot (Figure 4.5), in the condition where both participant and confederate have a *Self-Avatar* (C1), that there are high subjective feelings of trust. We observed that less trust is felt when the participant does not have a *Self-Avatar*, and the confederate does (C4), in line with research which supports that inconsistency in Avatar representation causes mistrust. It could also be argued that this is due to the confederate. In the setup of the study, the confederate is instructed to play a game with each participant whilst pretending they are playing it for the first time. There is research to suggest that when a confederate is being deceitful, this may provoke the participant to act differently and that 'suspicious' confederate behaviour may be more likely to compromise results (Martin, 1970a). In this case, this effect may have been heightened due to the confederate having a *Self-Avatar.* It could be that the deception overrode the impact of consistency. There is also research which suggests there is a risk of using confederates who are too familiar with the task (Kuhlen and Brennan, 2013a).

Participants with a *Self-Avatar* reported feeling higher levels of *Plausibility*, *Co-Presence* but surprisingly not *Place Illusion* - not fully accepting **H4**. However, as we believed, there were high scores across all three components, with those who were inconsistent conditions supporting **H1**. This is unexpected as previous studies have shown that a *Self-Avatar* can positively impact *Place Illusion.* This could perhaps be explained by the potential cognitive load on participants or an effect of the technical setup of the Avatar representation.

These findings support the importance of research in exploring the impacts of a *Self-Avatar* but also bring our attention to the use of a confederate and the nature of their representation. In the next study, we will continue this investigation with a larger sample in the UK. We will negate the effect of the confederate by using a dyad approach and solidify our understanding of the impact of Consistency in *Self-Representation* on trust.

4.5 Study 2: CVE with paired participants

Following the completion of Study 1, we ran a main study with improvements to the testbed and experimental design. We hoped to both validate our initial findings and expand on the results by using paired participants. The rest of the changes we included are listed as follows:

1. We set up a collaborative game in Virtual Reality where participants would be run in pairs instead of using a confederate, giving us more data and removing the potential for confederate bias.
2. We removed the masks from the full-body Avatars.
3. We used the DayTrader game as a means to objectively investigate trust and ran this exercise three times during the session. The repetition gives more insight into the changes in trust through the experience, improving our initial trust exercise process.

In each condition, the players will either have a high fidelity, gender-matched *Self-Avatar* who will be holding controllers or *Just Controller* without a *Self-Avatar*. This will also be consistent or inconsistent between-subjects 2 x 2 factorial design. This experiment aimed to continue investigating the impact of *Self-Representation* in paired consistent and inconsistent collaborative conditions. The hypothesis for this study is as follows:

H1 Paired participants in consistent conditions will feel more trust towards each other.

H2 Participants with a *Self-Avatar* in inconsistent conditions will feel less trust.

H3 Those in consistent conditions will invest more in the DayTrader game than those in inconsistent conditions.

Though similar to those in Study 1, we wished to evaluate how the findings in Study 2 will differ with the use of paired participants.

4.5.1 Experimental Design

A total of eighteen participants took part in this experiment. All participants were recruited from Goldsmiths College, University of London. Among them were nine females and nine males. Ages ranged from 18-34 (M = 25.18, SD = 6.43). All pairs were unacquainted with each other before the study and never interacted with each other except via their particular experimental condition. Participants were not allowed to exchange social information either before or during the game.

Similar to Study 1, this experiment was a between participants 2 x 2 Factorial design with the same factors (see Table 4.1). However, this time, instead of a confederate, each participant was paired with another participant. Another difference from Study 1 is that we replaced the Investment Game with the DayTrader game, following the 2017 study conducted by Pan & Steed (Pan and Steed, 2017), which also used paired participants. This is because we wished to follow the method setup in Pan's work (Pan and Steed, 2017) in which this study attempts to build.

DayTrader game

The DayTrader game is a social dilemma task in which the short-term interests of individuals conflict with the long-term interests or goals of the group. We chose this social dilemma scenario because it provides measures of trust that have been tested for reliability and validity. The use of the DayTrader game was inspired by previous work (D.Johnson and A.Mislin, 2007) (Rae et al., 2013) and used in a recent study (Pan and Steed, 2017). We decided to change the investment game from Study 1 to roughly follow the experimental design of this previous research in order to extend the findings of Pan's work. The three-stage method allowed us to see the changes in trust over time. This meant we had a baseline of trust established before VR as well as trust established after VR making it a much more robust measure.

The game involved three sets of five rounds. For each set of the DayTrader game, each participant was given 30 credits that they could either keep or put into a pool that was shared between the two participants. At the end of the round, the credits that they chose to keep doubled in value, while the credits in the shared pool tripled and were then split evenly between the two participants. At the end of each set of five rounds, the participant that earned the most credits in that set of 5, received a 300 credits bonus. This bonus had the effect of giving an extra profit to the participant who contributed less than his or her partner. If both participants earned the same amount, they both received the bonus. Each participant is only told their new amount at the end of a round. They are not allowed to ask the other participants amount or be given any means to work out the math. Game Example:

1. A gives 20 of the 30 points to the shared pool. B gives 10. Shared pool total is now 30. (A= 10, B= 20)
2. Kept money is doubled. (A = 20, B = 40)
3. Shared pool amount is tripled and shared between A and B. (30 x 3 /2 , A= 20 + 45, B= 40 + 45)
4. New amounts for round 2 are A = 65, B = 85.

In this scenario, ''B can also choose to keep all the points given and get more. However, both will gain more by giving all equally. This exercise tests the amount of trust 'A' has in 'B' and vice versa. Similar to (Pan and Steed, 2017), each pair of participants would play this game three times (3 sets), as detailed in section 4.5.1 Procedure.

Procedure

Two researchers led participants into different rooms. One 5 minutes before the other. They were briefed and asked to sign a consent form and fill out a short questionnaire to collect demographic information. Once complete, they were both given a sheet of paper explaining the rules of the DayTrader game. After confirming both participants understood the rules, the participants played 5 rounds of the DayTrader game with each other over voice-only communication, with each researcher recording the progress and results.

Participants were then given a sheet of paper explaining the 'Build the Block' game, and after confirming they understood the rules, they were helped into the VR setup. They were given the opportunity to learn how to play the game with a 'demo round'. In this demonstration round, participants were asked to build a pre-existing shape completely alone (i.e. the other participant was not present during this time) - this demo round was not timed or included in the analysis. Participants could not continue until they demonstrated an understanding of how to use the Vive controllers to pick up blocks, and how to use the Vive controllers to progress levels (change sequences) as part of the demo round completion. Following this, the researchers prepared to run the main task. The participants were once again reminded of the instructions before they began. They were encouraged to speak to one another and strategize on how they would complete the task efficiently over the voice communication setup, as well as utilising the VR environment. They had 10 minutes to complete 10 levels of 'Block Build'. Participants completed the task in either of the four conditions while remaining seated for its entirety. During this time, participants' performance outside of VR was also recorded on video. Once finished, participants were asked to fill out a questionnaire survey which gathered subjective data on their level of *Presence*, *Subjective Trust* and interaction towards each other when playing. Participants were then asked to play 5 rounds of the DayTrader game once again. After this second DayTrader game, participants were given the opportunity to communicate over voice for 30 seconds in order to develop a strategy to play the final round. After a consensus was reached, or time ran out, participants then played a final 5 rounds of the DayTrader game for the last time. When evaluating the DayTrader exercise, it was our intent that the first set gives a baseline of trust, the second set establishes trust based on the VR encounter, and the third set validates this trust built in the second set.

At the end of the experiment, participants took part in a semi-structured interview with the researchers, were paid for their time and were debriefed, if desired. The HTC Vive headsets were wiped with a cleaning cloth, and other touched equipment was touched with an antibacterial wipe after each participant. This session took roughly 45 minutes.

4.5.2 Measurements & Data Analysis

All measures and data analysis follow the same as Study 1, other than 'The DayTrader game' (described in section 4.5.1) instead of the previous Investment Game.

4.5.3 Results - Behavioural data

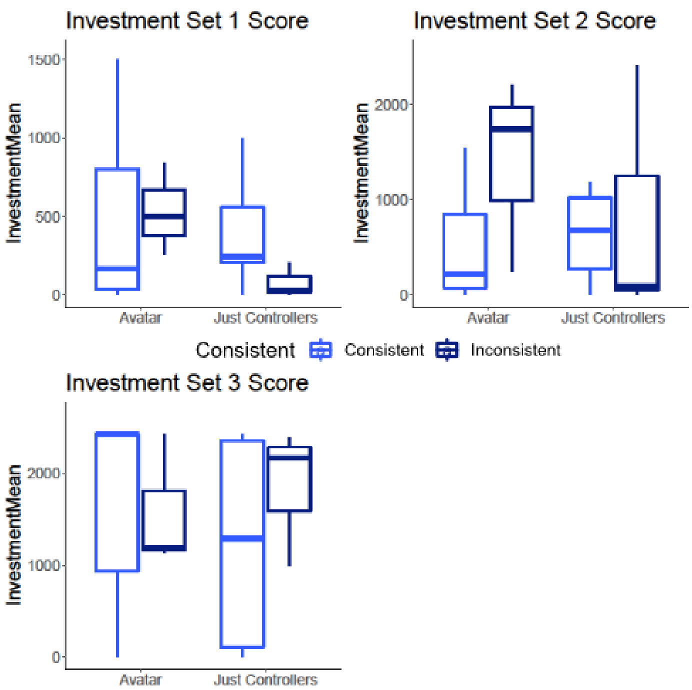


Figure 4.6: Boxplots of Sets of DayTrader game Investments

DayTrader game Results: Investment Money

Here, we only used the final round (round 5) from each of the 3 sets to look at participants' level of trust: before the experiment (Set 1), after VR (Set 2), and finally after the phone call discussion (Set 3) as seen in Figure 4.6. A two-way ANOVA was conducted on the *Investment Money* for each set, with *Consistency* x *Self-Representation* as between-subjects factors.

For Set 1, no effect was found for *Self-Representation* ($F(1, 14) = 1.404, p = .256, \eta^2 = 0.091$), or *Consistent*, ($F(1, 14) = 0.32, p = .582, \eta^2 = 0.02$), and no interaction effect was found ($F(1, 14) = 0.67, p = .426, \eta^2 = .05.$). As expected, before the VR collaboration game interaction, there were no significant differences among the four conditions, with respect to trust between participants.

However, contrary to our hypothesis, for Set 2, no effect was found for *Self-Representation*, ($F(1, 14) = .3, p = .595, \eta^2 = .021$) or *Consistent* ($F(1, 14) = 1.82, p = .198, \eta^2 = .12$), and no interaction effect was found ($F(1, 14) = 0.73, p = .406, \eta^2 = .05$).

Similarly, set 3 reveals no effect *Self-Representation*, ($F(1, 14) = .03, p = .66, \eta^2 = .01$), *Consistent*, ($F(1, 14) = .23, p = .642, \eta^2 = .02$), or an interaction effect, ($F(1, 14) = .45, p = .513, \eta^2 = .03$).

Mean Game Time Results

There were three sets assessed from the collaborative 'Build the Block game'. Set 1, Set 2 and Set 3 as seen in Figure 4.4. A two-way ANOVA was performed for each set on *Mean Game Time* with *Consistency* x *Self-Representation* as between-subjects factors.

For Set 1 we found no interaction effect ($F(1, 14) = 0.026, p = .874, \eta^2 = 0.002$), and no effect for *Self-Representation* ($F(1, 14) = 0.026, p = .874, \eta^2 = 0.002$). However, there was a statistically significant effect on ***Consistency***, ($F(1, 14) = 6.21, p = .028, \eta^2 = 0.341$), suggesting that participants in the inconsistent conditions were able to complete their task faster (inconsistent: 39.0 ± 8.1, consistent: 64.7 ± 6.4). Data was normally distributed as assessed by Shapiro-Wilk's test ($p < .05$).

Similarly, for Set 2, there was no interaction effect ($F(1, 14) = 0.31, p = 0.863, \eta^2 = 0.01$), and no effect on *Self-Representation* ($F(1, 14) = 0.31, p = 0.863, \eta^2 = 0.01$). However, there was an effect on ***Consistency*** ($F(1, 14) = 12.16, p = 0.004, \eta^2 = 0.47$), but this time participants in the inconsistent conditions were slower (inconsistent: 77.0±10.9, consistent: 30.7±7.7). Data was not normally distributed as assessed by Shapiro-Wilk's test ($p < .05$). A Mann-Whitney U test on *Consistency* confirmed our finding ($U = 4, p = .003$, using an exact sampling distribution for U).

No interaction effect was found for Set 3 (*Self-Representation* × *Consistency*: $F(1, 14) = 0.48, p = .83, \eta^2 = 0.01$; *Self-Representation*: ($F(1, 14) = 0.48, p = 0.83, \eta^2 = 0.01$; *Consistency*: $F(1, 14) = 0.91, p = 0.355, \eta^2 = 0.06$).

From Figure 4.7 we can see that significant results of *Consistent* for Set 1 indicated that in consistent conditions, participants took longer to complete the set. This effect however reverted in Set 2 where participants performed faster in consistent conditions, before finally vanishing in Set 3.

We also tested the game time average, and again, no significant difference was found.

4.5.4 Results - Questionnaire

Subjective Trust

A two-way ANOVA was conducted on *Subjective Trust* with factors *Consistency* and *Self-Representation*. No interaction effect was found ($F(1, 14) = 0.1, p = .761, \eta^2 = .01$), and no effect was found for *Self-Representation* ($F(1, 14) = 0.1, p = .761, \eta^2 = .01$). However, there was an effect of ***Consistency*** ($F(1, 14) = 9.62, p = .008, \eta^2 = .879$). Data was normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$). This indicated that participants in consistent conditions reported a higher level of *Subjective Trust* (consistent: 6.2 ± 0.2, inconsistent: 5.1 ± 0.3), supporting our **H1**.

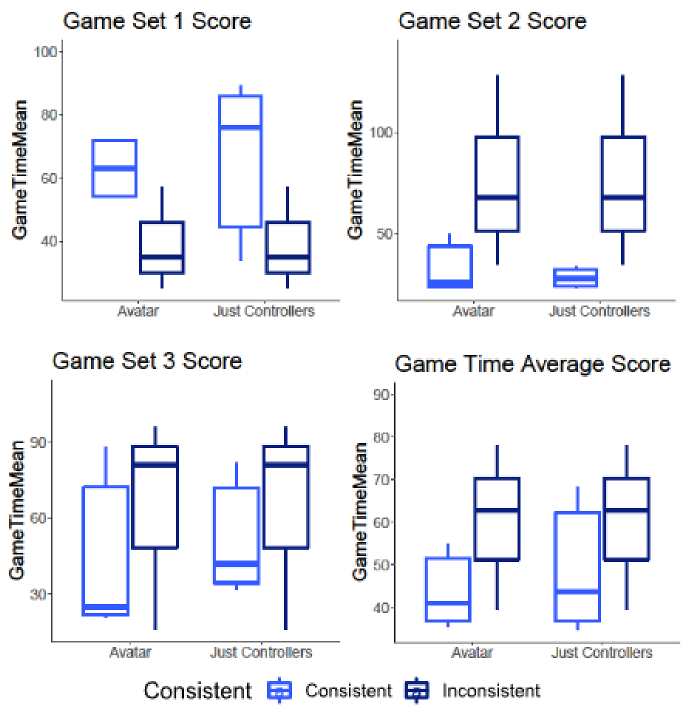


Figure 4.7: Boxplots of 'Build the Block' Mean Game Times

Liked

A two-way ANOVA was conducted on *Liked* with factors (*Consistency* and *Self-Representation*). No statistically significant effect was found for *Consistency*, $(F(1,14) = 0.02, p = .889, \eta^2 = 0.01)$, *Self-Representation*, $(F(1,14) = 0.851, p = .372, \eta^2 = 0.057)$, and *Consistency* × *Self-Representation*, $(F(1,14) = 0.01, p = .944, \eta^2 = 0.01)$.

Place Illusion

A two-way ANOVA was conducted on *Presence* with *Consistency*, and *Self-Representation*. No statistically significant result was found. *Consistency*: $F(1,14) = 0.001, p = .98, \eta^2 = 0.001$, *Self-Representation*: $F(1,14) = 0.001, p = .98, \eta^2 = 0.001$, and *Consistency* × *Self-Representation*: $F(1,14) = 1.13, p = .31, \eta^2 = 0.074$.

Plausibility

A two-way ANOVA was conducted on *Plausibility*. No effect was found for *Self-Representation* $(F(1,14) = 0.01, p = .921, \eta^2 = .01)$ nor *Consistency* $(F(1,14) = 0.83, p = .379, \eta^2 = .06)$. However, there was an interaction effect found between (***Consistency* x *Self-Representation***), $(F(1,14) = 5.4, p = .036, \eta^2 = .28)$. Data was normally distributed, as assessed by Shapiro-Wilk's test $(p > .05)$.

As shown in Figure 4.8, this suggested that participants reported the experience to be more plausible when the person they interacted with was without a *Self-Avatar*.

Co-Presence

A two-way ANOVA was conducted on *Co-Presence* with the two factors. No statistically significant results were found over *Consistency* $(F(1,14) = 0.45, p = .506, \eta^2 = 0.03))$, *Self-Representation* $(F(1,14) =$

$0.01, p = .924, \eta^2 = 0.01$) or *Consistency* × *Self-Representation* ($F(1, 14) = 0.37, p = .301, \eta^2 = 0.08$).

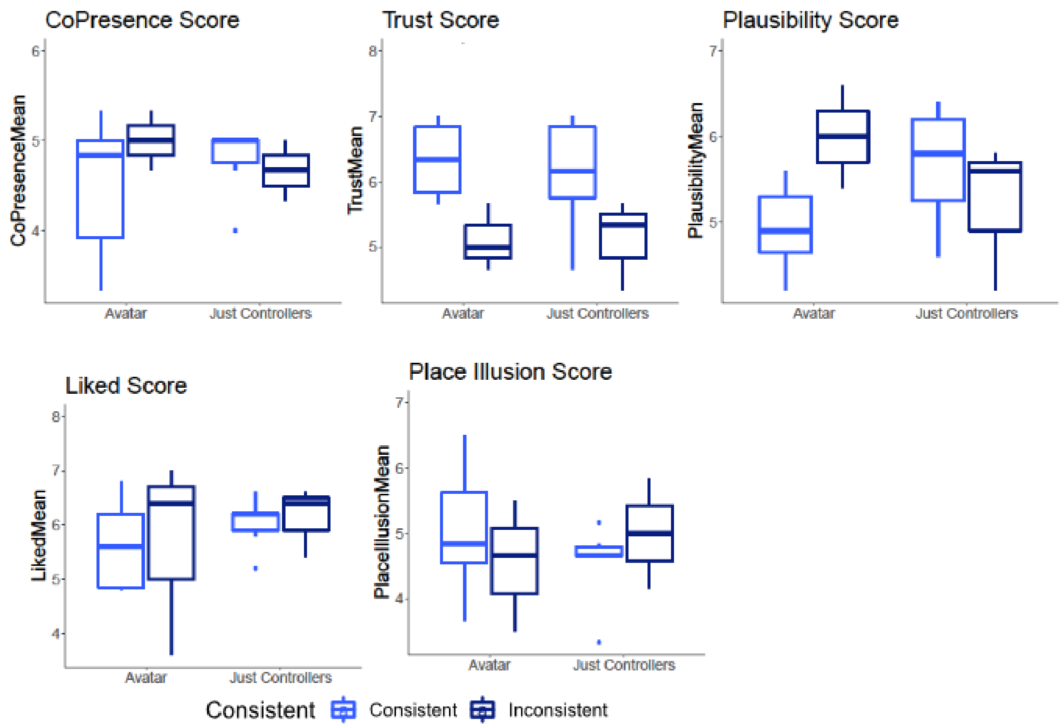


Figure 4.8: Boxplots of Social Presence questionnaire components

4.5.5 Semi-Structured Interview

After the experiment, participants took part in a semi-structured interview to gather some additional feedback about their experience. In this paragraph, we will explore some of the themes that arose through their answers. Responses were recorded by the researchers after the experiment and later coded into recurring themes. The general high-level themes were as follows:

Participants felt that overall, the first DayTrader game did not affect their interaction in VR. Most participants either "did not relate the two experiences." (P11) or felt that they "still didn't know what the person was like." (P13). This is important in validating that the first impression received of the other player was experienced through VR, and whether or not they gained the bonus did not colour their interaction.

Participants felt that the VR session made the player seem more 'real' and gave them an impression of the other player. The participants felt working together on a task made the person seem real. Some felt the "person was a blank slate before but started filling with detail" (P2) as they played. They were able to become "familiar with [their] personality and thinking." (P1).

Participants felt a shift from Competitive to Collaborative when playing the VR Game. Most participants started off with a competitive mentality with a goal to win. It is interesting to note that participants thought of the DayTrader game as a competitive activity as it could explain the variance in the results between conditions. One participant mentioned that their partner was "friendly in the VR version, more collaborative, and a team player. But in the DayTrader game [they] seemed a bit more calculated and logical." (P3). Some participants also suggested that they believed players acted differently or had different strategies in each separate game.

Participants' VR experience had the greater impact overall on their impression of the other person, but the phone call also helped in solidifying their feelings. Participants felt that over "just speaking", having an interaction with the other player helped them foster a sense of collaboration and made the other seem more real. The phone call was "reassurance" for many, in their opinion. "It's hard to say, they both were effective in different ways. The VR gave me an impression of their actions, and then the 30-second phone call was very informative - and then the follow-through on the phone call kinda cemented my opinion of them." (P18).

Below, we summarise the patterns found when we separated the feedback by Condition Group, which gives us more perspective on the impact of the configuration of *Self-Representation* in this experiment.

Participants in the Avatar/Avatar condition felt that the presence of the *Self-Avatar* fostered a stronger sense of connection and trust through both verbal and visual interactions. Having a *Self-Avatar* made the interaction feel more immersive and personal, as participants could see the other person's actions and interpret their behaviours in real-time. "Seeing how they worked helped me trust them more." (P13). However, some participants acknowledged that their focus was still primarily on the task rather than interpersonal dynamics. "I wasn't thinking of them as a person, just the objective." (P5). Overall, we see support for *Co-Visual Consistency*, which enhances collaboration and makes interactions feel more engaging.

Participants in the Avatar/No Avatar condition noted a disparity in their experiences, with those without *Self-Avatar* feeling less engaged and those with *Self-Avatars* relying more on voice and actions to gauge their partner. Non-Avatar participants often described feeling a slight disconnect due to the lack of *Embodiment*. "Used to communicating without a body[in VR], but it felt different and less engaging." (P2). Those with *Self-Avatars* observed that their partner's lack of visual representation made interpreting their behaviour more challenging. "The other person didn't have an Avatar, so I relied more on their voice and actions to understand them." (P13). Despite these challenges, participants still found ways to collaborate effectively.

Participants in the No Avatar/No Avatar condition relied heavily on verbal communication and task-based interactions to build impressions. The absence of *Self-Avatars* made interactions feel less personal at first, but participants highlighted how collaboration during tasks gradually humanised their partner. "The person was a blank slate before, but started filling with detail as we interacted." (P2). The lack of *Embodiment* sometimes made the experience feel more mechanical, yet participants appreciated the equal footing provided by the shared condition. "Not having a representation made me rely more on how they communicated and solved problems." (P16).

Overall, *Self-Representation* influenced participants' VR experience, with *Self-Avatars* fostering quicker connections and trust, while verbal and task-based interactions compensated for the lack of *Embodiment* in non-Avatar conditions.

4.5.6 Discussion

In this study, we observed four conditions of Avatar *Self-Representation* between dyads: AVxAV, AVxJC, JCxJC, JCxAV. Participants were tasked to collaboratively complete a game in Virtual Reality in one of these four conditions, and their sense of trust was assessed both objectively through the DayTrader game and subjectively through the use of questionnaires.

Surprisingly, contrary to our Study 1, we found no significant effects on how much participants were willing to invest cooperatively. This finding does not support **H2**. Hale proposed in her research that there are different kinds of trust that can be measured, and perhaps this method (Investment Game) may not be robust enough to filter all types effectively (Hale, 2017). More research must be done using DayTrader as a valid metric for measuring trust in an Avatar-mediated virtual environment.

Our secondary behavioural measure was the time taken for each of the three sets of the 'Build the Block' game. We can see that in Set 1; it was participants in the inconsistent conditions who were able to finish faster.

One possible explanation relates to Sadagic *et al.*'s work on leadership in Collaborative Virtual Envi-

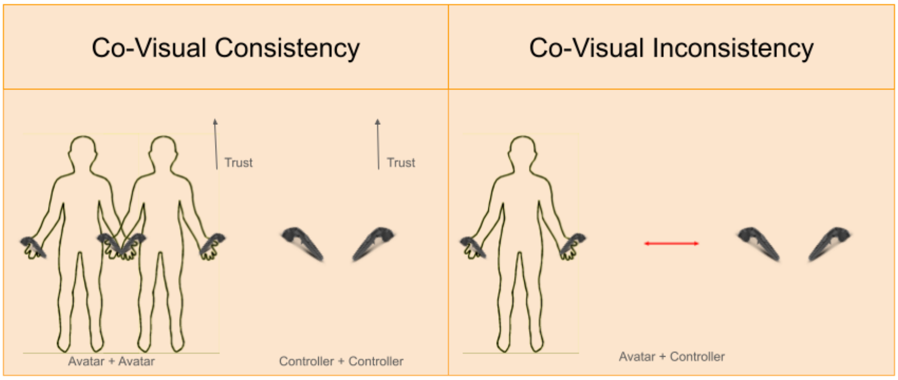


Figure 4.9: The figure shows the summary of the impact of Co-Visual Consistency in configuring the *Self-Avatar* in Social VR.

ronments (Steed et al., 1999). They found that, in inconsistent Collaborative Virtual Environments, the participant in the most immersive condition took a leadership role. It is possible that in our study, the participant with the Avatar naturally took on a leadership role. This would initially simplify the social dynamics in the unfamiliar game condition and enable the participants to work more quickly without the need for implicit negotiation of collaborative roles. On the other hand, consistent participants may put more effort into establishing how to work together. More research would be needed to confirm whether this is the case.

This pattern, however, has been swapped in Set 2, where the participants in consistent conditions were significantly faster to finish their task. It's best to consider that as the rounds increase, so does the complexity of the shapes to recreate. We see here that the initial advantage of inconsistent conditions disappears, and consistent pairs can work faster, presumably because they are able to work together more effectively once a pattern of interaction has been established in the first round.

In Set 3, there was no significant difference between groups on their time. However, we can see from the data (Figure 4.7) that participants in consistent conditions still continued to play faster than those in inconsistent conditions, suggesting that, overall, consistency has a positive effect on productivity in CVE, this could be due to interaction affordances (Joy et al., 2022). A recent study conducted by Mal and colleagues compared the interactions between different *Self-Avatars* (Personalised Realistic or Custom Stylised) and found that groups of virtual entities with higher realism—more closely aligned with participants' real-world experiences and expectations—were perceived as more human-like. This perception enhanced the sense of *Co-Presence* and the impression of interaction possibilities (Mal et al., 2024).

Overall results suggested that there were significant values for *Subjective Trust* amongst participants in the consistent condition AVxAV and JCxJC over inconsistent conditions AVxJC and JCxAV, supporting H1. Several factors might explain this result. For example, perhaps having the same representation fostered higher levels of *Social Presence*, leading to increased interpersonal trust between participants. Alternatively, the consistency of *Self Representation* made finding ways to express themselves non-verbally easier and less of a cognitive effort.

Surprisingly, mean *Liked* scores were observed to be higher in inconsistent conditions than in consistent conditions. Some studies have come to show positive correlation patterns between *Liked* and *Subjective Trust*, but there are also those that do not. A study found that being mimicked did not change trust or liking within or across CVE social groups (Hale, 2017).

The results for *Plausibility* were higher in conditions where the 'other' participant did not have a *Self-Avatar*. This could be due to technical limitations when engaging with the environment, e.g., the Avatar interaction rendered was not realistic enough to hinder the *Plausibility Illusion* rather than facilitate it.

4.6 General Discussion

This work extends the research introduced in previous work (Pan and Steed, 2017) by focusing on the impact of *Self-Representation* and *Consistency* in CVE. As we continue to progress within this virtual age, it is important to understand the effect of consistency in Avatar *Self-Representation* to inform the development of social collaborative applications within the various industries utilising VR. The results of this investigation firstly reinforce the positive effect of the *Self-Avatar* within social interactions, but moreover, addresses the second research question of this thesis. We infer *Co-Visual Consistency* can improve trust if there is an equal and transparent dynamic between active participants, validating this dimension of the *Embodied Consistency* framework and supporting the second hypothesis of this thesis, see Figure 4.9 (also see the previous interview feedback section for supportive qualitative evidence). This is highlighted in Study 2, where we see that subjective scores are higher in consistent conditions. This is also true for productivity. Study 1 highlights a potential caveat in utilising a confederate in paired studies supported by previous literature (Martin, 1970a; Feng et al., 2004; Kuhlen and Brennan, 2013a). When using a confederate who is acting in deceit, it invites suspicion into the social dynamic, which may affect interactions between pairs. In this study, it is suggested in particular that when a confederate is deceitful and uses a *Self-Avatar*, this may have a negative effect on subjective levels of trust as the configuration of *Embodiment* allowed for mapping of negative *Self-Representation* from the physical space to be experienced in VR. This may be due to greater non-verbal 'leakage' of social signals through the *Self-Avatar*, which enables the participant to pick up more cues of deceit. This shows the potential difficulties of using experimental designs based on confederates.

Using a social dilemma exercise to gather objective measures of trust proved to be unreliable in this context. We see completely opposing results in both *Subjective Trust* and *Liked* between Study 1 and Study 2. This also could potentially have been affected or compounded by the use of a confederate. In Study 1, the confederate is an 'expert' at the experiment process and, therefore, has less cognitive load, overcoming the learning curve of using the system and working in a pair to complete the task. In Study 2, both are novice participants to the system, and perhaps in this case, it was more difficult to establish relationships whilst trying to complete the task correctly. Alternatively, in this context, participants may have found their partners trustworthy to complete the task but not likeable. The type of trust and likability that would warrant sharing something as valuable as money, perhaps, had not been able to develop. In Study 1, the confederate played a 'consistent role', which may have helped participants relate to them better.

Study 2 showed that the efficiency of consistent and inconsistent pairs varied over time. Initially, inconsistent pairs were faster, possibly due to one partner naturally taking on a leadership role. However, over time, the consistent pairs were more efficient, perhaps because they were able to establish more effective collaboration strategies after an initial period of familiarisation with each other.

In this study, we looked at the effect of having consistent and inconsistent conditions between partners when using a confederate and when using paired participants, as this could have interesting implications in the design of shared virtual spaces, and our findings have both supported and challenged previous notions. But more importantly, this approach has given insight into how we can begin thinking about consistency in utilising the *Self-Avatar*. More research needs to be done in this area to get a fuller understanding of this phenomenon.

Overall, both Chapter 3 and 4 dealt with looking at the psychological impact of different configurations of the first two dimensions of *Consistency in Embodiment*, see Chapter 2, Table 2.2. Both studies led us to understand, in terms of the construct of *Agency*, that *Sensory Consistency* was preferable over heightening sensory input. Additionally, *Co-Visual Consistency* in collaborative scenarios can help facilitate positive initial attributes of *Social Presence* like trust (see Figure 4.9). In both studies, we present accessible technical pipelines for configuring *Self-Representation*, but there were some limitations. Our first study, due to using the early Kinect version 1, could not facilitate full body rotations; however, due to the Mirror focus, participants did not feel affected by this. In this Chapter, despite minimal facial expression, vocal cadence was a powerful Top-Down mechanism to override limited Bottom-Up configurations of no facial expressions. In Chapter 5, we now conclude our investigation on the configuration of *Self-Representation* and address our last research question. We present a study on the impact of different configurations of *Embodied Virtual Perspective-Taking* on *Self-Efficacy.*

Chapter 5

Delivering Bad News: Using Embodiment as Tool of Self-Evaluation for Medical Communication Training

In Chapter 4, the results revealed that *Co-Visual Consistency* in a virtual social dynamic could potentially lead to the fostering of more trust and collaborative play between dyads. Chapter 3 demonstrated that *Sensory Consistency* is more effective than heightened sensory fidelity for *Agency* and *Body Ownership*. We have been able to build up our understanding and effect of *Embodied Consistency* within two lab settings, strengthening our framework as an alternative lens for how we can configure consistency in *Self-Representation* within Solo and Social VR.

This study moves from an in-lab investigation to an in-application one. Our understanding of how we configure our *Self-Representation* has now shifted into a final exploration of the phenomena of *Embodied Virtual Perspective-Taking* in the Medical Field.

All participants were trained professionals, and according to Slater's research in an update on *Place Illusion* and *Plausibility Illusion* (Slater et al., 2022), when both Illusions are at play, individuals tend to react authentically to situations and occurrences within a VR environment, even though they are fully aware that these are illusions and not real. However, when the environment is designed to mimic real-life scenarios where accuracy is essential, any seemingly inconsequential element in the environment that deviates from expectations can disrupt the overall sense of realism. It's with this challenge that we present this experimental technical pipeline and test the configuration of Perspective-Taking for *Self-Evaluation*.

In this Chapter, we address the third research question in our thesis:

- *What impact does the configuration of Embodied Virtual Perspective-Taking have on learning processes such as Self-Evaluation?*

In one condition, the participants will review their consultation in VR from a first-person perspective in the body of their charge; in the second condition, the participants will review their consultation from a disembodied third-person condition. Unlike in the last two studies, we aim to utilise a high-end immersive setup - we have included facial expressions (random eye movement with target points and lip-sync triggered with sound) in the configuration of our embodied *Self-Avatar* and facial Motion Capture to our *Semi-Autonomous Agent*. We hypothesise:

- Configuring Perspective-Taking, an application of *Embodiment* through a first-person perspective versus a no-Avatar third-person perspective, will result in a significant negative difference in *Self-Evaluation* in the dimension of *Self-Efficacy.*

In this between-subjects experimental design, we will investigate if there is a significant change in participants' *Self-Efficacy* ratings due to the manipulations of these configurations of perspective.

5.1 Introduction

Healthcare worker skills can be broadly split into two domains: technical and non-technical skills. If technical skills are composed of specialised knowledge and procedural abilities - the knowledge and dexterity needed to perform a particular surgical procedure, for example - then non-technical skills can be defined as 'cognitive, social and personal resource skills that contribute to safe and efficient performance' (Fletcher et al., 2003). Proficiency in communication is a core non-technical skill. Previous research has shown that 79% of patients feel emotionally unsupported by their Doctors, and poor communication skills by healthcare professionals lead to lower quality healthcare outcomes and higher costs (Korsch and Negrete, 1972). Studies conducted outside of VR have shown that Communication skills training can improve clinicians' evaluation of his or her ability to perform a specific communication task—measured as *Self-Efficacy* (Ammentorp et al., 2007). Nevertheless, Bandura's theory of *Self-Efficacy* describes how individuals can learn to determine and modify their estimate of *Self-Efficacy* by using role play and feedback as one of the most effective methods (Bandura, 1977). In this study, the aim is to see if *Embodied Virtual Perspective-Taking* can manipulate this effect.

VR simulation has previously been shown to be an effective tool for healthcare worker training and can be more resource-efficient than traditional methods. However, a systematic assessment of VR for non-technical skills training is required to demonstrate improved learning outcomes (Bracq et al., 2019) and to determine whether it achieves its ultimate goal of improving the quality of service given to patients.

In this work, we have investigated using *Embodied Virtual Perspective Taking* (EVPT), or 'bodyswap' as it is commercially known, to propose a template framework for self-assessment of communication skills for Medical practitioners in delivering or breaking bad news. In using high-fidelity Avatars animated with mocap data from professional actors and a realistic, credible virtual environment, we were able to simulate a virtual scenario where healthcare workers would be able to practice their responses against an interactive *Semi-Autonomous Agent.*

Two studies were conducted to gather preliminary data. The purpose of Study 1 was to validate the implementation and experimental design of the investigation. We hypothesise that by working with a professional actress for Motion Capture and collaborating with a professional animation studio, our VR scenario has the polished production quality that would trigger a high level of both *Place Illusion* and *Plausibility Illusion.*

Study 2 focused on testing the framework for its impact on *Self-Evaluation.* Through our interview and qualitative data, we are interested in whether this ability to evaluate performance from another perspective can be used as a tool for improving Medical communication and *Self-Evaluation.* Furthermore, we suggest in our configuration that swapping first-person perspectives during the evaluation process in VR can significantly impact self-assessment compared to using a third-person perspective. In this Chapter, we present the questionnaire and interview results for both works.

5.2 Background

5.2.1 Embodiment in Healthcare

Virtual VS Standardised Patients in Medical Training

It has been argued that using virtual characters can elicit the same information from medical students as real human beings. Lok created an interactive virtual clinical scenario of a virtual patient with acute abdominal pain - depicted by a life-sized projection on the wall of an exam room in a Medical centre. The participant was tasked to act as a Doctor and evaluate the patient's condition by asking questions, providing a cost-effective and objective way to practice communication skills(Lok et al., 2006). Results suggested that, in comparison with using a standardised patient approach, participants elicited the same information from both virtual and standardised patients and performed equally well overall. Additionally, virtual interaction was found to be similar to real interaction in many important educational measures.

O'Rourke investigated the emotional and behavioural impact of delivering bad news to virtual versus real standardised patients amongst a group of Medical students (O'Rourke et al., 2020). Results suggested that the students had similar emotional and behavioural responses when delivering bad news to a virtual simulated patient compared to a real simulated patient, with participants in both states performing similarly, except for tone of voice.

Assessing Communication Skills in Medical Training

VR is also being used as a way of assessment for Medical training in communication skills. This has the advantage of providing replicable conditions for self-reflection and evaluation.

In (Andrade et al., 2010), participants were instructed to deliver bad news to a standardised female Avatar in a 3D simulated clinic. The trainee then evaluated their *Self-Efficacy* via an effective competency score (ASC) before and after the experience. Results showed that the participants' ASC scores increased overall; however, they mentioned the lack of nonverbal behaviour impeded realism. Similarly, more recently, in Ochs's experiment, they looked at comparing the impact of virtual environment displays on the sense of presence and evaluating the system as a means of self-report (Ochs et al., 2019). Their research results favoured Head Mounted Displays (HMD) and CAVE, producing a higher presence; however, their results on self-assessment are yet to be published.

Healthcare professionals engage with patients from a wide range of cultural backgrounds, each with unique expectations and coping strategies. They must have a secure environment to thoroughly assess their communication skills without fear of judgment or bias. VR proves highly effective in providing such a platform. Hence, we have selected this domain as the ultimate testbed for our research on *Self-Representation*, focusing on Perspective-Taking.

5.2.2 Perspective-Taking in Healthcare

Embodied Virtual Perspective-Taking (EVPT) training for communication skills in healthcare is limited. (Hoek et al., 2023) looked at two patient-embodied VR experiences from a first-person patient perspective, deploying both negative and positive communication styles during a pre-operation consultation and induction of anaesthesia. Ten anaesthesiologists experienced both conditions, and a semi-structured interview followed each experience. Interviews revealed acknowledgement of the importance of good communication skills and highlighted that patient-embodied VR can influence beliefs and values on pre-operative anxiety and its reduction. This experiment, however, did not first include an initial *Embodiment* of the anaesthesiologist and was done using 360 Video VR. We propose that adding this condition first will help to facilitate a robust tool for *Self-Evaluation* and assessment.

Other literature surrounding VPT suggests that EVPT elicits reflection on the perspectives of others (Raij et al., 2009). During the EVPT, participants reflected on their use of empathy and Perspective-

Taking - similar to our study, they took part in a Medical interview where Medical students would converse with a patient experiencing a breast cancer exam and then review the conversation as the patient through video stream in an HMD, allowing for dynamic control of viewpoint. This is evidenced in the decrease in participants' self-ratings of Perspective-Taking and empathy between their first and second exposures to the consultation in VR.

As per the findings of Gorisse *et al.*, (Gorisse et al., 2017), a first-person perspective is ideally suited for tasks requiring intensive interaction, while a third-person perspective offers better spatial awareness and environmental perception, potentially extending to an understanding of how other individuals are engaging within the environment. This might explain why the conventional real-world approach to *Self-Evaluation* post-training tends to favour the third-person perspective, as depicted by Pan (Pan et al., 2016). However, we present a hypothesis that, considering the accumulating evidence suggesting that a first-person perspective can influence empathy and behaviour, there may be notable disparities in participants' *Self-Efficacy* regarding their performance.

Nevertheless, it is the hope that this investigation and its results will generate future avenues for research in Medical communication training and insight into the psychological impact of different configurations of EVPT.

5.3 Technical Implementation

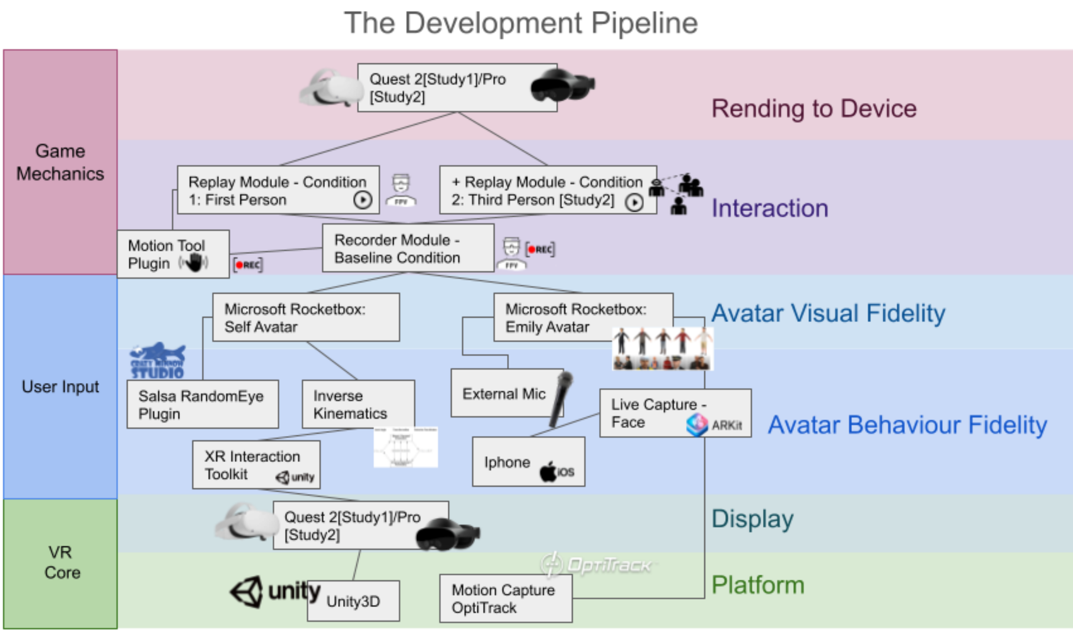


Figure 5.1: The figure shows the technical pipeline of the project.

VR Core Module - The Platform

The consultation environment in Figure.5.2 was created in Unity3D 2020.3.41. The hospital ward was purchased from the Unity Asset Store.

VR Core Module - The Display

In Study 1, we integrated VR into our project using the Oculus Quest 2, a standalone VR headset with a resolution of 1832 x 1920 pixels per eye, a field of view (FOV) of approximately 90 degrees and a mic. For development in Unity3D, we utilised the XR Interaction Toolkit plugin. The XR Interaction

Toolkit provided core interaction functionality, such as grabbing and manipulating objects. It enabled the use of the XR Rig, which manages the camera and tracked controllers of the Quest, ensuring an accurate representation of the user's movements within the virtual environment. This setup streamlined the integration of VR.

In Study 2, the Virtual Reality system used was the same as in the first study; however, it was upgraded to Unity3D version 2023.1.2f1. The hospital ward environment was a modified asset purchased on the Asset Store. Further modifications in this study included removing several bedside equipment and other out-of-context decor, and changes to lighting and graphic shaders were implemented by an external studio, Buko Studios - an animation company based in the Philippines. The treatment condition - third-person perspective *NVPT*, was implemented using a custom record and replay UDP system.

Instead of the Oculus Quest 2, we used the Meta Quest Pro. The Meta Quest Pro is a standalone Virtual Reality headset featuring a per-eye resolution of 1800 x 1920 pixels, a horizontal field of view (FOV) of 106 degrees and a vertical FOV of 96 degrees. A full diagram of the technical pipeline of both studies is shown in Figure 5.1.

VR Core Module - The Avatar

The Avatars were sourced from Microsoft's Free Rocket-box Library package of high-fidelity models with a diverse range of applications. We picked a male and female *Self-Avatar* with Medical occupations. The female Avatar in scrubs was unavailable, so we edited the texture to match the scrubs of the male Avatar. The female *Semi-Autonomous Agent*, Emily, was also sourced from this package. The Avatar was edited to appear darker in skin tone to diversify our platform and to wear stockings.

The User Input Module

Inverse kinematics (IK) for body movement was implemented using the FinalIK plugin, an advanced IK system for Unity that enables precise and dynamic character movement, animation, and interaction. FinalIK provided the tools necessary for realistic full-body tracking with the Rocket-box Library Avatar through IK. It also integrates with tracking systems such as the XR Interaction Toolkit. Head and hand tracking data were obtained through the Camera Rig provided by the XR Interaction Toolkit, ensuring accurate synchronisation of upper-body movements within the virtual environment. As the experience was designed to be seated, leg movement was intentionally disabled to maintain focus on upper-body interactions.

Technical Contribution

For this project, I first edited the hair texture for the female *Self-Avatar* in Scrubs, as the Avatar was the same base character as Emily. We hid this with a Medical mask, and I edited the hair texture to appear lighter.

We created a 'Record and Play system' to capture the participant's verbal and non-verbal communication during the consultation. I was responsible for curating a pipeline to record and play the non-verbal actions whilst the Audio 'Record and Play system' was outsourced.

I set up Inverse Kinematics (IK) using the FinalIK plugin to enable realistic Avatar movement. Additionally, I integrated the Motion Tool plugin to enable recording and replaying of GameObject movements in Unity. However, the Motion Tool lacked a module for recording Avatar animations natively. To address this, I duplicated the Avatar rig joints and configured these duplicates as parameters for the FinalIK solver. This approach avoided conflicts with Unity's animation system by isolating IK adjustments from the original rig joints. The duplicated joints inherited movement data, ensuring the Avatar responded accurately to live input captured through the Oculus SDK.

For recording, I used the original head and hand GameObjects as inputs for the Motion Tool Recorder. These objects captured the participant's real-time movements within the VR environment. Later, in the playback scene where participants reviewed their consultation, I reused the duplicate joints with the FinalIK solver. However, since the input for this phase came from recorded data instead of live Oculus SDK tracking, I introduced parent GameObjects for each duplicate joint. The recorded movement was replayed onto these parent GameObjects via the Motion Tool Replay module, and the duplicates inherited their orientation. This setup ensured that the inverse kinematics system functioned seamlessly during playback, accurately replicating the participant's movements and preserving the integrity of the animation system throughout the process.

Finally, I designed and implemented the Graphical User Interface (GUI) for controlling Emily using the Wizard of OZ technique explained later in this Chapter. Using Unity's Animator window, I created a state machine to manage Emily's responses dynamically, which was triggered by a UI display corresponding to the verbal response. To achieve this, I synchronised FBX files containing body animations captured with Motion Capture, facial animations created using Unity3D's ARKit + LiveCapture Plugin, and audio recordings captured with an external microphone. The challenge was that the facial animation files could not be divided into individual animation clips compatible with the Animator State Machine. Therefore, I utilised Unity's Timeline to synchronise the facial animation with the corresponding Audio clips.

Using the Timeline's Playable Director component, I implemented a system that connected the GUI, Timeline and the Animator State Machine. When a button in the GUI was pressed, it triggered a state change in the Animator's state machine. Simultaneously, the Playable Director component was instructed to jump to the specific time frame on the Timeline that matched the corresponding facial animation and Audio clip for that state. This approach ensured precise synchronisation between Emily's body animations, facial expressions, and audio, creating a cohesive and responsive character experience controlled via the GUI.

In the next section, I will discuss the contribution of the production pipeline for the consultation with Emily to ensure its plausibility and, therefore, the transfer of skills from VR to reality.

Figure 5.2: Figure shows consultation with Emily in Virtual Reality. The participant is embodied in the Avatar of a Male Doctor.

Production Pipeline - Stage 1: The Script

The script was written with the support of parent feedback and two external medical practitioners. This ensured that the scenario and dialogue were plausible, felt familiar to the participants, and provoked empathy. Since empathy creates an isomorphic response to another person's feelings, an empathetic response to the distress of others can cause overwhelming distress in the observer and can lead to "an egoistic motivation to reduce stress by withdrawing from the stressor" (Decety, 2010) and therefore lead to social avoidance. However, moderate levels of distress may be necessary to drive one to feel empathetic

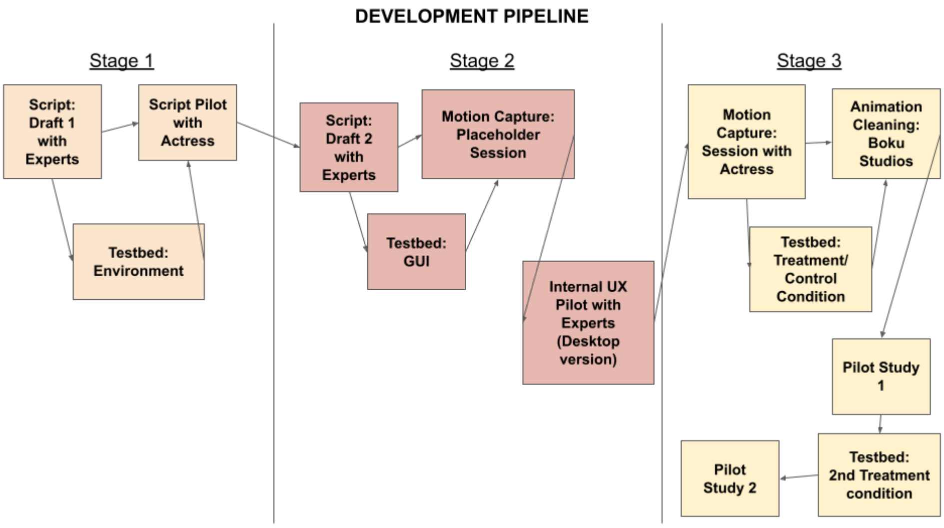


Figure 5.3: Production Development Pipeline

concern, which is the desire for the well-being of others and, therefore, the desire to help. Due to this concern, the dialogue was first tested in a pilot with an actress and voluntary staff at the Great Ormond Hospital to gauge the response provoked by the scenario.

In our scenario, a virtual character, Emily, is the parent of a five years old young boy, Sam, who has been scheduled to have a routine surgery for a "PICC" line insertion. PICC stands for "peripherally inserted central catheter", and a PICC line is a long, thin tube inserted through a vein in the arm and passed through to the larger veins near the patient's heart. Due to primary immunodeficiency, Sam needs long-term immunoglobulins therapy and thus has been scheduled for this procedure. In order to be performed on for this surgery for minors, a general anaesthetic is needed. Thus, the background of our scenario is that Emily is waiting with Sam, who has been sedated and is ready for this routine procedure. However, due to an emergency (e.g., another child needing an unexpected and complex surgery for something life-threatening), the doctor scheduled for this procedure is, very unfortunately, no longer available. Therefore, someone will need to inform Emily about this and reschedule the appointment. As most hospitals are often understaffed, when there is an emergency, the responsibility to explain this to the parent may fall on some junior members of staff. This is not an uncommon scenario at hospitals and is just one example of many which could have been used for this framework.

Our script is a dialogue between Emily (virtual character) and the medical staff (participant). Although it is not possible to anticipate exactly how the participant would respond towards our virtual character, based on experience, it was decided that Emily should go through three stages of emotions, which we used to structure our script development:

- Stage 1: Anticipation for procedure + Break news - Uncertainty/denial
- Stage 2: Anger Escalation
- Stage 3: Shut down – Parent accepts rescheduling reluctantly

The dialogue needed to follow a uniform linear format so that participants experienced Emily in the same way and received the same distress cues (see Table 5.1). This also made sure that the focus of whether the consultation went smoothly was not reliant on the reaction from Emily but on their confidence in their behaviour and training. In addition, empathic distress in contexts like this is related to burnout (Zenasni et al., 2012), and so we added this measurement to the demographic data collected to be used for future correlation analysis.

The feedback from this pilot provided great insight into ways the dialogue can be amended to make Emily seem realistic. The script underwent another cycle of changes; the final version of the script can

Stage	Example Dialogue from Emily
Stage 1:	"What? No, we were told by Dr Lacey that we would definitely have the procedure today"
Stage 2:	"Don't tell me to calm down. This is your fault!"
Stage 3:	"Fine. Okay. Can he keep the line in overnight?"

Table 5.1: Dialogue stages with examples from Script

be found in Appendix C. At this point, the testbed was in development. Two engineers from Goldsmiths were recruited to help implement the audio and animation replay system for the evaluation conditions.

Emily:
Well no one told me that, wait you're not listening. Nobody told me that, nobody…nobody told me that there could be an emergency and this would be cancelled. Then at least I would have prepared myself, I would have had that as an option!

P8:
Okay, I understand, um it's quite frustrating about it, um…but sometimes, uh it's just because there is an emergency the child needs to have that schedule um for the procedure...

Emily:
I can't come in tomorrow, I have a presentation to do at work, what am I supposed to do, ring up my boss and say oh, you know that day I took off work for my son's procedure well the procedure isn't actually happening today, it's happening tomorrow so I can't come and do the presentation, it's for clients in America, they've flown in all the way from America, what am I supposed to do?

P8:
Okay, so um in regards to that, is there any time that would suit you-

Emily:
What I would like is to have the procedure today!

P8:
Okay, so um in regards to that, I'm sorry that's the only information that I have and doctor Khan can't really do it today due to the emergency...

Figure 5.4: Example dialogue taken from experiment run.

Production Pipeline - Stage 2: Motion Capture and Testbed

An internal Motion Capture session was held to block the recording segments and synchronise media captures. To animate Emily, we would need to collect Facial Tracking data, Motion Tracking data and Audio data. Motion capture was done using the Opti-Track Motive system with a 12-camera sensor setup. As mentioned, facial animation was captured using the Live Capture Package and the Apple ARkit XR Plugin simultaneously with body-tracking. A mobile stand was used to hold an iPhone for face-tracking in position during the Motion Capture session. This only worked because the researcher was seated as Emily was during the experience. The audio was collected using a wireless microphone attached to the researcher and recorded with Audacity software from a separate Desktop.

These captures were used as placeholders during the development of the testbed.

To bring Emily to life, we used the Wizard-of-Oz method, where an experimenter selects the dialogue reaction from a command window of set responses. Similar approaches have been used in previous work, including therapy for social anxiety (Pan et al., 2012), and more recently, training for GPs to resist the demand to prescribe antibiotics (Pan et al., 2016).

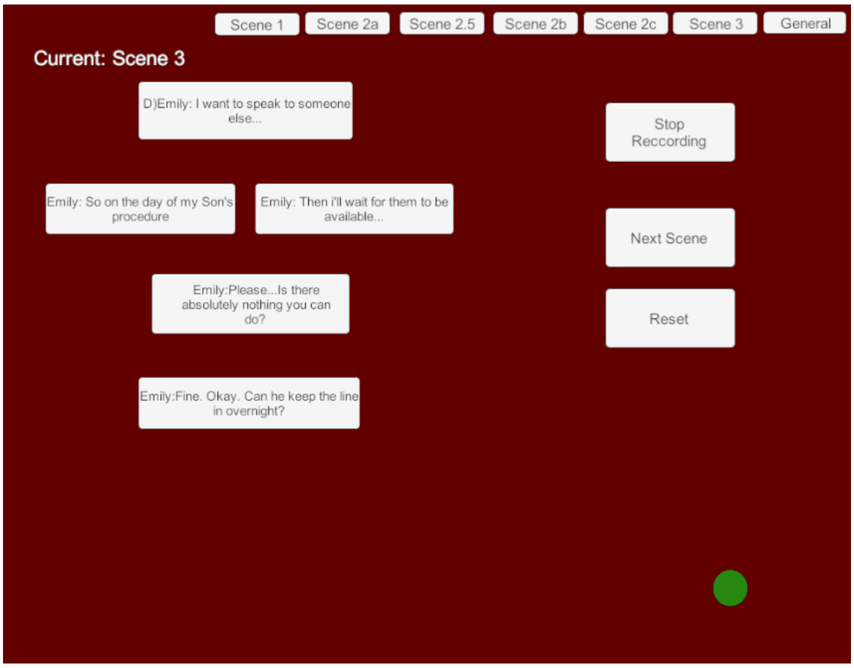


Figure 5.5: GUI of Wizard of Oz Interface

Production Pipeline - Stage 3: Final Motion Capture with Actress

Once the script was finalised, the final Motion Capture session was conducted using the Opti-Track Motive system. Another actress was recruited to voice and grab the facial and body animation for Emily. The animation was then used in Unity3D to update Emily's Animation State Machine.

The Motion Capture and Environment were modified by a commissioned external Animation Studio, Buko Studios, to improve realism. This included an update in Shaders and changes to Emily's posture and finger animation, which could not be recorded during the Motion Capture Session. See Figure.5.6.

5.4 Study 1

5.4.1 Experimental Design and Methodology

Sample

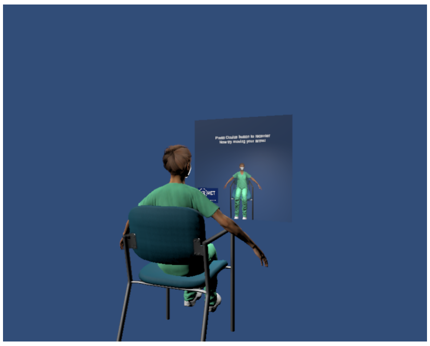
Six Participants were randomly recruited from Great Ormond Street Hospital by volunteering through advertisement and word of mouth. It was advertised as a training simulation project. Nothing was revealed about the nature of the scenario at this point. Interested participants were directed to the study room via email or text. This study was approved by the University of London ethics board, and the corresponding guidelines and regulations in conformity with the ethics body were carried out using all methods. All participants gave written consent before the participant before participation. All six participants were between the ages of twenty-nine and thirty-five. There were three men and three women recruited from Great Ormond Street Hospital through word of mouth - three were anaesthesiologists, and three were Nurses.

Procedure

The experiment procedure followed similar studies based on evaluating performance (Pan et al., 2016; Raij et al., 2009), which follows an initial consultation, a questionnaire, and then a viewing of the performance. The only difference here is that participants viewed their consultation in IVR.

Each participant was briefed and given a pre-questionnaire, which gathered information on their role,

(a) Before and after editing by Buko Studios



(b) Training Scene

Figure 5.6: Figures from the Testbed Development Pipeline

experience, and level of stress management. Participants were then given a headset and, after a brief discussion, began a consultation with a virtual character, Emily, in VR. After the end of the dialogue, a second scene was loaded, and participants could observe their behaviour towards Emily from her perspective, as well as having agency over her body. After watching the consultation in VR, participants were given a questionnaire to fill out on *Plausibility Illusion*, *Place Illusion*, *Social Presence* (Biocca et al., 2003), and *Embodiment* (Botvinick and Cohen, 1992). A semi-structured interview followed this.

Experiment Procedure							
	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
C1	Q0 & Q1	VR Training	VR Consult	Q2	VR Eval 1st	Q3	Interview
C2	Q0 & Q1	VR Training	VR Consult	Q2	VR Eval 3rd	Q3	Interview

Table 5.2: Table of Experiment Procedure. Note: Q0 = Demographic Questionnaire, Q1 = Post VR Consult Questionnaire, Q2 = Post VR Eval Questionnaire, Q3 = Post VR Eval Questionnaire, VR Eval 1st = VR Evaluation from Emily's Perspective, VR Eval 3rd = VR Evaluation from 3rd Person Perspective.

The hypothesis for this experiment is as follows:

H1 There will be high levels of Subjective *Plausibility Illusion* and *Place Illusion* felt by participants.

H2 There will be high levels of Subjective *Embodiment* felt by participants.

5.4.2 Analysis and Results

Questionnaire Results

Figure.5.7 shows the results of the subjective questionnaire on *Plausibility Illusion*, *Place Illusion*, *Social Presence*, and *Embodiment* on a Likert scale of 1-7, with 7 representing a high rating. *Body Ownership* and *Agency* were mid to high level supporting **H2**. This was surprising as previous design practices for *Self-Representation* aligning with synchronised *Visuomotor* cues have shown positive results. This may be due to the lack of a stage of priming pre-VR interaction. In some studies, such as (Banakou et al., 2013) (see Chapter 2 for full discussion), the Mirror acts as a primer, which allows the user to get used to the body they are in before or during the main session. However, there are mixed views on whether they enhance *Embodiment* more than in non-mirror experiences; this is something we will investigate more in future studies.

In terms of *Social Presence*, we can see from Figure.5.7, from the *Emily Real* attribute that there were relatively mixed feelings on how believable Emily was, but still, most participants felt like it was similar to a face-to-face meeting as depicted in *F2F Meeting* and that they were present with her in the environment, as in *Copresence*. Emily's voice and the provocative and emotional cadence were highlighted as adding plausibility. Participants noted that the script immersed them into the conversation, allowing them to 'suspend disbelief' for the duration of the consultation, so though there were moments where Emily did not look realistic (e.g. technical fault), the Top-Down mechanics were able to stabilise plausibility. However, they felt that there could be a slight lag in discourse at moments - this is one of the potential drawbacks of using the Wizard of Oz technique to animate Emily.

Most participants found both the environment and the scenario realistic and believable in *Plausibility Illusion* and *Place Illusion*, "cancellations happen", so it felt familiar, and participants felt very immersed in the situation, supporting **H1**. It was the small details that gave the environment plausibility - aspects like the hospital logo and ward setup - however, in the same vein, small details such as the sofas, paintings, and dynamic content on the monitors made the room feel too fancy and not feel like a "familiar bed space" with the NHS.

As seen in Figure.5.8, participants gave mid-to-high feedback for *Environment_Realism* and *Interacton_Realism* specifically. These were rated on a Likert Scale of 0-3. Short-comings may be due to the feedback on the environment needing to be shifted to resemble a child ward. Interaction scores could be due to technical fidelity and delays in dialogue flow (see Semi-Structure Interview).

As seen in Figure.5.9, most participants felt it was difficult to advise Emily as they felt the pressure of the scenario, giving validation to the script. Emily was "asking difficult questions" and was not receptive to re-booking. Some participants felt that, as they didn't have more information about the patient, they were slightly at a loss as to what to say. In contrast, some felt that it was more of the technical limitation of Emily's responses that impacted their experience.

Semi-Structured Interview

Participants expressed a need for better *Embodiment* mechanics to enhance the feeling of control and accurate *Self-Representation.* For instance, "People don't engage with their bodies because they forget they have one in VR." (P6). This feedback highlighted the importance of priming sessions to familiarise users with the Avatar's limitations and capabilities. Additionally, they suggested that small improvements, such as using gloves or better hand tracking, could enhance the sense of realism, "I felt fixed to a machine... using a glove might improve the agency". To some participants, the motion fidelity was insufficient to balance the visual fidelity.

When reviewing their experiences, doctors were quite happy with their performance and felt the review configuration captured their *Self-Representation* well. "When I watched it back, I wasn't surprised…What I thought I would say and what I said was what happened…from the point of the

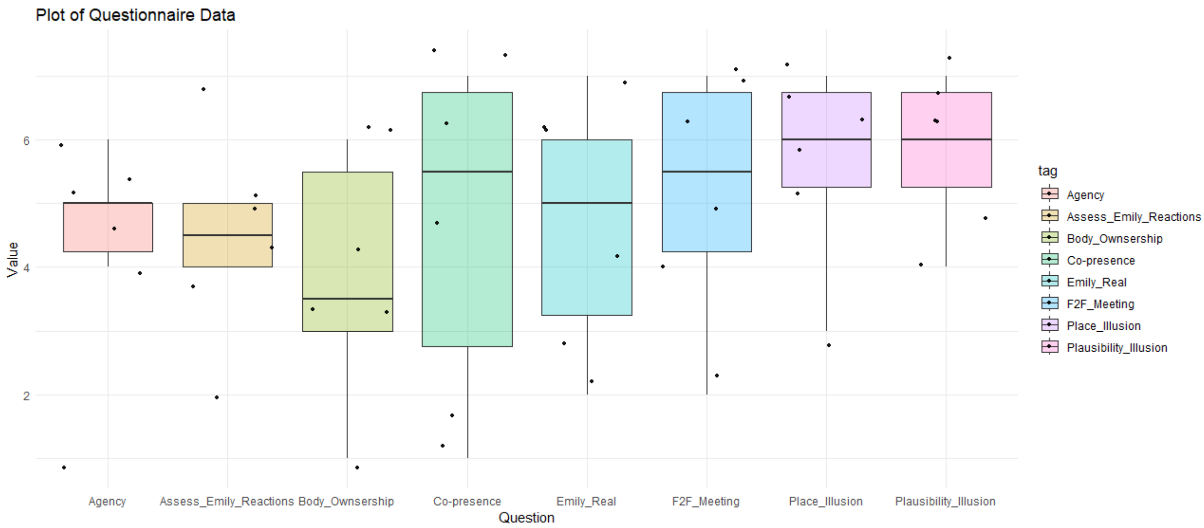


Figure 5.7: Figure shows the results of Questionnaire Data with the individual distribution of each question.

material, or if you're asking, did I *show* empathy. . . I went about the conversation in the way I wanted to." (P5). However, some found the consultation made them think about their approach to their patients on both a verbal and a non-verbal level. "There were loads of times during that first bit that I thought I could have worded that differently, and I felt the same listening to it back...where was I trying to go with what was saying? I can't think of. . . how I do present myself and my body language with what I'm doing when I'm speaking to someone. . . " (P5). When reflecting on their embodied performance, they commented, "I must sit quite calmly, and I don't seem to gesture a lot".

The participants overall felt that the experience was good and useful. "Not everyone can deal with confrontation, so [they] think it's a good practice." (P1). Because you are not dealing with real people but with animated virtual characters, it may take away social anxiety that may interfere during a role-play scenario, as some may " find it hard to interact with each other." (P3). The experience overall seemed to be more of a comfortable alternative, "Watching an Avatar back is much less uncomfortable than watching a straight video of yourself, which is what you are meant to do as Medical students. . . you're better able to watch the Avatar back without cringing." (P4).

One of the participants reflected on how scenarios such as this are viewed by early-career professionals in the context of the competitive process of securing a permanent position in a high-profile institution. A participant told us:

"Getting screamed at by that mum. . . I was so stunned I didn't really know what to do. . . And also I was a [term for starter] as well; I know that sounds really silly, but I was quite new. . . I was a new consultant, and when we are on [starter] contracts, it's fixed term. So, like, you compete to get a fellowship here, and that's like [gesture] amount of people, then you compete to get a locum job, and that's like [gesture] that many people and then you compete to get a life long job, and that's like..two people. So at that point, I didn't yet have the lifelong job. . . and I'd only been a consultant here for one or two months, so you're still in that stage of 'oh my gosh, I've messed up, it's my fault..." (P4).

Using this experiment, where you can see and assess your behaviour with perspective-changing, could prove useful to this potential group of users as this alleviates the pressures placed by these dynamics and allows them to look at their behaviour without added anxieties practically.

The feelings towards realism were overall positive, mainly due to the nature of the engagement with Emily. They found her to be provocative, and her responses plausible, "What she was saying and how she was saying it, was realistic in that the points being made." (P2) and "she reacted like a lot of parents would react to that news. . . Her responses felt really organic; it didn't feel scripted." (P5). Keywords repeated throughout were "realistic", "immersive," and "familiar".

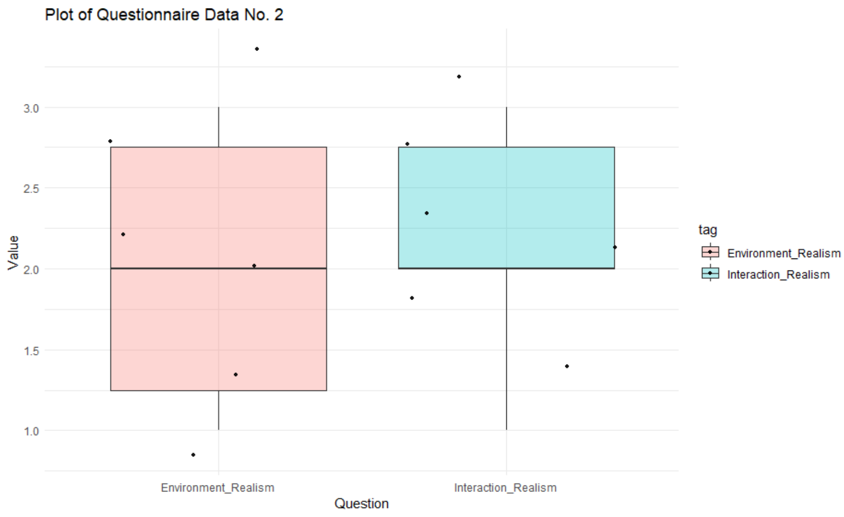


Figure 5.8: Questionnaire plot of Environmental and Interaction Realism.

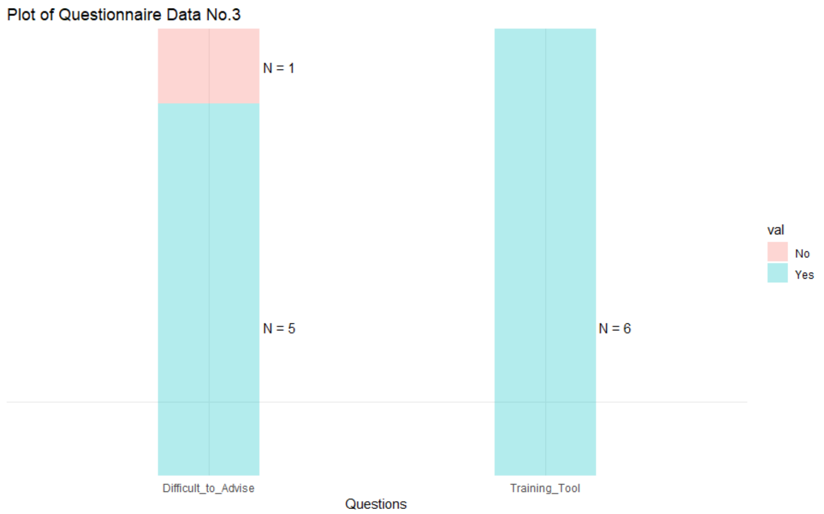


Figure 5.9: Questionnaire plot of whether participants felt (left) Emily was difficult and (right) Whether this application could be used as a Training Tool.

As we found in the questionnaire, the dialogue and scenario were plausible to the participants. Still, their exposure to dealing with such situations varied and so allowed them to handle it in different ways, befitting their experience and role. We see that those anaesthesiologists with a bit more experience and exposure to this event did not have much patience with Emily; they had a tolerance threshold. “The point in which she escalates to, right, I’m just going to starve him and not let him have anything; that’s when I exited. . . that’s where it went from me feeling sorry for her to me thinking, okay, enough.” (P4). Others who were quite new to the scenario were drawn into her plight and found it stressful and hard to manage. “Yes, it’s stressful. The voice was the most real thing. You know she’s not real, but when she speaks, it’s definitely the voice.” (P1).

Overall, there is a consensus that this scenario would be better suited for junior levels “Maybe it’s not targeted at those senior people; I don’t see why you’d need to simulate a scenario that someone is seeing in real life every week; you need to simulate scenarios for people who don’t get access to them, i.e. people that are a lot more junior.” (P2).

There were a few limitations and points that broke plausibility for some participants; most were due to, as mentioned in the questionnaire responses, the environment design. “Well, there is fruit in the bowl; from what I can tell, we don’t put fruit in the bowl next to people that are fasting. . . And there would not be a hoist above the bed...It’s a children’s hospital; the pictures would be more childish.” (P2).

However, technical limitations, such as the set responses available for Emily, also hindered plausibility for some participants. "At times, I felt that what was being responded to was not exactly what I had said....it's double irksome because you kind of zone out just a little, and it reminds you that this isn't truly real-time interaction." (P2). However, another participant found the haphazard nature of Emily's responses to be realistic for a character in her situation. "You do find yourself stuck in a loop without really knowing what you can say to move it along, but that's not entirely unrealistic either ... because sometimes the conversation is like that." (P6).

The last question we asked was if participants had examples of use cases (mostly for senior staff) where they felt this framework would be effective. Their answer is listed below and have been noted for future consideration:

- Unexpected death
- Practising debriefing
- Talking to difficult staff
- Interviews for Overseas Doctors

5.4.3 Discussion

The results from the first study were encouraging. Many of the participants felt that this platform could offer an additional medium for Medical Communication Training skills, as previous literature has suggested. Additionally, feedback proved informative and justified our methodology and technical decisions, as well as giving us a clear direction for improvements for the next round of experiments for Study 2. The changes implemented are listed below:

- Changed the Consultation room to remove assets that felt out of place for a children's ward.

  There was a considerable amount of feedback picked up on certain elements in the room that broke plausibility, such as the fruit bowls, sophisticated imagery on the walls, and certain hospital equipment around the bed. These were removed and replaced where necessary.

- Included a training session for priming *Embodiment*

  To address concerns raised about building stronger awareness of the virtual body, we added a training scene to allow users to see themselves embodied in a gender-matched *Self-Avatar* in scrubs.

- Included two conditions for watching back the consultation in Virtual Reality.

  To address our third research question, we created a treatment condition where participants can re-watch their consultation with Emily from a neutral third-person perspective. This was done to investigate if there is a significant difference in effect from the control condition orchestrated within the first experiment.

5.5 Study 2

5.5.1 Experimental Design and Methodology

Study 2 was a two-group experimental design with one independent variable, 'Perspective', and two levels: Emily's perspective(E_VPT) and an additional Neutral Perspective ($NVPT$). This condition was added to the testbed with a custom Record and Play module; this replayed Emily's animation simultaneously with the Motion Tool Replayer. This was sourced to an animator to configure due to time and complexity.

Sample

16 Participants were randomly recruited from Great Ormond Street Hospital by method of volunteering through advertisement and word of mouth. It was advertised as a training simulation project. Nothing was revealed about the nature of the scenario at this point. Interested participants were directed to the study room via email or text. This study was approved by the University of London ethics board, and the corresponding guidelines and regulations in conformity with the ethics body were carried out using all methods. All participants gave written consent before participation. Although the total number of registrants was twenty, two were excluded due to technical fault, and another two were excluded due to participants terminating their involvement during the participant due to a ward emergency. This resulted in a final sample size of $n = 16$. Our sample included nine Doctors and seven Nurses. Seven participants identified as male and nine as female.

The Procedure

Upon signing the consent form, participants were asked to fill out a Demographic Questionnaire and given an information sheet that gave them context on the consultation scenario. They were asked if they had any questions and then asked to fill out a Pre-VR self-assessment questionnaire (*PreVRQ*). They were then helped into a Meta Quest Pro and put into a training scene where they saw their gender-matched embodied Avatars in front of a mirror. Instructions on the screen guided them in adjusting settings for their personal use. They were asked to become familiar with their virtual body by moving their arms and exploring movement limitations. In this experiment, participants were asked not to try and move the bottom half of their body as only the top half was being tracked. This helped to strengthen Embodiment and Agency. After a maximum of two minutes, participants were placed in the consultation room to speak to Emily. This was the first exposure to stimuli (*VRConsult*).

The consultation with Emily ranged from 4-7 minutes. After *VRConsult* experience, the participants were helped out of the HMD and given a Post VR questionnaire to fill out, which included a modified self-assessment Checklist (*VRPreCheckList*) taken from (Posner and Nakajima, 2011), modified self-assessment Likert-Scale on Delivering Bad News (*VRPreScale*) taken from (Vermylen et al., 2018) and a *Social Presence* questionnaire. More information on the questionnaires can be found in the Appendix C.

Following this, the participants were helped back into the Meta Quest Pro and either placed into the control condition, *NVPT*, where they did not have a body, or the treatment condition, *E_VPT*, where they were embodied with *Agency* in Emily's body. Here, they watched back their consultation.

When the consultation was finished, they were prompted that the experiment had ended and they could remove their headset. This was the second exposure to stimuli (*VREval*). They were asked to complete a Post-VR Evaluation Questionnaire (*VREvalQ*). This questionnaire consisted of a repetition of the first set of evaluation questions, the Checklist (*VRPostChecklist*), and the Likert-Scale on Delivering Bad News (*VRPostScale*).

Upon completion, Participants took part in a semi-structured interview (see Supplementary Materials for full questionnaires). To collect more qualitative information on their experience. Finally, participants were thanked for their time and excused.

The hypothesis for this study is as follows:

H1 *There will be a significant difference in Checklist Scores between Conditions.* E_VPT *condition would see a bigger drop.*

We think that being able to see the replay of their performance from the virtual parent's perspective (1st person perspective) would be particularly beneficial for their *Self-Evaluation*. Here, we hypothesise that the drop after *first-person perspective* will be bigger than in *third-person perspective* (**H1**).

H2 *There will be a significant difference in Checklist Scores between Roles. Doctors will rate themselves higher on the Checklist and BBN-Likert Scale than Nurses.*

Medical education for Doctors often focuses on diagnostic and procedural skills, with a growing emphasis on communication skills, and not all Medical schools include training on communication or empathy Camargo et al. (2019). Research from Barnett et al. (2007) indicated that while senior hospital doctors recognise the importance of breaking bad news, they often did not pursue courses in this area. In contrast, nursing education places a strong emphasis on patient-centred care and interpersonal communication, as nurses are trained to meet patients' physical, emotional, and social needs through communication. Nurses play a crucial role in breaking bad news by providing information, preparing patients, and offering support, though often the responsibility of delivering the news falls to physicians Piironen (2016). Therefore, our hypothesis (**H2**) posits a significant difference in Checklist Scores between roles after a VR Replay, with Nurses likely experiencing a greater decline in *Self-Evaluation* scores compared to Doctors, reflecting more critically on their performance.

H3 *There will be a significant difference in scores between* VRPreChecklist *and* VRPostChecklist*.*

We think being able to see the virtual consultation replay in VR, despite the perspective, would give participants an opportunity to reflect on their performance. We measure their *Self-Evaluation* of their performance with the checklist. We think that there would be a drop in their Checklist Scores after they see the replay of their performance (**H3**).

5.5.2 Measures and Analysis

Checklist Scores

To answer **H1** and **H2**, we took the 21-point checklist extracted from the guidelines for disclosure of adverse events developed by the CPSI and published by the CMPA. This questionnaire has been used in previous studies, (Posner and Nakajima, 2011). We removed three questions that did not apply to this use case, leaving us with 18 Checklist options. This questionnaire was given to participants after the first and second VR segments. We created a new factor *Checklist_Diff* by calculating the difference in score (percentage) between *VRPreChecklist* and *VRPostChecklist*.

Bad News Likert-Scale

To answer **H2**, we utilized a Likert Scale from (Vermylen et al., 2018). This gave us a 6-item self-reflection scale on Breaking Bad News, given to Participants after their first and second VR segments. The results were aggregated into factors of Overall Performance (*Pre_Overall*) and (*Post_Overall*) and Overall Empathy (*Pre_Empathy*) and (*Post_Empathy*).

Social Presence and Embodiment

Embodiment was factor measured by two items *BodyOwnership - Own* and *Agency - Move*. The Social Presence Questionnaire was an adaption of (Biocca et al., 2003) and consisted of items for Factors of Self Reported *Copresence* (*S_Copresence*), Perceived Other *Copresence* (*P_Copresence*) and *Telepresence*. We were also interested in reported feelings of *Nervous* and *Stressed* and how they would be impacted by *Role*.

Big Five Inventory

We collected participant data using the 10-item scale Big Five Inventory questionnaire (Rammstedt and John, 2007). This was taken to find if there is a relationship between *VRPreCheckList* and certain personality traits. All questionnaires are available in Appendix C.

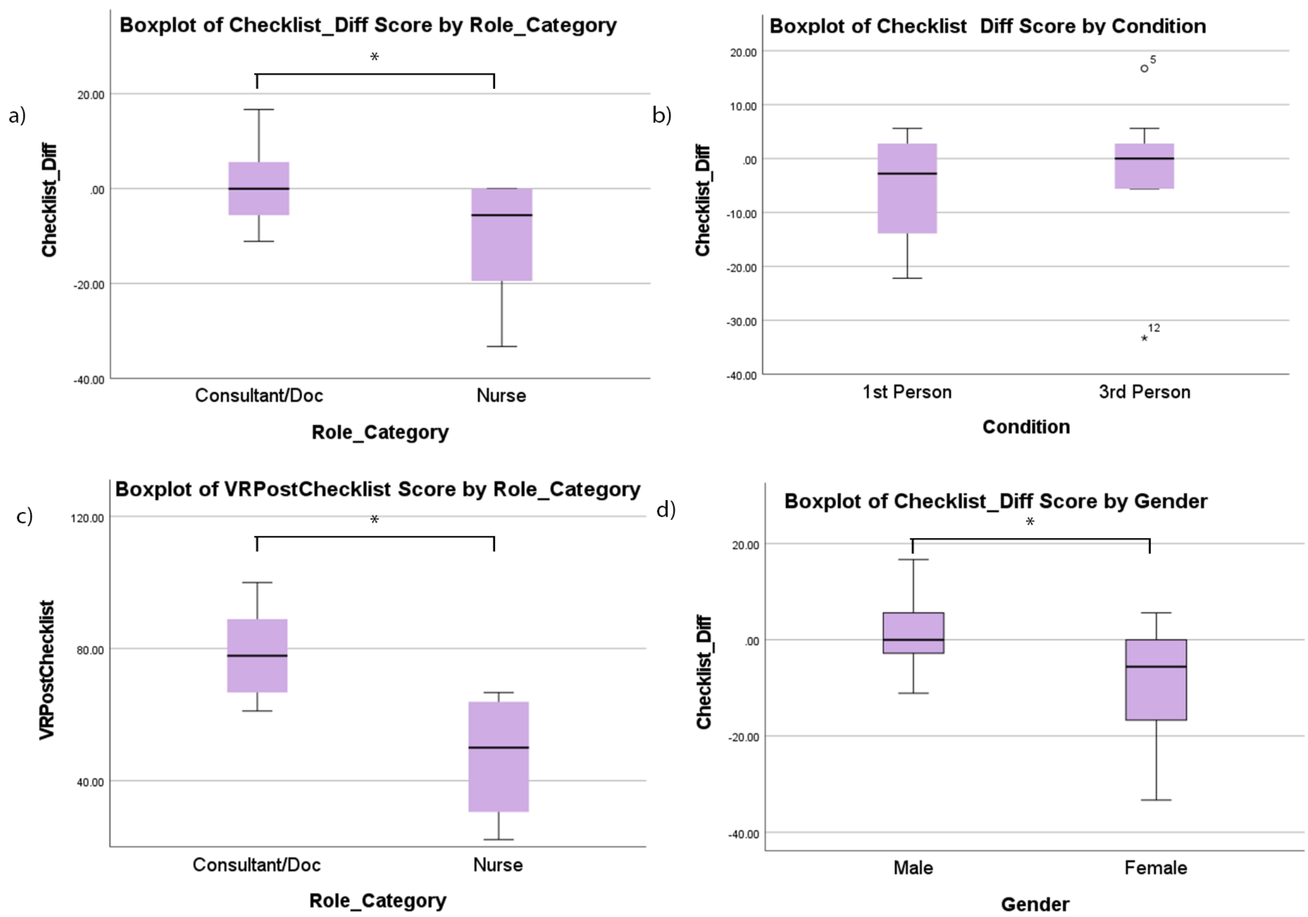


Figure 5.10: a) Boxplot of Checklist_Diff Score by Role, b) Boxplot of Checklist_Diff Score by Condition, c) Boxplot of VRPostChecklist Score by Role d) Boxplot of Checklist_Diff Score by Gender

5.5.3 Analysis and Results

Results for Checklist Questionnaire

In this section, we will discuss the results by *Condition*, *Role*, and then *Gender*. Multiple outliers were detected via visual inspection of a Boxplot. Therefore, we ran a Mann-Whitney U test to determine if there were differences in *Checklist_Diff* between conditions. Distributions of the Checklist scores were similar, as assessed by visual inspection. Median engagement score for $NVPT$ (-2.800) and E_VPT (0.0) was not statistically significantly different ($U = 37, z = .54, p = .592$). It is evident in Figure 5.10 that Participants rated themselves to have performed the same or worse, though slightly more apparent in E_VPT, which is what we expected in H1, but it is not significant.

We then checked to see if there was an effect using *Role* as a factor. An Independent-sample t-test was run to determine if there were differences in *Checklist_Diff* between *Role*. There were no outliers in the data, as assessed by inspection of a Boxplot. Scores for each level of *Role* were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), and variances were homogeneous, as assessed by Levene's test for equality of variances ($p = .086$). The Difference slightly increased with Doctors from baseline (1.2 ± 8.25) than Nurses, which fell from baseline(-11.1 ± 13.21); we can see from Figure 5.10 that there was a heavier drop in ratings from Nurses ($(1, 14) = 0.43, p = .037$).

An independent-sample t-test was run to determine if there were differences in *VRPostChecklist* between *Role*. There were no outliers in the data, as assessed by inspection of a Boxplot. Scores for each level of *Role* were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), and variances were homogeneous, as assessed by Levene's test for equality of variances ($p = .230$). Doctors rated themselves better (78.4 ± 14) than Nurses (46.8 ± 19.49) post *VREval* experience ($(1, 14) = 0.37, p = .002$).

An Independent-sample t-test was run to determine if there were differences in *Checklist_Diff* between *Gender*. Females showed higher reported levels of *Checklist_Diff* (4.11 ± 1.9) than Men ($2.00 \pm .816$), a statistically significant difference of ($t(14) = -2.111, p = .012.$). See Figure 5.10.

Results for Bad News Likert Scale Questionnaire

In this section, we will report the results of the overall performance of participants by *Role*, and then *Gender*. Due to violations of normality ($p < 0.05$) as assessed by Shapiro-Wilk's test, we ran a Mann-Whitney U test to determine if there were differences in *Post_Overall* between *Role*. Distributions of the Checklist scores were similar, as assessed by visual inspection. Median *Post_Overall* score for Doctors (4) and Nurses (3) was statistically significantly different ($U = 14, z = -2.3, p = .021$). It is evident in Figure 5.11 that Doctors rated themselves to have performed better. There was no significant difference in *Post_Overall* between *Condition* ($U = 44, z = 1.5, p = .117$).

An Independent-sample t-test was run to determine differences in *Post_Overall* between *Gender*. There was no significant difference found between genders ($U = 14, z = .826, p = .411$). See Figure 5.11

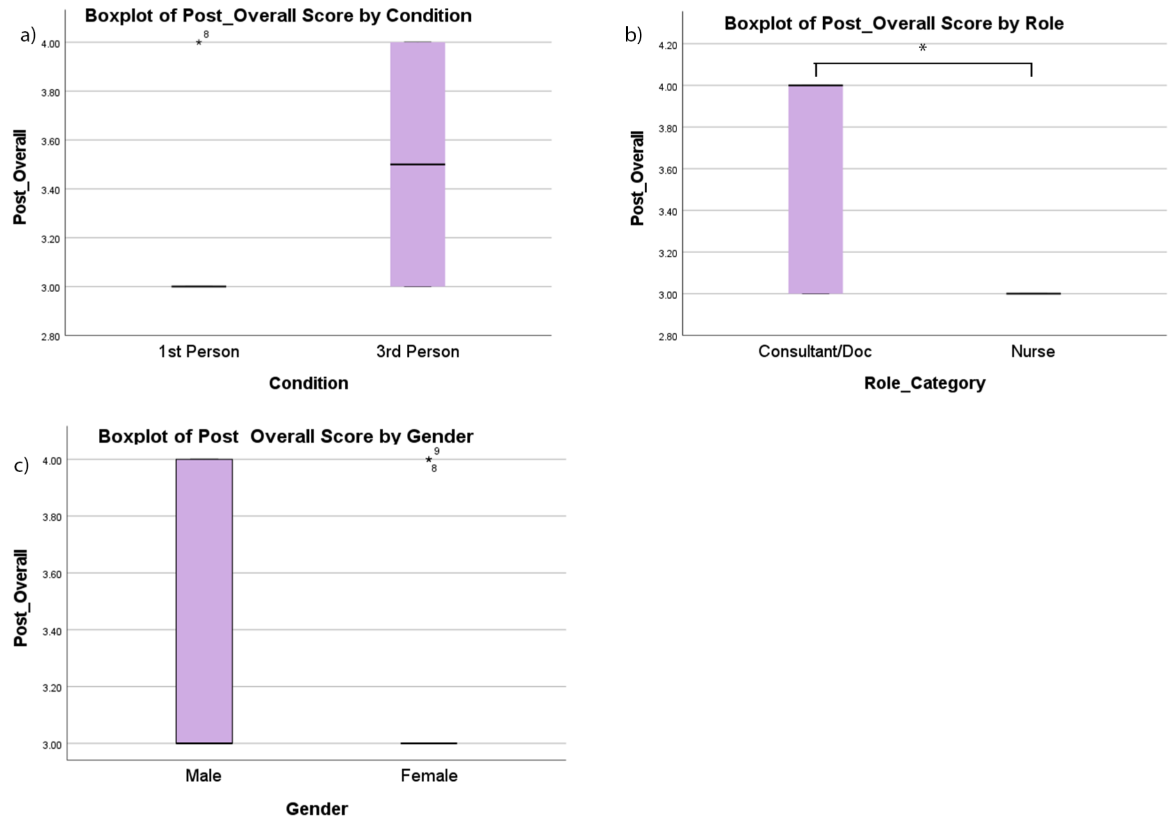


Figure 5.11: a) Boxplot of Post_Overall Score by Condition, b) Boxplot of Post_Overall Score by Role, c) Boxplot of Post_Overall Score by Gender.

In this section, we will report the results of the overall empathy felt by participants by *Role*, and then *Gender*. Multiple outliers were detected via visual inspection of a Boxplot, and therefore, we ran a Mann-Whitney U test to determine if there were differences in *Post_Empathy* between *Role*. Distributions of the Checklist scores were similar, as assessed by visual inspection. Median *Post_Empathy* scores for

Doctors (4) and Nurses (3) were statistically significantly different ($U = 7.5, z = -2.8, p = .004$). It is evident in Figure 5.12 that Doctors rated themselves to have more empathy.

Multiple outliers were detected via visual inspection of a Boxplot, and therefore, we ran a Mann-Whitney U test to determine if there were differences in *Post_Empathy* between *Gender*. Distributions of the Checklist scores were similar, as assessed by visual inspection. Median *Post_Empathy* scores for Males (4) and Females (3) were statistically significantly different ($U = 13.5, z = -2.138, p = .033$). It is evident in Figure 5.12 that Men rated themselves to have more Empathy.

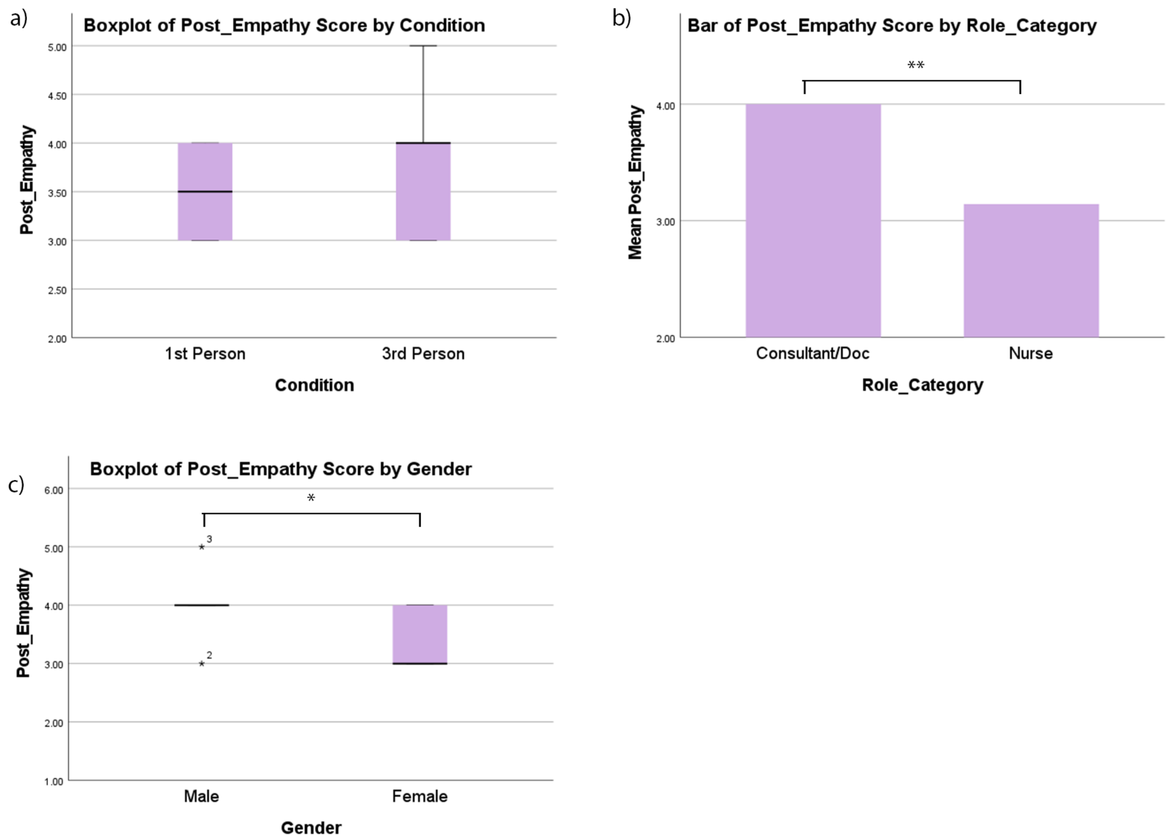


Figure 5.12: a) Boxplot of Post_Empathy Score by Condition, b) Boxplot of Post_Empathy Score by Role, c) Boxplot of Post_Empathy Score by Gender.

Results for Embodiment

In this section, we will discuss the results by *Role*, and then *Gender*. Embodiment was made up of two factors: *Body Ownership*(*Own*) and *Agency* (*Move*). An Independent-sample t-test was run to determine if there were differences in *Own* between *Role*. There were no outliers in the data, as assessed by inspection of a Boxplot. Scores for each level of *Role* were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), and variances were homogeneous, as assessed by Levene's test for equality of variances ($p = .248$). Nurses felt more *Body Ownership* (4.14 ± 1.9) than Doctors (2.44 ± 1.5), but the result was only slightly statistically significant ($t(14) = -2.01, p = .063$). There was no significant difference in *Agency* between *Role* ($t(14) = -1.53, p = .145$). See Figure 5.13

An Independent-sample t-test was run to determine differences in *Own* between *Gender*. Females showed higher reported levels of *Own* (4.11 ± 1.9) than Men ($2.00 \pm .816$), a statistically significant difference of ($t(14) = -2.111, p = .012.$). We can see from Figure 5.13 that Females felt more body ownership. There was a sign of slight significance in *Agency* ($t(14) = -2.02, p = .063.$). Females felt more *Agency* (4.56 ± 1.42) than Males (3.14 ± 1.35). See Figure 5.13.

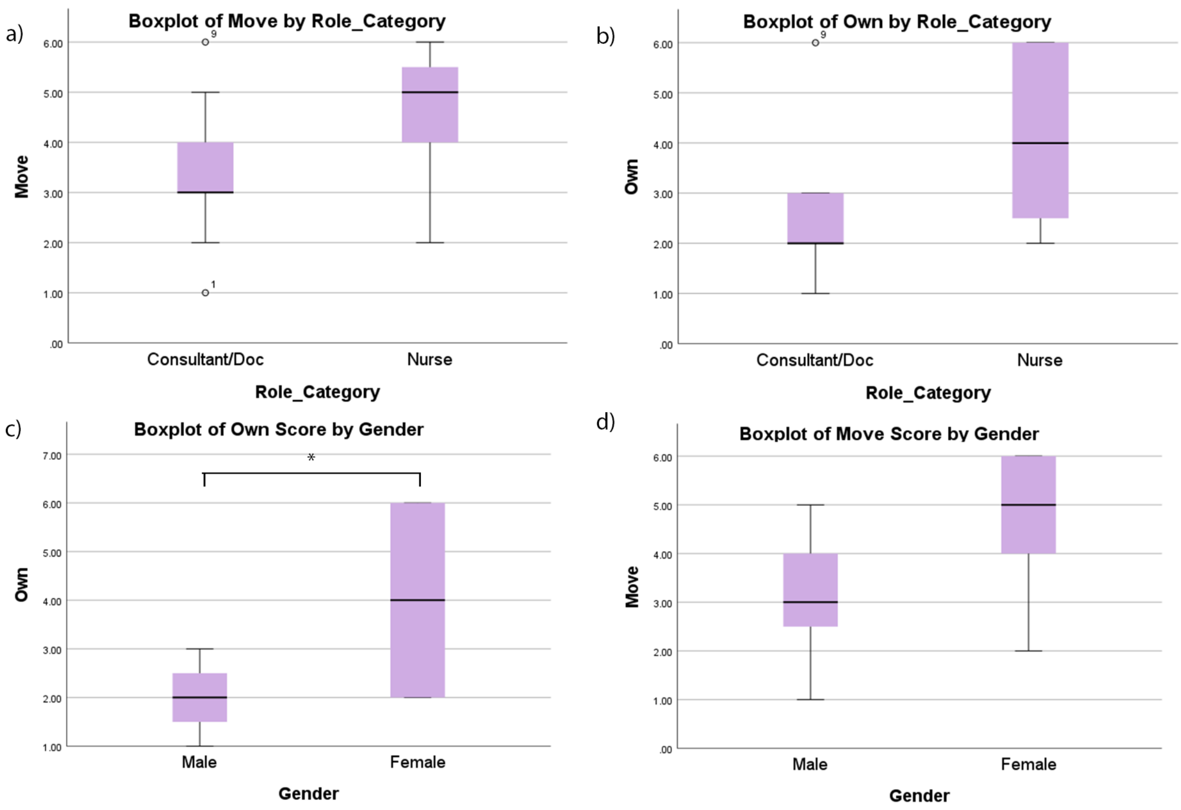


Figure 5.13: a) Boxplot of Agency (Move) Score by Role, b) Boxplot of Own Score by Role, c) Boxplot of Own Score by Gender, d) Boxplot of Agency (Move) Score by Gender

Results for Social Presence

In this section, we will discuss the results by *Role*, and then *Gender*. An Independent-sample t-test was run to determine if there were differences in the Social Presence factors; *S_Copresence*, *O_Copresence*, and *Telepresence*, between *Role*. There was no significance found in either factor; *S_Copresence* ($t(14) = .424, p = .679$). *O_Copresence* ($t(14) = 1.570, p = .139$). *Telepresence* ($t(14) = .000, p = 1$). This is evident in Figure 5.14.

An independent-sample t-test was run to determine if there were differences in the Social Presence factors; *S_Copresence*, *O_Copresence*, and *Telepresence*, between *Gender*. There was no significance found in either factor; *S_Copresence* ($t(14) = 1.167, p = .263$). *O_Copresence* ($t(14) = -.783, p = .447$). *Telepresence* ($t(14) = .562, p = 583$). See Figure 5.15

Results for Nervous, Stressed and Hard to Advise

In this section, we look at three questions asked on the survey to address further subjective feedback that could help us understand participants' responses to Emily, *Nervous*, *Stressed* - from the adapted *Social Presence* questionnaire above and *Hard_To_Advise* - a new additional question added. We will discuss the results by *Role*, and then *Gender*. An Independent-sample t-test was run to determine if there were differences in the nervousness between *Role*. Nurses showed higher reported levels of *Nervous* (5.86 ± 1.46) than Doctors (3.44 ± 1.74), a statistically significant difference of ($t(14) = -3.010, p = .011.$). There was no significance found *Stressed* ($t(14) = -1.604, p = .121$). This is evident in Figure 5.16.

An Independent-sample t-test was run to determine if there were differences in *Hard_To_Advise* between *Role*. Nurses showed higher reported levels of *Hard_To_Advise* (5.71 ± 1.73) than Doctors ($4.00 \pm .95$),

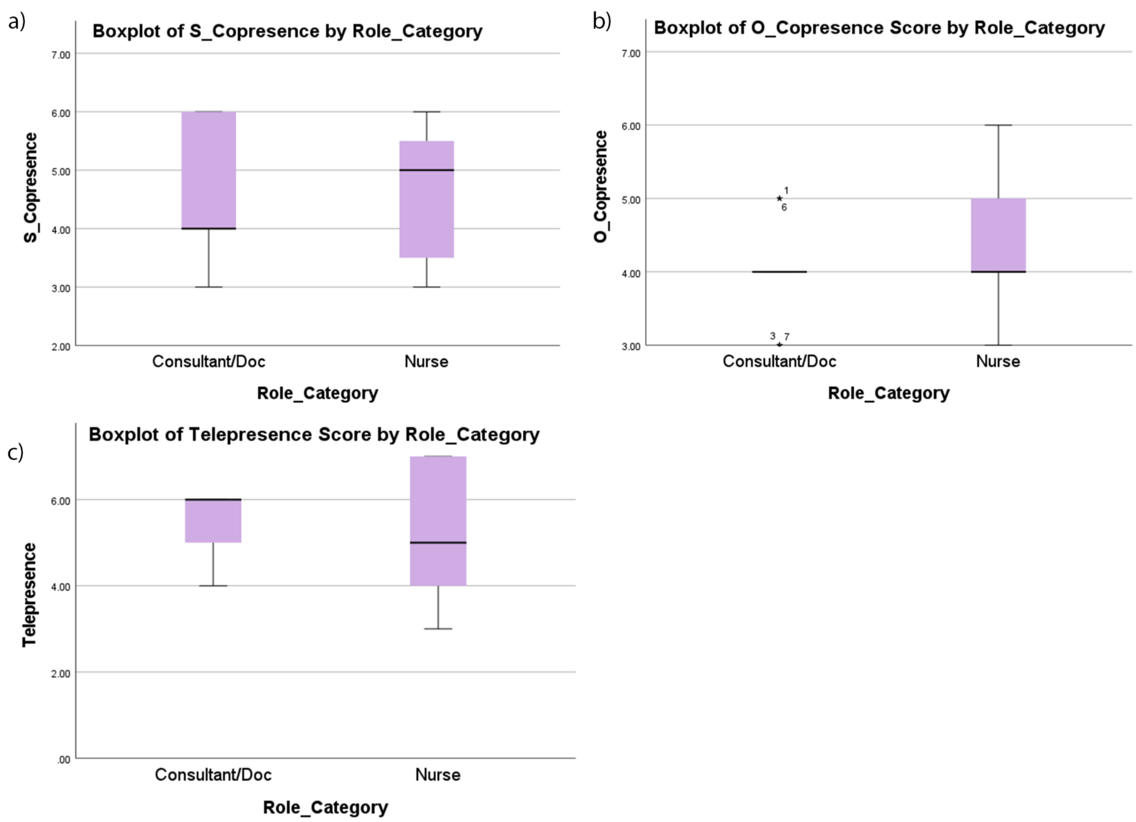


Figure 5.14: a) Boxplot of S_Copresence Score by Role, b) Boxplot of O_Copresence Score by Role, c) Boxplot of Telepresence Score by Role.

a statistically significant difference of ($t(14) = -2.346, p = .034$), see Figure 5.16.

An Independent-sample t-test was run to determine if there were differences in the nervousness between *Gender*. Females showed higher reported levels of *Nervous* (5.44 ± 1.81) than Males (3.29 ± 1.60), a statistically significant difference of ($t(14) = -2.483, p = .025$.). See Figure 5.17. There was no significance found with *Stress* ($t(14) = -1.204, p = .248$). There was also no significant difference found with *Hard_To_Advise* ($t(14) = -1.328, p = .205$). This is evident in Figure 5.17.

Results for Big Five Personality Questionnaire

The first test examined the correlation between *BFPQ_Nervous* and *Pre_Overall*. Preliminary analyses showed the relationship to be linear. Not all variables were normally distributed, as assessed by Shapiro-Wilk's test ($p < .05$), and there were no outliers. Therefore, we used Spearman's correlation test.

There was a statistically significant, negative correlation between how nervous- *Nervous_A* participants were and their rating on their overall performance - *Pre_Overall*, ($r(14) = -.59, p < .006$). The more nervous they were, the less they rated their consultation delivery; this is evident in Figure 5.18.

The second test examined the correlation between *Fault_Of_Others* and *Checklist_Diff*. Preliminary analyses showed the relationship to be linear. All variables were normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$), with no outliers. Therefore, we used the Pearson's correlation test.

There was a statistically significant, positive correlation between the level of fault participants found in others and their rating on the difference in Checklist scores ($r(14) = -.68, p < .004$). The more nervous they were, the less they rated their consultation delivery, as depicted in Figure 5.18.

The third test examined the correlation between *Relaxed* and *Pre_Overall*. Preliminary analyses showed the relationship to be linear. Not all variables were normally distributed, as assessed by Shapiro-

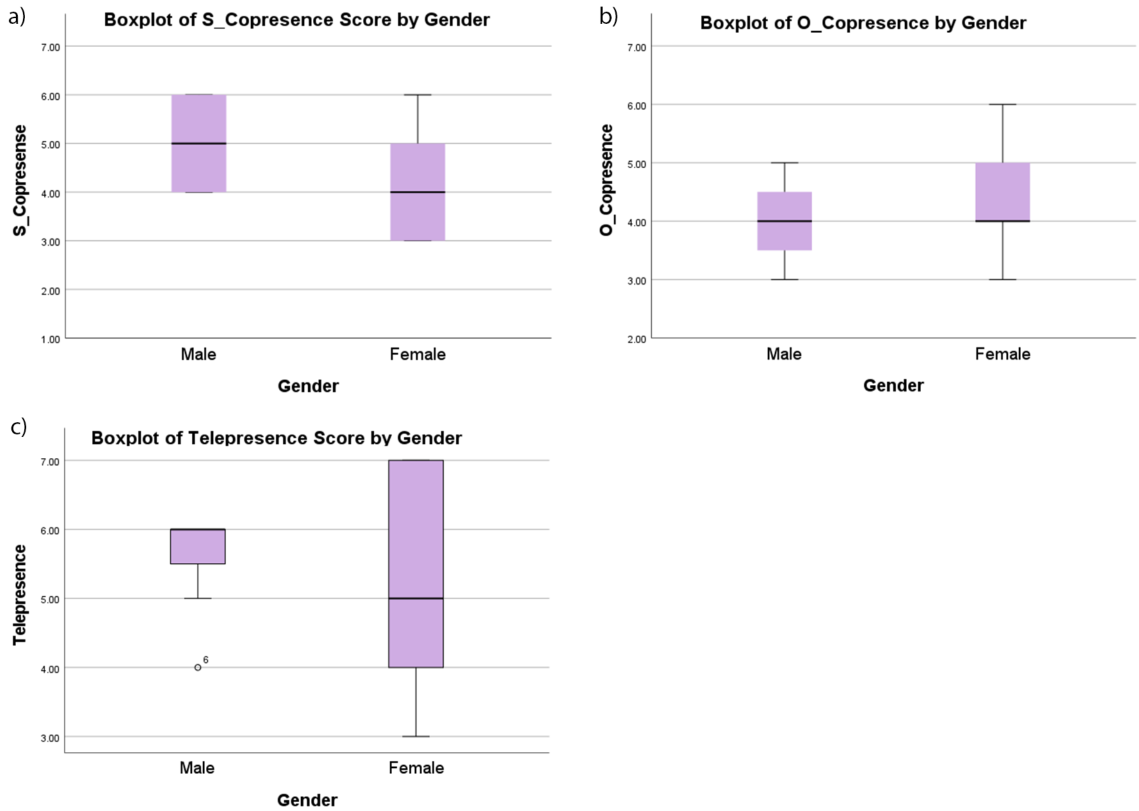


Figure 5.15: a) Boxplot of S_Copresence Score by Gender, b) Boxplot of O_Copresence Score by Gender, c) Boxplot of Telepresence Score by Gender.

Wilk's test ($p < .05$), and there were no outliers. Therefore, we used Spearman's correlation test.

There was a statistically significant, positive correlation between how relaxed participants felt they were and the rating of their overall performance ($r(14) = -.67, p < .005$). The more relaxed (not stressed) they were, the more they rated their consultation delivery. We can see this in Figure 5.18.

The fourth test examined the correlation between *Trusting* and *Hard_To_Advise*. Preliminary analyses showed the relationship to be linear. Not all variables were normally distributed, as assessed by Shapiro-Wilk's test ($p < .05$), and there were no outliers. Therefore, we used Spearman's correlation test.

There was a statistically significant, positive correlation between how Trusting - *Trusting* participants were and how hard they found it to advise Emily - *Hard_To_Advise*, ($r(14) = .68, p < .004$). The more trusting they were, the harder they found it to advise Emily. This is evident in Figure 5.18.

The rest of the factors of the Big Five Personality Questionnaire (BFPQ) were not significant. See Table 5.3 and 5.4.

Semi-Structured Interview

After the VR experience, we conducted a semi-structured interview with participants (not all practitioners could stay to finish it due to work commitments). Below, we list the key findings:

Self-Representation and Evaluation: Participants found the self-reflection component beneficial, "Getting the opportunity to watch yourself back is amazing...it's really fascinating," (P5), showing how VR can act as a mirror of oneself. Another mentioned, "I was quite surprised to hear how hesitant my voice sounded." (P16). One participant expressed surprise at their own appearance and body language, "Looking back at the video, my hands were so stiff, but I didn't really like that. Why were they like

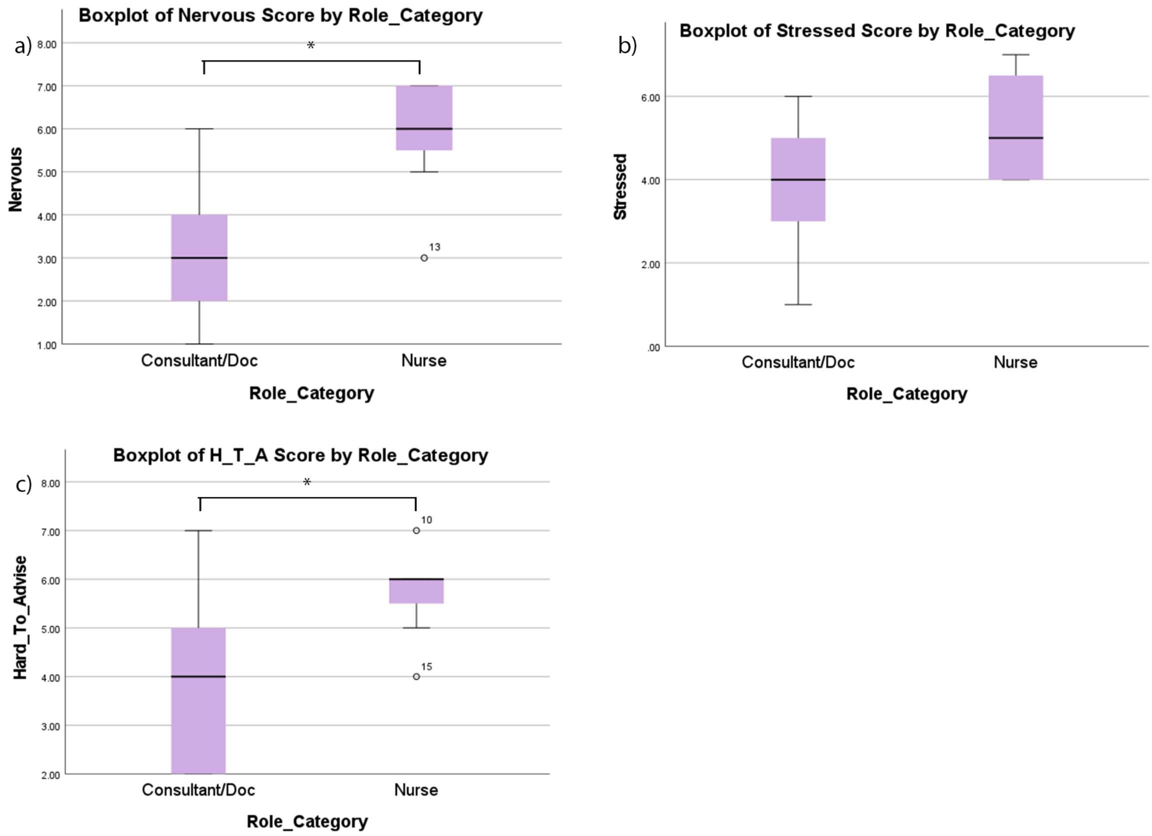


Figure 5.16: a) Boxplot of Nervous Score by Role, b) Boxplot of Stressed Score by Role, c) Boxplot of Hard_To_Advise (H_T_A) Score by Role

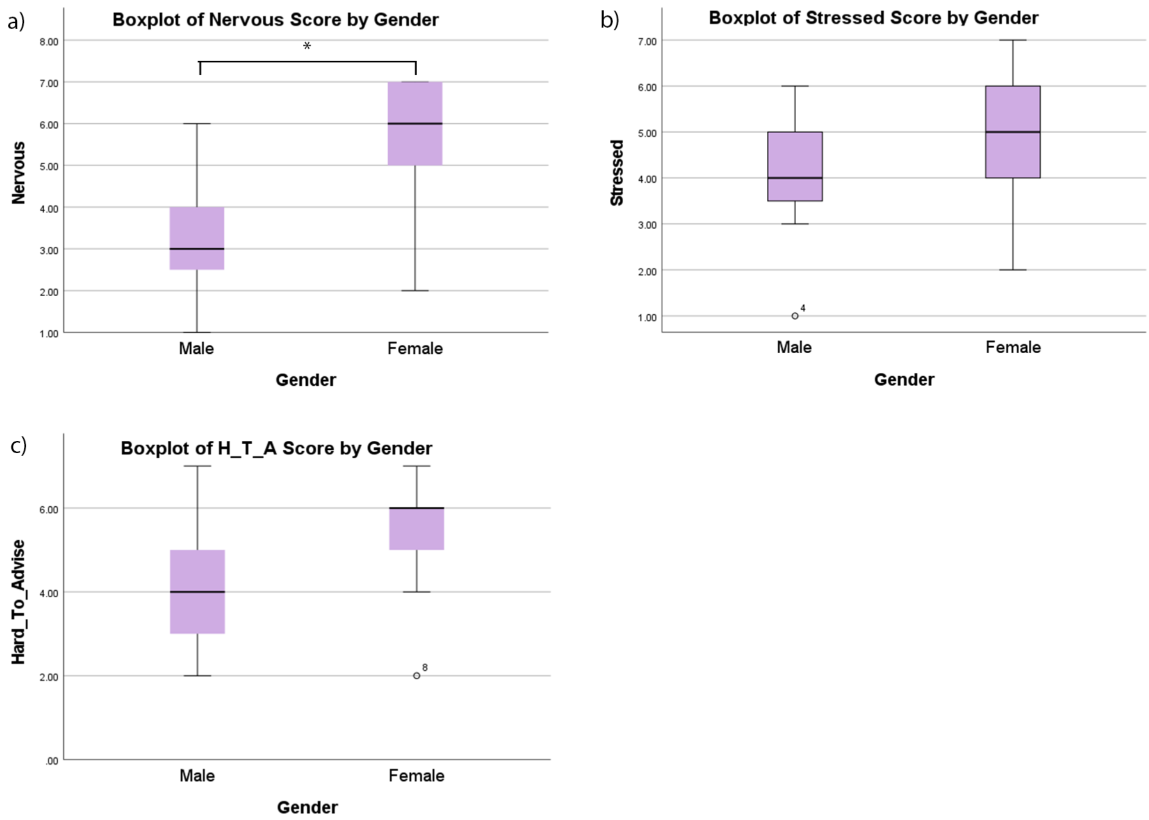


Figure 5.17: a) Boxplot of Nervous Score by Gender, b) Boxplot of Stressed Score by Gender, c) Boxplot of Hard_To_Advise (H_T_A) Score by Gender

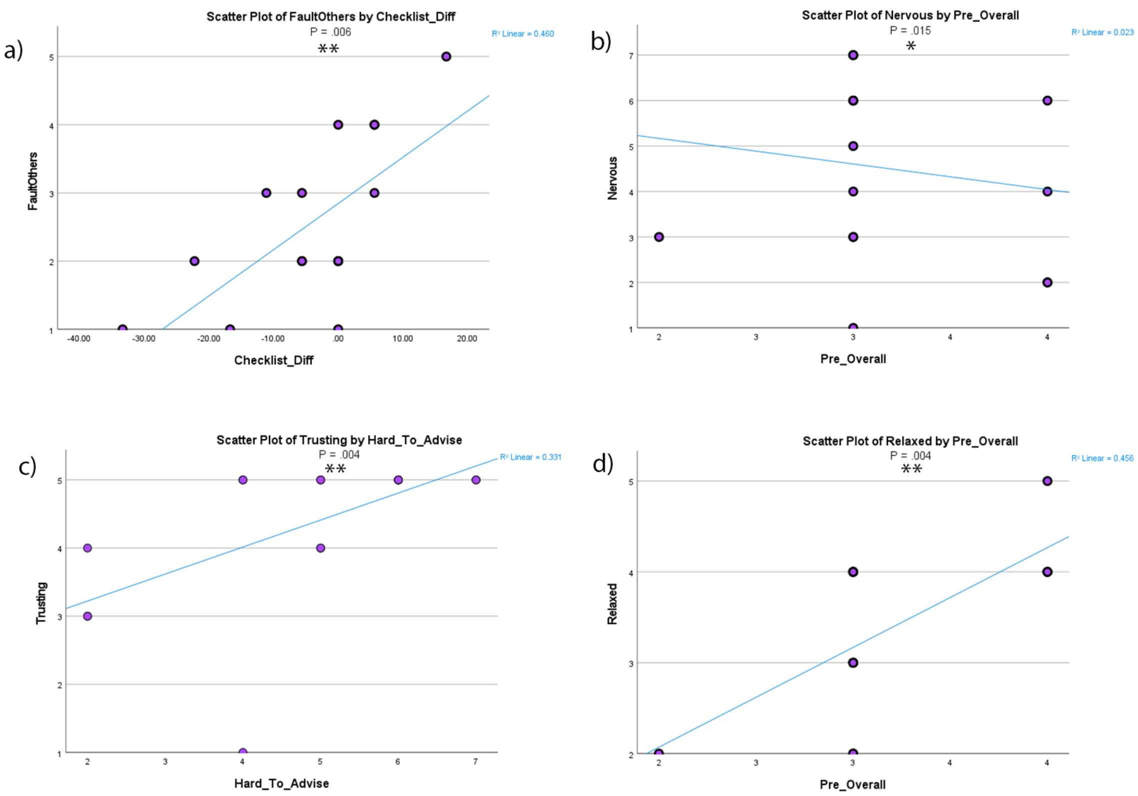


Figure 5.18: a) Scatterplot of Fault in Others by Checklist Difference, b) Scatterplot of Nervous by Pre_Overall Score, c) Scatterplot of Trusting and Hard_To_Advise, d) Scatterplot of Relaxed by Pre_Overall Score.

	Reserved	Trusting	Lazy	Relaxed	Artistic	Outgoing	FaultOthers
Reserved	NR	-.149	.081	.162	.054	-.059	-.107
Trusting	-.140	NR	-.257	.108	.098	.208	-.459
Lazy	.081	-.257	NR	-.200	-.193	-.149	-.078
Relaxed	.162	.108	-.200	NR	-.036	.651**	-.032
Artistic	.054	.098	-.193	-.036	NR	-.023	.169
Outgoing	-.059	.208	-.149	.651**	-.023	NR	-.188
FaultOthers	-.107	-.459	-.078	-.032	.169	-.188	NR
Thorough	.322	.249	-.791**	.274	.135	.128	-.123
Nervous	.103	.109	.309	-.672**	.250	-.475	-.348
Imaginative	-.019	.029	-.010	.111	.328	.217	.075
Checklist_Diff	-.217	-.298	-.399	.141	.184	-.286	.679**
Hard_To_Advise	-.182	.680**	-.080	.141	-.027	.271	-.258
Pre_Overall_Rate	.067	-.388	.058	.670**	-.139	.309	.242
Pre_Overall_Emp	.176	-.458	-.073	.393	.057	.453	.312

Table 5.3: Correlations of main study variables part 1

	Thorough	Nervous	Imaginative	Checklist_Diff	H_T_A	Pre_Overall_Rate	Pre_Overall_Emp
Reserved	.322	.103	-.019	-.217	-.182	.067	.176
Trusting	.249	.190	.029	-.298	.680**	-.388	-.458
Lazy	-.791**	.309	-.010	-.339	-.080	.058	-.073
Relaxed	.274	-.672**	.111	.141	.093	.670**	-.073
Artistic	.135	.250	.328	.184	-.027	-.139	.057
Outgoing	.128	-.475	.217	-.286	.271	.286	.459
FaultOthers	-.123	-.348	.075	.679**	-.258	.242	.312
Thorough	NR	-.117	.242	.111	.038	.046	.092
Nervous	-.117	NR	.113	-.319	-.094	-.594*	-.435
Imaginative	.242	.113	NR	.030	.054	.401	.299
Checklist_Diff	.111	-.319	.030	NR	-.304	.104	.349
Hard_To_Advise	.038	-.094	.054	-.304	NR	-.249	-.223
Pre_Overall_Rate	.046	-.594*	.401	.104	-.249	NR	.554*
Pre_Overall_Emp	.092	-.435	.299	.349	-.223	.554*	NR

Table 5.4: Correlations of main study variables part 2

that?" (P2). These quotes evoke self-awareness that the VR simulation was able to prompt through the configuration of *Self-Representation* on this platform. The participant continued on, commenting, "I didn't really like how stiff I appeared. It didn't feel natural, and watching myself was a bit uncomfortable." (P2).

Realism and Immersion: The VR experience was praised for its realism, with participants commenting, "It's incredibly realistic. I mean, I felt like I was in there." (P5) and "It's like you're actually there. You can look around and see everything as if you're really in the hospital room." (P13). Experiencing a VR environment from an embodied stance can also change your perspective Banakou et al. (2013); one can argue that the *Embodiment* in the participants' work uniform increased plausibility, which has been tied to *Embodiment* previously (Skarbez et al., 2017).

Emotional Impact and Stress: The simulations evoked strong emotions, "It was very stressful, very stressful" (P4) and "I could feel myself shaking a bit...I was really nervous" (P7), highlighting the provocative and emotional realism of the VR scenarios.

Authenticity of Interactions: Authenticity was a noted strength, "The mom's conversation was very realistic. "(P15). Others felt realism could be enhanced by more dynamic interactions, "Sam moving and interrupting would be really good." (P5).

Utility in Professional Training and beyond: The practical applications of VR were widely recognised, "This cancellation one is definitely a big one..." (P7), "..It would be really good to have for staff-to-staff conversation." (P16).

5.6 Discussion and Conclusion

It's important to note that the results reflect self-judgement scores that don't correlate with real performance; however, they should be seen as informal observations of *Self-Efficacy* similar to data collected in (Ammentorp et al., 2007).

In this study, 16 participants took part in a consultation with Emily in IVR. After the consultation, they could view their performance in E_VPT or $NVPT$.

Overall, the results suggest no difference in evaluation ratings due to *Perspective* rejecting **H1**. More research needs to be done on exploring configurations of EVPT for Self-Evaluation. Doctors were quite confident in their overall performance and less willing to find fault in their conduct during the consultations. The difference between their evaluation *Checklist_Diff* was mostly the same, if not slightly improved. They significantly rated themselves with higher performance in both the *Checklist_Diff* and *Post_Overall*. Nurses, on the other hand, experienced a statistically significant drop in Checklist ratings after *VREval*, suggesting that they believed, on average, that they performed worse than what they initially expected; this rejects the null hypothesis of **H2**. This is important feedback as this implies that Nurses could benefit from this format as they could be more inclined to acknowledge errors. Data revealed that Nurses felt significantly more nervous talking to Emily than Doctors and felt she was hard to advise - Figure 5.16. Other studies have pointed out that to gain patient confidence in their new roles, Nurses must be both confident and competent in their own abilities (Rashid, 2010). This could also be an effect of Gender, as shown in Figure 5.10, that there was a significant difference between Gender for *Checklist_Diff*, where women had more drop-in ratings than men. This score mimics the results of *Role*;

It's important to note that there were only Female Nurses ($n = 7$), and the majority of Males were Doctors (Male Doctors $n = 7$, Female Doctors $n = 2$). This complicates the attribution of performance disparities solely to professional Roles or Gender.

To gain a more comprehensive understanding of the factors contributing to these observed differences, further research may be needed, such as controlling for Gender within each professional group or considering additional variables that could be at play, such as experience, training, or other relevant factors. This would help disentangle the complex relationship between professional Roles and Gender in this investigation.

Results could suggest an impact of confidence levels on *Self-Efficacy.* Looking at the Correlation Table 5.3 and 5.4, results suggested that the more relaxed (not stressed) the participant was, the more they rated themselves in *Pre_Overall_Rate* and a negative correlation was present suggesting that the more nervous participants rated themselves, the lower the rated their overall performance. This outcome was observed in the context of a Partial Pearson's Correlation Matrix Analysis, which included the factor of *Role.* The absence of *Role* as a significant factor in the data in this context implies that it did not have a substantial impact on this discovery. More research, therefore, should be done to investigate whether iterative training with feedback can potentially provide the confidence to handle these cases regardless of Role and experience.

In this Chapter, we address our third research question of this thesis - *What impact does the configuration of Embodied Virtual Perspective-Taking have on learning processes such as Self-Evaluation?* Though the results did not support the third thesis hypothesis **(H3)**, configuring Perspective-Taking through a first-person perspective versus no-Avatar third-person perspective did not result in a significant negative difference in *Self-Evaluation* in the dimension of *Self-Efficacy*, the findings reinforce the value of using *Embodiment* as a tool in Medical training while also highlighting the need for ongoing optimisation and research of high-fidelity sensory and visual congruency to fully realise the potential of VR for professional development.

In the next Chapter, we discuss additional studies that were completed during the course of this PhD, which aligns and gives further insight into our research questions.

Chapter 6

Related Additional Research

This chapter will detail additional work which has impacted and influenced the research in this thesis. There are two studies which will be discussed. The full study and all acknowledgements will be included in Appendix D.

6.1 Evaluating Quality Experience through Participant Choices

6.1.1 Contribution

This study was done during my time as a research assistant for USTechSolutions at Meta. I contributed by running the participant sessions alongside another researcher, who is the first author and lead researcher on this project. I also helped sculpt the methodology as well as write segments of the report. This work has been added to the additional works, though I was not the initial lead for the study; it still relates to the work done in Chapter 3.

6.1.2 Summary

When building VR applications, developers and product teams must decide between different hardware and/or software aspects to find the right features for their use-case. This is usually based on presumptions and empirical evidence and does not involve the users' contribution, as it is difficult and time-consuming to gather feedback for each possible scenario to inform the process. In this study, we extended a framework for assessing how select factors may contribute to the quality of experience in an example evaluation. For this iteration, we considered how four factors related to Avatar expressiveness affect the quality of experience: Eye Gaze(EG), Eye Blinking(EB), Mouth Animation(MA), and Micro-Expressions(ME).

55 participants experienced an *Agent* delivering a presentation in VR. At fixed times, participants had the opportunity to spend a virtual budget to modify the factors to improve their quality of experience incrementally; however, they were given a maximum of 7 budget units to use, and each of the four factors had three levels of implementation. They could stop making transitions when they felt further changes would make no further difference. They had up to 7 transitions to make a change. A Markov matrix was built from these transitions, along with probabilities of a factor being present at a given level on participants' final configurations.

Most participants did not spend the full budget, suggesting a point of equilibrium was reached that did not require maximising all factor levels. After the 1st transition, the most likely changes were to Eye Gaze and Mouth Animation. By the 5th transition, the most likely configuration had at least each factor at level one (out of three). Overall, the group's most likely final configuration was EG (2), EB (1), MA (1), and ME(1). This configuration could be recommended to groups looking to implement a 1:1 presentation experience using Immersive Virtual Reality at the lowest effective threshold.

This research supports and extends previous work utilising this methodology (Skarbez et al., 2017). Moreover, it highlights the importance of acknowledging the users' criteria and presents a method for gathering participants' preferences in real-time; the data could then be used to inform decisions regarding investment into features and other attributes of VR applications. Full details of this study can be found in Appendix D.

This work supports the methodology from Chapter 3, which looks at the impact that different configurations of *Consistency* in *Agency* can have on the feelings of embodiment in virtual reality. The results suggested an interaction effect of arm and lip, showing reports of higher levels of *Embodiment* with the consistent as compared to the inconsistent conditions. Though this study focuses on the 'other's implementation of visual fidelity, both findings still suggest that there are configurations below the presumed high fidelity in behaviour realism that are enough to deliver the same level of *Presence* to the user. This study also supports work in Chapter 5 as Gaze and Mouth Animation were critical to Emily's implementation to feel like a believable character.

6.2 A Study of Professional Awareness Using Immersive Virtual Reality: The Responses of General Practitioners to Child Safeguarding Concerns

6.2.1 Contribution

I joined this research project as a research assistant and technical support for the VR lab at University College London (UCL). This study was run with support from Great Ormond Street Hospital. In this research study, I assisted in the recruitment effort by creating material to share across different platforms. I ran the participant sessions alongside another researcher and kept maintenance on the testbed's Unity application build. I also made a small contribution to the written report. This study was not included in the main body as I was not the lead researcher; however, my experience during this project influenced the last research investigation for this thesis (see Chapter 5).

6.2.2 Summary

Recognising the indications of potential child abuse within a household is a skill reliant on various non-cognitive abilities, making it challenging to impart through conventional teaching methods. Additionally, its study is hindered by the numerous factors that can impede the application of this skill in a professional, real-world context. To address these challenges, we employed an immersive virtual reality environment for our investigation, involving 64 general practitioners (GPs) with varying levels of experience. Our primary objective was to assess whether the level of experience affects the ability of GPs to discern child-safeguarding concerns. We sought to understand whether more experienced GPs would exhibit greater proficiency in identifying subtle, as opposed to overt, signs of child-safeguarding issues.

Several external factors may influence the practical application of these skills in real-life scenarios, such as the stress levels of GPs. Moreover, understanding how these factors could impact the capability of GPs to identify subtle indicators of child-safeguarding concerns is particularly intriguing, as these signs may not always manifest blatantly in a public setting.

In this study, 64 practitioners were recruited with different levels of experience. The main measurement was the quality and detail of the GP's note at the end of the virtual consultation. After the experiment, a panel of 10 practitioners experienced in child Safeguarding regulations was asked to rate the feedback of the GP notes depending on how functional it was in identifying the necessary steps required concerning the child safeguarding concerns. The cognitive load level (defined by the parents' condition's complexity) was manipulated to see whether stress could also play a factor. The experiment was run using CAVE, and the *Semi-Autonomous Agents* displaying the child and parent were controlled using the 'Wizard of Oz' technique, which involves a researcher remotely controlling responses using a supporting user interface.

Results showed that professional experience did not determine a GP's ability to address those concerns. However, the parents' level of aggression toward the child showed evidence of having an influence. While cognitive load did impact GPs when the parents' aggression was more obvious, it was not significant. Furthermore, the results also suggest that GPs who are less stressed, less neurotic, more agreeable and extroverted tend to raise potential child abuse issues in their notes. These results not only point to the considerable potential of virtual reality as a training tool, but they also highlight avenues for further research, as well as potential approaches to support GPs in their dealing with highly sensitive, emotionally charged situations. Full details of this study can be found in Appendix D.

This work informs the future work discussed in Chapter 5 by first validating virtual reality as a platform for training and learning in the medical field and giving evidence of using it as a tool for self-reporting. In this experiment, after the participants completed their consultation simulation, they watched their performance on a laptop gathered by a camera hidden within the CAVE setup. In our project, we will extend this by using a fully immersive setup with an HMD. Instead of showing the participants their performance back from a video, we will immerse them back into the scenario from a different perspective using *Embodiment*. The hypothesis is that *Virtual Embodied Perspective-Taking* could significantly affect *Self-Efficacy*.

Chapter 7

Conclusions

7.1 General Discussion

In this body of research, we exploited IVR to investigate the relationship between different technical attributes of *Self-Representation* - such as *Visuomotor* mechanics and Avatar representation, and its psychological impact on participants and their perceptions of others. As an additional contribution, we also leveraged findings and gaps from the literature surrounding *Embodiment* and consistency in VR to curate a new framework, '*Embodied Consistency*'. We validated the dimensions of *Sensory Consistency* and *Co-Visual Consistency* within our first two studies. We employed novel and extended methodologies, which enabled us to explore the psychological impact of different configurations of *Embodiment* with *Self-Avatars* in both Solo VR and Social VR.

Finally, we performed an exploratory small study with a high-fidelity Medical Communication Training platform, looking at the impact of different configurations of Perspective-Taking on *Self-Evaluation*, producing a novel technical pipeline for a plausible social interaction with a *Semi-Autonomous Agent* in a simulated Paediatric ward.

We conducted three experimental studies in this thesis, discussed in Chapters 3, 4 and 5. Based on our results, we can now gain insight into our research questions and defend our proven thesis hypotheses.

7.1.1 R1: What amount of sensorimotor inputs and configuration of synchronicity is necessary for *Embodiment*?

Hypothesis 1: Synchronised Visuomotor configurations of Arm tracking and Lip-Sync will invoke higher feelings of Embodiment within the dimensions of Agency and Body Ownership.

In 2012, Kilteni defined the *Sense of Embodiment*, supporting VR research with an additional contribution outlining a strategic way of measuring the phenomenon through the *Sense of Body Ownership*, *Sense of Agency* and *Sense of Self-Location* (Kilteni et al., 2012a). Previous studies have shown that when there is accurate *Visuomotor* synchronicity between the participant and the *Self-Avatar*'s movement, there is an increase in *Body-Ownership* and *Agency* (Dewe et al., 2024). Research has also depicted when designing scenarios mainly involving interactions that visual fidelity isn't necessary for high *Agency* (Lougiakis et al., 2020; Zhang et al., 2020); however, it is more useful for *Body Ownership* (Argelaguet et al., 2016) - that is why there are active experiences on the market for fitness and high-intensity gaming that successfully embed partial limb or low poly *Self-Avatar Embodiment* into their configuration of *Self-Representation*, it's saving on computational costs to implement a simpler set up of a *Self-Avatar* when there are higher Top-Down contingencies. The aim requires higher synchronicity and feedback.

We also know from previous research that aligning a virtual body with the participants' own in VR can be enough to enable strong feelings of *Body Ownership* and *Self-Location.* Still, we see stronger results

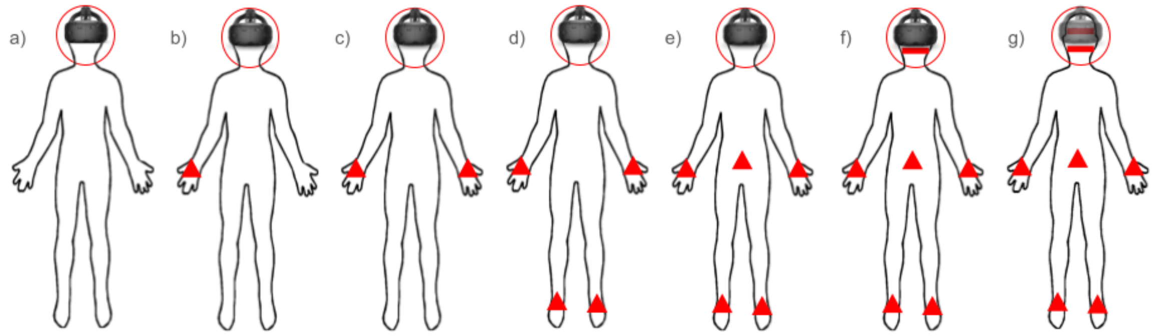


Figure 7.1: Examples of other sensory integration configurations of low to high immersion. Tracking: a) Head, b) Head + Hand, c) Head + Hand(s), d) Head + Hand(s) + Feet, e) Head + Hand(s) + Feet + Pelvis, f) Head + Hand(s) + Feet + Pelvis + Lip-sync, g) Head + Hand(s) + Feet + Pelvis + Face (Lip-sync + Gaze + Micro-expressions)

from those that use a more realistic, humanoid *Self-Avatar*(Slater et al., 2008). Many earlier experiments of the 'Rubber Hand Illusion' using Semi-Immersive VR (projection) also support this hypothesis, as they utilised static portrayals of the virtual hands that relied on *Visuo-proprioception* and *Visuotactile* mechanics to induce *Body Ownership.* In current literature, there is still support for high fidelity *Self-Avatars* but also a defence of simpler designs if there is a balance of visual and behavioural fidelity (Ma and Pan, 2022; Garau et al., 2008).

Many theories state that the use of Mirrors can enhance this effect, but this has still not been validated; the empirical belief is that it supports the priming of body perception to a virtual body (Jenkinson and Preston, 2015; Gonzalez-Franco et al., 2010; Slater et al., 2010) and so has been used in this study, but it has seen better success as a tool of modifying the perception of the body schema (Dunn et al., 2017).

We see a need for a framework to help developers weigh investment vs cost of configuring a *Self-Avatar* via the understanding of the impact of different thresholds of sensory input and congruence. Currently, in the market, we have a wide range of multi-sensory integration through VR Headsets and additional third-party sensors, see Figure 7.1. Still, as we have acknowledged, not all are necessary to induce *Embodiment* in every application. In examples of previous literature looking at delivering a presentation or speech, there has been a focus on facial animation (lip-sync) and arm movement (Murcia-Lopez et al., 2020; Gonzalez-Franco et al., 2020), so we focused on the configuration of these two sensory integrations.

Our research investigated the possible effect the relationship between consistency and *Visuomotor* mechanics could play on the illusion of *Body Ownership* and *Agency.* In other words, whether *Embodiment* can be impacted by synced or a-synced control over both lips and arm movement. This study also informed our *Embodied Consistency* framework, giving insight into the use and impact of *Sensory Consistency.*

Thirty participants took part in a controlled experiment where they were asked to deliver a job interview speech into a Mirror whilst in different configurations of arm and lip tracking (one on and one off, or both on or both off). Moreover, the setup was done with easily accessible resources, making it very repeatable. Motion Capture was done using the Kinect version 1, and the application was built using Unity3D with the Oculus Rift DK1, providing full immersion into VR.

There was no significant difference in results within conditions with just arm movement or lip-sync enabled - this suggests that participants in this sample were impartial to both for this task. Results showed an interaction effect between the arm movement and lip-sync with the component 'MOVE'. There were higher levels of *Embodiment* in consistent conditions; the consistent conditions were when both the lip and arm movement were synced or a-synced, and the inconsistent conditions were when only one of them was synced, not supporting **H1**. Additionally, over all variables, there was a pattern of higher *Embodiment* with consistent conditions. Though insignificant, it still indicated that participants felt more *Embodiment* over the *Self-Avatar* when both factors were present or off. Suggesting the overall positive impact of *Embodied Consistency*.

This study supports previous literature suggesting that a base level of *Visuo-proprioception*, combined with Top-Down mechanics such as human-likeness, is sufficient to evoke *Embodiment*. This has been evident in other studies focused exclusively on implementing Head-Tracking (Pan et al., 2016). Additionally, this study utilised a Mirror, allowing participants to see their facial features. Although there was no explicit evidence to suggest an impact on *Embodiment*, we can infer that it did not hinder it either. The use of the Mirror provided *Visuomotor* cues of asynchronous (or no) lip-sync and arm movement. Nevertheless, results from this environmental configuration still indicate a higher level of *Embodiment*. It enabled participants to assess their *Self-Representation* and refine their *Self-Perception*. We employed high-fidelity humanoid *Self-Avatars*—characterised by a high degree of human-likeness. According to previous literature, this should have been sufficient to evoke *Body Ownership* (Slater et al., 2008), and our findings confirm this in this study. Regarding *Agency*, however, this study both challenges and contributes to the literature, indicating that congruence over *Visuomotor* higher fidelity could elicit increased *Agency*. There are few studies examining arm and lip configurations together, making this an intriguing contribution to the sensory-motor literature.

7.1.2 R2: How can inconsistent and consistent configurations in *Self-Representation* have varying impacts on *Social Presence*?

Hypothesis 2: Inconsistency between Avatar configurations of Embodiment will have negative effects on Social Presence in dimensions of Trust.

As we saw in the first study, consistency over the sensory integration was more effective at provoking *Embodiment* than inconsistent configurations of the two factors, lip-sync and arm movement. However, this experiment was done only considering the *Self-Avatar* in a single user testbed; in this second investigation, we looked at not just sensory congruence but another factor debated in the literature, visual *Self-Representation*, particularly in shared environments. We know already from previous literature that having a *Self-Avatar* in comparison to no-Avatar can lead to heightened *Embodiment* and, by theory of *The Proteus Effect* (Yee and Bailenson, 2006), when you are embodied in a *Self-Avatar* divergent to your own self in some attribute, this can impact behaviour within that state of *Embodiment* (Kilteni et al., 2013) or post the experience (Banakou et al., 2013; Peck et al., 2013). This result was expanded upon within the literature regarding *Social Presence*. Pan and Steed found in a 2017 study that when participants were paired to play a collaborative game in Immersive VR, those paired with configurations of a full *Self-Avatar* felt more subjective levels of trust towards each other (Pan and Steed, 2017). Additionally, Yee depicted in their work in 2007 that when participants with taller *Self-Avatars* were engaged in negotiation tasks, they exhibited increased confidence (Yee and Bailenson, 2007). We understand from the literature that there can be a mediating effect on how an individual person's *Self Avatar* is configured, which impacts behaviour and cognitive approaches to others, therefore also impacting attributes of *Social-Presence* such as trust, positive and negative impressions. Nevertheless, it was interesting to see there were not many studies that looked at the inconsistencies between participant *Self-Avatar Self-Representation* in shared(multiple users) and social(*Agent* or Semi-Autonomous) environments. A research study in 2007 suggested that participants depicted delayed judgement on *Agents* with inconsistent conditions of humanoid appearance and human talk (Gong and Nass, 2007a). Latoschik introduced in 2017 an interesting result where seeing an *Agent* inconsistent with the aesthetic and realism of the participant's own influenced impressions of their own *Self-Perception* (Latoschik et al., 2017). The interaction of a wave between them helped to increase the suspension of disbelief for the respective Avatar owners, which could also add weight to the notion that Top Down mechanics, such as tasks, can mediate psychological effects like *Embodiment* and *Social Presence*. We became interested in how inconsistent and consistent *Self-Representation* can impact attributes of *Social Presence* and *Self-Representation*, we decided to test this in Chapter 4 to extend the research by Steed in 2017 and validate *Co-Visual Consistency* in our *Embodied Consistency Framework*.

This study was run in two parts, first with a confederate with 17 participants and second with 18 participants run in pairs. What we wanted to know is how *Consistency* would impact trust and other elements of *Social Presence*, as well as productivity during a task. The *Self-Avatar* conditions were being embodied in a full high fidelity human Avatar holding controllers, or just controllers. On the market right now, there are a multitude of different platforms that utilise a range of Avatar representations. Some range from high fidelity, such as *Engage*[1] to other more aesthetically abstract, which allow a full range of diverse representations, such as *Rec Room* with just disjoined hands and head, but studies have shown that is still enough for *Embodiment* (Kondo et al., 2018; Eubanks et al., 2020). Yoon and colleagues (Yoon et al., 2023) also suggest that Avatars with strong visual presence are not required in situations where accomplishing the collaborative task is prioritised over social interaction. This created an interesting dynamic to test the impact of this configuration on *Social Presence* but also the task itself.

In Study 1, we used a confederate. There is a conversation within literature outside of VR that suggests confederates could cause issues with experimental design due to familiarity and could cause suspicion due to uncontrolled non-verbal behaviour. Kulen advised that confederates are best used when the experimental task calls for the confederate partner to take the initiative as a speaker (Kuhlen and Brennan, 2013b). A study in 1970 also cautioned in results that experienced users will elect more suspicion than others due to being unable to 'keep it fresh' or act deviant (Martin, 1970b).

Trust was tested using both subjective and objective measures in order to get a robust result. Overall, we found that when the confederate is deceitful, there may be leakage of this into their body language, which becomes more obvious when they have an Avatar, provoking mistrust. It was interesting to see the effect of VR, as, to our knowledge, there are limited studies with confederates in the present research, as there is a conflict in the definition. Most studies depict confederates(virtual) as posing as real humans (de Melo et al., 2013). For example, De Melo's study showed results of successful social influence when participants believe the 'confederate' *Agent* is a human-controlled *Self-Avatar*.

We also found that consistency once again had a positive effect on trust and task productivity when run in pairs in Study 2; those in consistent conditions played faster, hinting at better collaboration calibrating with the thesis **H2**. This informed findings on the positive psychological effect of *Co-Visual Consistency* in *Self-Representation* within Social VR and contributed to research highlighting the risks of using confederates in Social VR experiments.

The scenario was built in Unity3D using the HTC Vive HMD for VR immersion. The high-fidelity Avatar models were the same as in Study 1, as they had a neutral appearance, though, in Study 1, they were wearing masks; this did not affect results. This study also highlighted the lack of robustness of using 'The DayTrader Game' as an objective measure of trust. More research is needed to find better alternative measures.

Just as in the literature, we found that the use of the *Self-Avatar* has a positive impact on *Social presence*. This is evident in the results as though both consistent conditions produced higher trust, the condition with the greater effect is where both participants have a *Self-Avatar* (Pan and Steed, 2017). The lack of a *Self-Avatar* did, however, have some effect on building a perception of the 'other'. In our semi-structured interview, we had feedback implying that when the participant didn't have a *Self-Avatar* and the other participant did, they felt this limitation to their *Self-Representation* made the experience feel different and less engaging, even though they'd interacted without a *Self-Avatar* before. Giving some support to theories of participants' embodied states affecting each other (Latoschik et al., 2017). Overall, we can see that this study supported previous theories of *Social Presence*, as well as adding foundational findings to suggest that inconsistency in *Avatar Self-Representation* can have a negative impact in social collaborative contexts in VR.

[1] https://engagevr.io/

7.1.3 R3: What impact does the configuration of Embodied Perspective-Taking have on learning processes such as Self-Evaluation?

Hypothesis 3: Configuring Perspective-Taking, an application of Embodiment through a first-person perspective versus no-Avatar third-person perspective will result in a significant negative difference in Self-Evaluation in the dimension of Self-Efficacy.

In Chapter 5, we take a look at *Embodied Virtual Perspective-Taking*. Perspective-Taking (in terms of body swap) involves a process of embodying a *Self-Avatar* and then being transferred into an embodied/disembodied alternative *Self-Avatar* within VR. This new embodied state usually provides a *Proteus Effect*. Either shifting perspective view (first or third) or shifting Identity. In Osimo's study, participants were shifted from their own photorealistic *Self-Avatar* into Sigmund Freud during a virtual therapy session. Results suggested that this type of setup could provoke participants away from habitual ways of thinking (Osimo et al., 2015). In a 2009 study by Raij and colleagues, they utilised *Embodied Virtual Perspective -Taking* in a mixed reality human called Amanda - a life-sized virtual human registered to a tangible interface (mannequin) representing a virtual human body. The participants wore an HMD to see the virtual body co-located with the mannequin. Participants were asked to do a breast cancer exam and then were able to watch the video of their performance from Amanda's perspective. Results showed participants reflected on their use of empathy and Perspective-Taking and felt encouraged to change their behaviour in future consultations (Raij et al., 2009). Inspired by this setup, we explored the configuration of this form of fluid *Self-Representation* in IVR within the first-person and third-person perspectives to examine the effect that this may have on evaluation metrics, such as *Self-Efficacy*.

The first study in Chapter 5 was informative in validating the technical pipeline of our Medical Communication Training platform (Codename VR:MCT) for *Plausibility* and *Place Illusion*, as these are critical fundamental attributes of skill transfer from Virtual Reality to real life. Three male and three female participants were randomly recruited from Great Ormond Street Hospital. After their VR consultation, they could watch their performance from the first-person perspective of Emily, the patient's mother. *Plausibility*, *Presence*, and *Co-presence* were measured via questionnaire. Results highlighted good reports of *Presence* and *Co-presence*, and verbal feedback highlighted the script as being a strong factor of *Plausibility*. There was feedback that participants weren't too aware of their *Embodiment* in Emily - the *Semi-Automated Agent*. Therefore, we added a priming Training session before a Mirror in the next study.

The second study gave us insight into the effect of *Embodied Virtual Perspective-Taking* on learning. The focus was on investigating the impact of the first-person vs third-person perspective on *Self-Efficacy* and the validation of our platform as a training and learning tool. Unexpectedly, results led to support of the null hypothesis; there was no significant difference between conditions on the change in *Self-Efficacy*. This is evident in Figure 5.10, which depicts the difference in Checklist Scores between the first and second ratings, *Checklist_Diff*. We can see that even though slightly more participants in the first-person perspective had a drop in scoring, it was not significant. This could be due to a small sample size, but perhaps other stronger Top-Down variables at play have an effect on the evaluation process. This is discussed in the following section.

The data did reveal interesting results when looking at the impact of *Role*. Doctors appeared to rate themselves the same or better after their first scoring, whilst Nurses had a significant drop in ratings after watching their consultation back in VR, see Figure 5.10. There was also an effect of *Gender*; to note, 100% of Nurses were female and 67% of Doctors were male, but results depicted that females rated themselves significantly lower after watching their consultation back in VR. More research needs to be done here in order to make a definitive statement on this effect.

Within previous research, the narrative empirically believed is that Doctors tend to hold more confidence in their roles, and studies have highlighted the need for Nurses to have more confidence in their own abilities (Rashid, 2010); the results show that Nurses found it significantly harder to Advise Emily than Doctors, see Figure 5.16. Looking at the correlation data, it is evident that there was a positive correlation between participants who felt more relaxed and the rating for *Pre_Overall*, but this effect was independent of *Role*, perhaps suggesting that confidence overall was a key variable in the outcome of impacting *Self-Efficacy*. Other literature has also noted this possible variable, and in similar studies outside of VR and in order to counter this effect, have added subject training for participants (Ammentorp et al., 2007).

Overall, though there was no effect of *Embodied Virtual Perspective-Taking* on *Self-Efficacy* in this context and configuration, rejecting **H3**, there was an interesting result that suggests that this training framework may be suitable for those who lack confidence in their skills. It would be interesting to run more research with participants with less experience.

In this study, though there was no evidence to suggest that first-person or third-person perspective has a significant impact on *Self-Evaluation*, there was support for the literature in highlighting that Perspective-Taking in VR can enable participants to think about their actions in new ways and encourage future behavioural improvement (Raij et al., 2009; Osimo et al., 2015). In the semi-structured interviews, we see that some participants felt uncomfortable watching themselves back due to realising how their body language appeared to Emily, making comments such as their 'hands were so stiff', and they were 'surprised to hear how hesitant' they sounded. The *Self-Representation* in VR was strong enough to bring self-awareness to provoke authentic *Self-Evaluation*. However, feedback also highlights technical limitations, which may have impacted results, as some did not feel that their movements were accurately captured and represented. Nevertheless, this research was still a good contribution to the literature, as there are limited studies with this methodology outside of using 360 videos.

7.2 Contributions

7.2.1 Theoretical Contributions

Self-Representation is a broad concept that can extend across the field of Social Sciences, as well as Psychological and VR research. Our initial contribution is the synthesis of these three schools of thought to frame the definition and evolution of *Self-Representation* in VR, as is outlined in both Chapter **??** and Chapter 2.

Existing frameworks in the literature surrounding the configuration of *Self-Representation* through *Embodiment* in VR have allowed researchers and developers to curate a wide range of experiences and open the door for further empirical investigations to refine our understanding of the mediating factors of the setups and the psychological impacts this could have. Key areas in the literature implicated in this thesis are sensory integration and Avatar realism. We were able to emphasise a core unifying dimension of consistency, which we coin *Embodied Consistency*, which has allowed us to curate setups in VR which explore how consistency enhances illusions such as *Body Ownership*, *Agency* and *Social Presence*.

This framework has set the groundwork for further research looking at the unique opportunities that VR offers across a range of accessible and complex technical pipelines. Mediating configurations of *Self-Representation* with congruency and synchronicity in mind can bridge low-level sensory integration and high-level psychological outcomes, providing a more holistic view of *Embodiment*. Additionally, it suggests a framework to study the psychological relevance of *Self-Avatar* characteristics and their consistency, for the first time in salience across different contexts, such as Solo VR and Social VR. This could lead to further research into the consistency of other configurations of sensory input within Social VR, such as whether consistency can mediate or enhance the acceptance of homuncular flexibility (modified virtual bodies). Moreover, now we know congruency may override fidelity - whether congruence with other combinations of sensory integration (i.e. mouth and feet, gaze and arms) can curate low-immersion but high-impact and accessible thresholds of *Embodiment*.

Context	Embodied Consistency	Consistent example	Inconsistent example	Results
Solo	**Sensory Consistency**	I see my body/body parts, it moves in sync	I see my body/body parts it moves async or no movement	*Congruency over Fidelity leads to higher subjective feelings of Body Ownership and Agency*
Social	**Co-Visual Consistency**	I see my body and their body	I see my body; I don't see their body	*Visual Congruency over Incongruency leads to higher Subjective feelings of Trust and higher performance collaboratively*

Table 7.1: Examples of dimensions of Consistency in Embodiment and the result from studies

Furthermore, we have extended our understanding of *Embodiment* as a construct and contributed to the field of *Agency*, adding more support to the notion of balancing Avatar realism with behavioural realism and added merit to the advantage of putting more effort into integrating consistency. Rather than immediately using photo-realistic models and immersive resources when not necessary, less can, at times, be more, and the threshold of plausibility may not always lie in higher fidelity but in understanding the balance of user expectancy. When both arms and lips were not moving in our experiment in Chapter 3, the participants still felt *Body Ownership* and *Agency*. We could argue that an understanding of a lack of movement in the body created no expectation of what should move. However, when arm movement was available, it created an expectation of other additional sensory input that could support their use of gestures missing. The use of a Mirror highlighted this to the participants more, though this priming technique is not always implemented in consumer applications. This is important for companies trying to create highly immersive first-person experiences to understand as this has proven to have both positive and negative effects on user experience, and adding advanced sensory input can become costly.

We have also observed the impact that consistency in Avatar representation has on collaborative tasks and *Social Presence* in VR. This extends the body of research that has already taken an interest in how Avatar representation can affect interaction by suggesting that consistency can also change how participants perceive each other in areas such as trust and other power dynamics. Non-verbal communication is critical in social interactions, and the mediator of what fidelity this becomes available is in the Avatar configuration. However, our research shows that lower fidelity cues can still be just as effective as long as it is consistent between the participants interacting, as our study in Chapter 4 showed that there was higher trust and collaboration evident in conditions where there was consistency, i.e., both had a body, or both did not have a body. We highlighted many areas of potentially continued research in this field whilst also testing out an extended framework of measuring trust using DayTrader and 'The Investment Game' in a new context (Pan and Steed, 2017), showing a potential lack of robustness in providing a reliable result.

Moreover, in Chapter 5, we contribute to the literature on *Embodied Virtual Perspective-Taking* or 'body-swap' to highlight the lack of impact between the first-person and third-person perspective on *Self-Evaluation* within VR. As this is still limited in the literature, this is an important fundamental finding that can allow researchers to build upon curating new ways of engaging evaluation through configuring *Self-Representation* in this context.

7.2.2 Methodology and Technical Contributions

This thesis explores novel methodologies that can be used for future experimental setups. Considering experimental design practices, our study in Chapter 4 has highlighted potential drawbacks to using confederates in conditions where they act deceitfully and have a *Self-Avatar* in VR. This supports other research that has warned of the risks of using confederates outside of VR (Martin, 1970a). In this context, it was significant as it caused feelings of distrust, which may impact other measured components. Though useful for dealing with small sample numbers, it is ill-advised in experiments which look to study social dynamics engaging with 'first introductions' in VR. More research must be done to extend the understanding of the limits of this potential hazard.

We introduced a novel methodology for *Self-Evaluation*in Chapter 5 within our third study to enhance *Self-Efficacy*. Previous studies have utilised Perspective-Taking as a tool for self-reflection; however, they have focused on using 360 videos for self-assessment. To our knowledge, this is the first study to attempt implicit self-reflection of performance through IVR. We implemented an out-of-lab, embodied ecological VR environment for plausible self-assessment with the expert consultation of Great Ormond Street Hospital(GOSH). Key milestones in the pipeline include working with Great Ormond Street Hospital(GOSH) to finalise the Script, working with Actors to pilot the dialogue with staff from GOSH, and recording Motion Capture data for Emily's character, see Figure 5.3. Participants responded realistically to Emily, as there was evidence in the qualitative data to suggest that they found her believable and hard to advise. There was also data to suggest participants found it similar to engaging in a real Face-to-Face meeting; see Figure 5.7.

For configuring *Embodiment*, we opted for a three-point IK rather than a full Motion Capture. Though hindered due to technical limitations in this investigation, it offers a framework to build and validate high-fidelity training platforms in VR for stand-alone evaluation of soft skills.

This research has suggested various setups of *Embodiment* and Motion Capture utilising a variety of current HMDs and motion tracking devices in use both in development and consumer markets, from low fidelity and economically friendly configurations of *Embodiment* with the Kinect version 1 and Oculus Rift CV1 to more capable tracking systems using the HTC Vive lightbox package which enables full room motion tracking capabilities with its four sensors. We also utilised the Motive Opti-Track system for our final study and the Meta Quest Pro, which provided even higher-quality motion tracking and was easily pipelined into Unity3D. All lab studies were designed for mobile testing with a technical pipeline and methodology that is accessible and repeatable.

Key technical considerations included working with IK to implement *Visuomotor* contingencies from the torso up for *Embodiment*. This enabled us to use an HMD within GOSH to conduct the study around the Doctors' schedule in the hospital in our study in Chapter 5. This also provided an example of a remote and economically friendlier approach to training tools that include body tracking. In our first study in Chapter 3, we produced a novel technical pipeline of simultaneously utilising the Oculus Rift CV1 for head tracking and the Kinect version 1 for body tracking when there was no out-of-the-box solution, which proved effective for *Embodiment*.

On the level of applications, our studies have provided valuable insight for the future development of VR experiences. With more accessible HMDs being introduced onto the market and the push for a metaverse where there is a consistent sense of *Embodiment* across different mediums of interaction along the internet, it's important to understand how visual and sensory integrations can influence solo and social dynamics. Our studies have provided interesting views on the impact of consistency, which can affect future projects. For example, embodied experiences of collaborative training or concept-sharing in VR - we know non-hand controllers can improve productivity (Joy et al., 2022), but now, visual congruence between users is also showing a tendency to facilitate trust and better performance for first-time interaction within VR.

In line with accessibility, in areas of struggling social-economic settings, we can still build low-fidelity and cost-effective embodied experiences with high psychological impact, as long as the sensory congruence aligns with the contextual expectations of the Top-Down mechanics in place, i.e. task. For example, no *Visuomotor* mechanics in a full-body Avatar in an active task would have negative effects.

Finally, we give an example of an application utilising the unique ability of *Embodied Perspective-Taking* in VR for *Self-Evaluation* in a platform for Medical Communication Training in Chapter 5. However, more research needs to be done on solidifying the level of fidelity needed to successfully observe and validate its influence.

7.2.3 Recommendations

In this section, we highlight high-level recommendations extracted from the thesis literature review and studies.

We recommend that developers consider, when optimising their projects, utilising the *Embodied Consistency* framework where contextually valid to uphold high psychological impact. For example, *Visuomotor* synchronicity with each sensory integration contextually in sight or in use. Additionally, prioritising congruence across multisensory input over higher fidelity.

Developers utilising Mirrors should be wary of proximity to the Mirror in bringing attention to finer low animation fidelity. But Mirrors are empirically believed to help prime initial *Embodiment* and are a pivotal first stage when *transforming the self* with customisable Avatars - this takes advantage of the unique ability within VR to become someone different. The use of Mirrors for *enhancing Embodiment* is still undecided.

Developers are advised to opt for visual congruence in contexts where stabilising trust and high-level collaboration are necessary. Research has depicted that having a *Self-Avatar* between pairs enhances a high collaboration effect; moreover, results suggest the effects are still higher with other low-visibility *Self-Representations* , such as controllers, than in inconsistent representations between pairs.

Developers are called to note task-dependent experiences; research has shown that having non-human hands increases *Agency* with most HMDs available, but human hands increase *Body Ownership.* This may be because technical constraints of hand tracking do not yet fully support accurate and consistent tracking and interaction, and it's more cognitive effort to map real-world affordances over to virtual objects. A suggestion is to curate or use *Self-Avatars* with contextually relevant instruments - controllers, wand, wrench, etc.

Developers, when designing training platforms for medical use, private or within the NHS, we suggest prioritising plausibility. When curating believable characters, we propose Motion Capture of both the body and facial animation of *Agents* (AI/Semi-Autonomous). We also advise high fidelity (human and realistic) *Self-Avatars* due to the need for real-world skills transfer. High-fidelity *Visuomotor* mechanics are necessary for contexts of practical delivery - this technical pipeline for *Embodiment* needs to be mobile and non-invasive. IK systems with VR Headsets and controllers are a good base, but there is a need for additional sensors and programming for more accurate body tracking for future use.

Researchers utilising 'body-swap' Perspective-Taking are advised to use Mirrors as a continuous prime for *Embodiment* when transforming the Self from an initially configured *Self-Representation* into another. The process of *Mirror Self-Recognition*, which is initially for priming, must occur again, especially if the previous 'Self' is still in view. Proximity to the original Embodied *Self-Avatar* must be significant to avoid potential threads of association or third-person *Embodiment.* The exact distance necessary requires further investigation.

Researchers are advised to avoid using confederates in social dynamic observations in VR unless the confederate takes on a role that does not interfere with the measures or hypothesis of the study.

7.3 Limitations and Future Work

7.3.1 Limitations and Future work within studies

In this thesis, we tackled many issues related to the psychological impact of different configurations of *Self-Representation* in IVR. However, each of our studies had various limitations, which give recommendations for further research to contribute to the knowledge in the related fields.

Limitations that presented themselves in our first study were that we did not have full-body Motion Capture. Though using Kinect Version 1 was a more inexpensive and easier way to track movement, we only had the movement of the head and arms. This active restriction may have impacted the participants' expressiveness, which would have been another interesting measure. Additionally, we used the LipSync plugin, which only allowed for random lip movement that reacted to audio and not specific sounds; it would have been better to investigate whether a more accurate sync would make a difference in results. Due to the distance between the participant and the Mirror and the resolution of the Oculus CV1, it was not very disruptive to the experience. However, it would be interesting to see now that devices such as the VIVE facial tracker provide lip-tracking and facial tracking to look at the configurations of more combinations of sensory input from users, more specifically, facial micro-expressions and higher fidelity lip-sync.

In the second study, there was no facial expression (e.g. blinking, lip-sync) of the *Self-Avatar*, which, from previous research, would have been another interesting factor that could have impacted how participants interacted with each other. There were some lag issues in the collaboration task provided by the networking plugin used(Photon), which potentially could have caused participants to shift their gaming strategy. Participants, however, did not point this out as an error; however, they accepted it as 'the way things are' in this environment, leaning onto Slater's notions on the flexibility of plausibility outside of realism (Slater et al., 2022). It would be interesting to look at how facial tracking with the VIVE facial tracker could provide feedback on how the visibility of non-verbal communication in both the body *and* face can impact trust and other aspects of *Social Presence*.

Limitations in our third study were that there was no finger tracking for *Embodiment* in the Doctor's and Emily's *Self-Avatars*; not meeting *Visuomotor* contingencies has been noted to have an additional impact on learning, which has been highlighted in other research, (Johnson-Glenberg et al., 2021). Additionally, having only one male and female Avatar meant some participants with varying arm lengths did not have accurate reach mapping on the X and $Y - axis$ for IK. Though participants were briefed on the scope of Avatar movement within the experiment's Training segment, these technical limitations could have impacted how participants moved. Additionally, we would advise the placement of Mirrors in the environment during the main *Embodiment* activity, like in (Raij et al., 2009) study. The consistent remapping of Body Schema to the virtual body can help solidify *Embodiment* and, therefore, the configuration of *Self-Representation*.

It would be interesting to test how consistency can mediate the effects of Perspective-Taking. This can be done by testing whether having *Visuomotor* control over Emily's head and arms (consistent) or just head movement (inconsistent with the pre-recorded verbal and non-verbal reactions playing) affects *Embodiment*. Research has shown it's possible to have *Agency* over a *Self-Avatar*'s imposed bodily action, such as speaking (Banakou and Slater, 2014). This could involve technically configuring a pipeline of semi-*Visuomotor* mechanics - a proprioceptive drift from their own movement to the pre-recorded movements when still (or a complete asynchronous condition of just Emily's movement and haptic feedback acting as a continuous re-synchroniser). Data may show useful evidence on whether there would be a ceiling effect in how this may impact *Self-Representation* and potentially how we think about configuring an embodied pre-lived experience in VR compared to real-time.

Nevertheless, this two-part study proved informative in suggesting that there is no effect on the evaluation process during a Communication Skills training simulation in VR from a first-person or second-person perspective. However, it's also important to note that the sample size was small, which could have impacted the results. In future work, we plan on working with a bigger sample size and looking at how accurate the evaluation ratings are compared to Expert ratings by working with a panel of practitioners to validate scoring. Another interesting area to investigate is to look at gaze data and see where the participant is focused during consultation.

It's also possible that the limitation of using one type of *Self-Avatar* (race, etc). would impact *Body Ownership* in all studies; it would have been interesting to have more racially aligned *Self-Avatars* to embody, as in each scenario, the participants were ‘themselves’.

7.3.2 Limitations and Future Work on the Embodied Consistency Framework

While not the primary focus of this research, the *Embodied Consistency Framework* offered an interesting way to address the gaps that look at the impact of consistency in configuring different setups of *Embodiment*. However, we acknowledge that the definition of consistency can be very broad and extending this framework requires careful consideration of what constitutes a contributing factor to consistency across the field. In this thesis, consistency has pertained to the binary case of implementing versus not implementing an attributing factor of *Embodiment*, essentially 'on or off,' however, we are aware that when it comes to *Avatar* representation, there are more dynamics of consistency that can be addressed that are not investigated and are out of the scope of this research; however, we will outline in this segment for future research the final consideration for the framework mentioned in Chapter 2, Table 2.2.

Co-perceived Consistency

In future studies, it would also be interesting to investigate the third paradigm of *Embodied Consistency*, which pertains to the synchronicity of how users perceive themselves versus how others perceive them. For example, in our study in Chapter 4, participants were in conditions where they did not have a body, or they did have a body, and this was consistent or inconsistent with another participant. A modification to this experiment could be that participant ‘A’ does not see themselves with their body, but participant ‘B’ sees their body and vice versa. Culling in rendering to optimise computation costs is normal, especially in first-person perspective games. It would be interesting to expand the framework to explore the impact of *Self-Representation* along this dimension; this could highlight how unique outputs of VR in terms of optimisation can still potentially evoke a high psychological impact.

7.4 Conclusion

Overall, VR has proven to be a powerful but unique platform for exploring *Self-Representation* through different configurations of *Embodiment*. The reach of its impact has allowed us to synthesise findings over various fields of study, such as *Embodiment* and *Social Presence*. Additionally, we have made notable niche contributions to the field of *Agency*, *Body Ownership* and *Perspective-Taking* in VR. Findings reinforce the importance of balancing Avatar visual realism with behavioural realism and highlight the value of integrating consistency within the configuration of *Embodiment*. This research also emphasises that the plausibility threshold doesn’t necessarily lie in higher fidelity but in understanding and meeting user expectations and input congruence. Finally, this research has explored novel methodologies that can be employed in future experimental setups. It has demonstrated the potential of *Embodied Virtual Perspective-Taking* to influence learning and *Self-Efficacy*, shedding light on the technological and methodological pipeline for creating high-fidelity training platforms for *Self-Evaluation*. Despite the valuable insights gained, each study in this thesis had limitations, offering room for further research and expanding our understanding of various related fields. These limitations suggest the need for continued investigation to refine our knowledge in the quest for more immersive and effective VR applications. Nevertheless, the results and discussions in this thesis could be useful guides for future research in this field.

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Appendix A

AppendixA

A.1 AppendixA - Supplementary material for Experiment 1:The Effect of Lip and Arm Synchronization on Embodiment: A Pilot Study

Items:

- Ethics forms
- Questionnaires

A.1.1 Ethics and Questionnaire

ETHICS APPLICATION

CONTENT:

1. ETHICS APPLICATION FORM
2. INFORMATION SHEET FOR PARTICIPANT
3. CONSENT FORM
4. PRE-QUESTIONNAIRE
5. VERBAL QUESTIONNAIRE
6. POST-QUESTIONNAIRE

Ethical Approval Form (EAF1)

CONFIDENTIAL

GOLDSMITHS COLLEGE University of London

Research Ethics Committee

NAME OF APPLICANT

Tara Collingwoode-Williams

CO APPLICANT

Xueni Pan

DEPARTMENT

Department of Computing

This form should be completed in typescript and returned to the Secretary of the Research Ethics Committee, for any research project, teaching procedure or routine investigation involving human participants or animals to be undertaken in the College or by or upon Goldsmiths College staff outside the College.

1. **Title of proposed project:**

The Effect of Change Blindness on Embodiment in Virtual Reality

2. **Brief outline of the project, including its purpose:**

In this work we are interested in two psychological illusions: Change blindness (the disability to detect gradual visual change) and body ownership in Virtual Reality (the illusion that they own a virtual body). Participants will be giving a presentation in an HMD, and they will see in a virtual mirror an avatar who copies their arm and lip movements (leap motion and microphone). Towards the end of the presentation the avatar gradually morphs into a deformed monster. We use a 2 x 2 factor design: arm (sync/async) and lip (sync/ascyn). We measure participants' reaction with questionnaires and their physical reaction towards the change. Our hypothesis is that when both arm and lip are synced, participants have a higher sense of embodiment ("the body changed" versus "my body changed") and are slower at detecting the gradual change. Further, we predict that lip sync contributes to a larger extend to this effect.

3. **Proposed starting date:**

Wednesday 6th July

4. **If external grant funding is being secured, does the research need ethical approval prior to the initiation of that funding?**

No

5. **Has the project been approved by an Ethics Committee external to the College? If so please specify.**

(NB for projects so approved, applicants may if they wish submit a copy of that application, but should sign the back of the form and return it as specified above)

No

6. **Please provide an ethical self-evaluation of the proposed research.**

Reference should be made to the ESRC Research Ethics Framework , to professional guidelines (such as provided by the BPS, the BSA or the SRA) or to guidelines by government (e.g. GSR) on ethical practice and

research. You may wish to provide your response on a separate sheet.

- When the participant arrives the examiner will reiterate to the user that the experiment is completely voluntary and they should feel free to withdraw at any point during the experiment.
- The participant will be given appropriate information about the nature of the experiment and be well informed of what is expected of them.
- The participant will be told that their data will be anonymised and that it will not be shared to any third party outside those running the experiment.
- The participant will be shown a quiet space where they can recuperate and drink water at any point during the experiment and after.
- After evaluation the results will be emailed to the participants if they request it.

7. **State the variables to be studied, topics to be investigated, procedures to be used and/or the measurements to be made. (Please attach a separate sheet if necessary)**

Variables:

- Lip sync
- Gestures
- Morphing

Topics:

- Embodiment
- Gradual Change(Change Blindness)

Measurement:

- Qualitative questionnaire on illusion of body ownership (verbal and written)
- Time
- Gaze during experiment

8. **Specify the number of and type of participant(s) likely to be involved.**

   The likely number of participates is 24

9. **State the likely duration of the project and where it will be undertaken.**

   The Experiment will take place at Goldsmiths, University of London, in a spacious office in the Department of Computing.

The duration of the experiment will be roughly 30 minutes

10. **State the potential adverse consequences to the participant(s), or particular groups of people, if any, and what precautions are to be taken.**

    As this is an experiment utilising the Oculus Rift (DK2) participate might experience slight nausea and disorientation. To help with this, there will be a quiet area where the participants can drink water and recuperate if needed. The participant will also be informed prior to the experiment that they are free to withdraw at any point of the experiment.

11. **State any procedures which may cause discomfort, distress or harm to the participant(s), or particular groups of people, and the degree of discomfort or distress likely to be entailed.**

As this is an experiment utilising the Oculus Rift(DK2) participants might experience slight nausea and disorientation. Additionally, the participate will witness a gradual morphing of facial features (from a human to a monster) which may cause slight discomfort.

12. **State how the participant(s) will be recruited. (Please attach copies of any recruiting materials if used).**

The participats will be recruited through email and word of mouth.

13. **State if the participant(s) will be paid, and if so, provide details and state reasons for payment.**

The participant will not be paid.

14. **State the manner in which the participant(s) consent will be obtained (if written, please include a copy of the intended consent form).**

The participant will receive a consent form to fill before the experiment takes place.

Attached.

14a. Will the participant(s) be fully informed about the nature of the project and of what they will be required to do?

The participant will be fully aware of what they will be asked to do during the experiment. However they will not be told the nature of the experiment until after the experiment is completed as it may affect the results.

14b. Is there any deception involved?

For the first part of the participant will be told that the experiments intention is to help with delivering speeches whilst the real intent is to test embodiment.

14c. Will the participant(s) be told they can withdraw from participation at any time, if they wish?

Yes

14d. Will data be treated confidentially regarding personal information, and what will the participant(s) be told about this?

Yes. The participants will be told that their personal details will not be used or shared to anyone outside of this experiment.

14e. If the participant(s) are young persons under the age of 18 years or 'vulnerable persons' (e.g. with learning difficulties or with severe cognitive disability), how will consent be given (i.e. from the participant themselves or from a third party such as a parent or guardian) and how will assent to the research be asked for?

N/A

15. **Will the data be confidential?**

Yes

15a. Will the data be anonymous?

The data will be anonymous

15b. How will the data remain confidential?

Each participant will be given a ID which will represent their data from the experiment.

15c. How long will the data be stored? And how will it be eventually destroyed?

The data will be stored for a year and then destroyed (deleted from computer).

16. **Will the research involve the investigation of illegal conduct? If yes, give details and say how you will be protected from harm or suspicion of illegal conduct?**

No

17. **Is it possible that the research might disclose information regarding child sexual abuse or neglect? If yes, indicate how such information will be passed to the relevant authorities (e.g. social workers, police), but also indicate how participants will be informed about the handling of such information were disclosure of this kind to occur. A warning to this effect must be included in the consent form if such disclosure is likely to occur.**

No

18. **State what kind of feedback, if any, will be offered to participants.**

The participants will be offered feedback via email on their results if they request it.

19. **State the expertise of the applicant for conducting the research proposed**

The applicant is a BSc Creative Computing graduate and Mphil/Phd student specialising in Virtual Reality.

20. **In cases of research with young persons under the age of 18 years or 'vulnerable persons' (e.g. with learning difficulties or with severe cognitive disability), or with those in legal custody, will face-to-face interviews or observations or experiments be overseen by a third party (such as a teacher, care worker or prison officer)?**

N/A

21. **If data is collected from an institutional location (such as a school, prison, hospital), has agreement been obtained by the relevant authority (e.g. Head Teacher, Local Education Authority, Home Office)?**

N/A

22. **For those conducting research with young persons under the age of 18 years or 'vulnerable persons' (e.g. with learning difficulties or with severe cognitive disability), do the investigators have Criminal Records Bureau clearance? (Ordinarily unsupervised research with minors would require such clearance. Please see College *Code of Practice on Research Ethics*, 2005).**

N/A

23. **Will research place the investigators in situations of harm, injury or criminality?**

No

24. **Will the research cause harm or damage to bystanders or the immediate environment?**

No

25. **Are there any conflicts of interest regarding the investigation and dissemination of the research (e.g. with regard to compromising independence or objectivity due to financial gain)?**

No

26. **Is the research likely to have any negative impact on the academic status or reputation of the College?**

No

ALL APPLICANTS

Please note that the Committee should be notified of any adverse or unforeseen circumstances arising out of this study.

Signature of Applicant **Date**

06/07/2016

Signature of Co-Applicant **Date**

06/07/2016

TO BE COMPLETED BY HEAD OF DEPARTMENT

Please note that the College Research Ethics Committee should be notified of any adverse or unforeseen circumstances arising out of this study or of any emerging ethical concerns that the Head of Department may have about the research once it has commenced.

Has there been appropriate peer review and discussion of the ethical implications of the research in the department (i.e. with yourself as Head of Department or the Departmental Research Ethics Committee or Research Committee)?

Yes/No (Please circle)

Are the ethical implications of the proposed research adequately described in this application?

Yes/No (Please circle)

Signature of Head of Department **Date**

Information Sheet for Participants

Thank you for participating in our study. Please read through this information sheet and feel free to ask any questions. The experimenters will answer any general questions; however the specific aspects regarding this study cannot be discussed with you until the end of the session. The whole study will take about *20 - 30 minutes*.

This particular study will be broken in to two parts. In the first part you will be asked to deliver a 3 minute speech in Virtual Reality for a job interview to teach English in Ghana. You will deliver the speech into a mirror where you will see an avatar. During the second part you will be asked to verbally voice when you detect a change in the Virtual Reality. Parts of the experience could be stressful if they were to occur in real life.

Please ask any questions that come to mind. Read and sign the **Consent Form**.

Information that we collect will never be reported in a way that specific individuals can be identified. Information will be reported in a statistical and aggregated manner, and any verbal comments that you make, if written about in subsequent papers, will be presented anonymously.

Procedures

You will be asked to read, understand and sign a **Consent Form**. If you sign it the study will continue with your participation. **Note that you can withdraw at any time without giving any reasons.**

You will be asked to complete some questions on paper, so that we can try to understand your responses during the study.

Part 1:

You will be then be introduced into the virtual room where you will deliver a 3 minutes speech in front of a mirror. You will go through some training sessions to get used to the virtual environment. Once you are familiar with interface, you will then be left on your own to give your speech. Afterwards there will be a verbal questionnaire where we will discuss your experience.

Part 2:

You will once again be introduced to the virtual room where you will be asked to verbally voice the changes you can detect in the Virtual Reality.

Finally, you will fill in a small questionnaire.

During the whole procedure, you might be videotaped.

Thank you for your participation. Please do not discuss this study with others for about **three months**, since the study is continuing.

Any other questions?

Please note that you may (or may not) find the situation that is depicted within the experience stressful. If at any time you do not wish to continue participating in the experiment remember that you are free to withdraw without being required to give reasons.

In case you have any enquiries regarding this study in the future, please contact:

Tara Collingwoode-williams, Mphil/Phd student, Goldsmiths, University of London. ma101tc@gold

CONSENT FORM

Project ID Number:

Investigator: Tara Collingwoode-williams

Virtual Reality Study Consent Form

Please read and answer the following questions carefully:

Have you read the information sheet about this study? YES/NO

Have you had an opportunity to ask questions about the procedure? YES/NO

Have you received satisfactory answers to all your questions? YES/NO

Have you received enough information about this study? YES/NO

Do you understand that your personal information will not be shared and your data will be anonymised? YES/NO

Do you understand that you are free to withdraw from this study

at any time and without giving a reason for withdrawing? YES/NO

Do you agree to take part in this study?

YES/NO

We would like to videotape you during the experiment, and audiotape your interview. This tape will be used for data analysis purposes only and will be kept entirely confidential

Do you agree to be audio/video taped?
YES/NO

Signed………………………..……………………………Date…………………………

Name in block letters ………………………………..………………………………

Virtual Reality Study

PRE- QUESTIONNAIRE

Please make sure that you answer each question. If you have any queries ask the experimenters who will be nearby.

Tara Collingwoode-williams(ma101tc@gold.ac.uk)

Your Given ID number	
Your Age	SHAPE
Your Gender	Male Female
How fluent is your English?	Basic Proficient Fluent
Occupational status	Undergraduate Student Masters Student PhD Student Research Assistant/Fellow Staff - systems, technical Faculty Administrative Staff Other
Are you taking any medication?	Yes No *If yes, please specify*
Did you consume more than 2 units of alcohol within the last 6 hours? *(2 units of alcohol = 1 pint of beer or 2 glasses of wine)*	Yes No
Please state your level of computer literacy on a scale of (1...7) (novice) 1 2 3 4 5 6 7 (expert)	
Have you ever experienced 'virtual reality' before? (no experience) 1 2 3 4 5 6 7 (extensive experience)	
How many times did you play video games (at home, work, school, or arcades) in the last year?	Never 1 - 5 6 - 10 11 - 15 16 - 20 21 - 25 > 25
How many *hours per week* do you spend playing video games?	0 < 1 1 - 3 3 - 5 5 - 7 7 - 9 > 9

Verbal questionnaire

ID:

(1) (OWN)How much did you feel that the virtual body was your own body?

Not at all 1 2 3 4 5 6 7 Very much

(2) (MOVE)How much did you feel that the movements that the virtual body made were your movements?

Not at all 1 2 3 4 5 6 7 Very much

(3) (ANOTHER)How much did you feel that the virtual body was another person's?

Not at all 1 2 3 4 5 6 7 Very much

(4) (MIRROR) How much did you feel that the reflection was your body?

Not at all 1 2 3 4 5 6 7 Very much

(5) Anything other comment about the experience?

Post- Examination Questionnaire

ID: ______________________________

Date: ______________________________

Condition: ______________________________

Instructions

Please read each question carefully and choose an answer between 0-7

False 0 …… 7 True

1) _____ **It seemed like my body was changing**

1 2 3 4 5 6 7

2) _____ **I feel like I noticed all the changes**

1 2 3 4 5 6 7

3) _____ **It seemed like the reflection was changing**

1 2 3 4 5 6 7

4) ______ **It seemed like there was no change**

1 2 3 4 5 6 7

5) ______ **How much control did you feel over the virtual body?**

1 2 3 4 5 6 7

6) ______ **How much did you feel the virtual body was your own?**

1 2 3 4 5 6 7

7) ______ **How much did you feel you were controlling another person's body?**

1 2 3 4 5 6 7

8) ______ **How much did you feel the reflection of the virtual body was your reflection?**

1 2 3 4 5 6 7

9) ______ **It seemed like the body was changing**

1 2 3 4 5 6 7

10) ______ **In your own words what changed during the experiment?**

Build-a- Block – Information Sheet

This game will take place within a virtual game room. You will be shown a sequence you must build with your teammate. This must be done as quickly and efficiently as you can. With each sequence, you must use the same blocks to complete the task. You must do this until the timer runs out. If you have any questions about the how to play the game please ask the experimenter before the game begins.

Note: During play, please keep your torso as still as possible in your seat and only move your arms.

DayTrader Game

The Daytrader Game is a social dilemma task in which the short-term interests of the individuals conflict with the longterm interests or goals of the group. We chose this social dilemma scenario because it has been used in several previous studies of computer- and video-mediated communication [1, 2], and it provides measures of trust that have been tested for reliability and validity.

Our use of the Daytrader Game was inspired by previous work [1,2,3]. The game involved three sets of five rounds. For each set of the Daytrader Game, each participant was given 30 credits that they could either keep or put into a pool that was shared between the two participants. At the end of the round, credits that they chose to keep doubled in value, while the credits in the shared pool tripled and were then split evenly between the two participants. At the end of each set of five rounds, the participant earning the most credits in that set received a 300 credits bonus. This bonus had the effect of giving a extra profit to the participant who contributed less than his or her partner. If both participants earned the same amount, they both received the bonus.

Trust Game – Information Sheet

To analyze trust the participant feels towards the confederate, once the player finishes the game they will take part in a trust exercise. The participant is rewarded with 100 points. They will be offered a chance to share some, all or nothing of this amount with the confederate. Every time points are sent to another player it is doubled by the experimenter. The confederate will then be given the same option. The amount the participant gives will be recorded. Example:

1. A gives 20 of the 100 points to B. (A = 80 B= 20)
2. This is doubled and given to B (A= 80,B = 40)
3. B can then send back an amount of the received money to A. B sends 20 (A = 80,B = 20)
4. This is doubled and given to A (A = 120, B = 20)

In this scenario B can also choose to keep all the points given. (B = 40, A= 80). This exercise tests the amount of trust A has of B. This exercise is based off of (Glaeser, Laibson, Scheinkman, & Soutter, 2000) Trust Game with a small modification of adding the doubling each turn. There will only be one turn as to gather the initial amount given by the participant.

Information to participant:

You have been rewarded with 100 points! You are now offered a chance to share some of this amount with your teammate. Every time points are sent to another player it is doubled by the experimenter. Your teammate will then be given the same option. By doing this you have the chance to increase you final point. How much will you give? You can only give once.

Pre-Questionnaire

* Required

1. **Participant ID**

2. **1. What is your gender?** *
Mark only one oval.
- Male
- Female
- Rather not say

3. **2. What is your age?** *

4. **3. I see myself as someone who …** *
Mark only one oval per row.

	Disagree Strongly	Disagree a little	Neither Agree nor Disagree	Agree a Little	Agree Strongly
… is reserved					
… is generally trusting					
… tends to be lazy					
… is relaxed, handles stress well					
… has few artistic interests					
… is outgoing, sociable					
… tends to find fault with others					
… does a thorough job					
… gets nervous easily					
… has an active imagination					

Post VR Questionnaire AV

taracw92@gmail.com Switch account

Not shared

Participant ID

Your answer

I felt Content

0	1	2	3	4
○	○	○	○	○

I felt skillful

0	1	2	3	4
○	○	○	○	○

I was interested in the game's story

0	1	2	3	4
○	○	○	○	○

I thought it was fun

0	1	2	3	4
○	○	○	○	○

I was fully occupied with the game

0	1	2	3	4
○	○	○	○	○

I felt happy

0	1	2	3	4
○	○	○	○	○

It gave me a bad mood

0	1	2	3	4
○	○	○	○	○

I thought about other things

0	1	2	3	4
○	○	○	○	○

I found it tiresome

0	1	2	3	4
○	○	○	○	○

I felt competent

0	1	2	3	4
○	○	○	○	○

I thought it was hard

0	1	2	3	4
○	○	○	○	○

It was aesthetically pleasing

0	1	2	3	4
○	○	○	○	○

I forgot everything around me

0	1	2	3	4
○	○	○	○	○

I felt good

0	1	2	3	4
○	○	○	○	○

I was good at it

0	1	2	3	4
○	○	○	○	○

I felt bored

0	1	2	3	4
○	○	○	○	○

I felt successful

0	1	2	3	4
○	○	○	○	○

I felt imaginative

0	1	2	3	4
○	○	○	○	○

I felt that I could explore things

0	1	2	3	4
○	○	○	○	○

I enjoyed it

0	1	2	3	4
○	○	○	○	○

I was fast at reaching the game's targets

0	1	2	3	4
○	○	○	○	○

I felt annoyed

0	1	2	3	4
○	○	○	○	○

I felt pressured

0	1	2	3	4
○	○	○	○	○

I felt irritable

0	1	2	3	4
○	○	○	○	○

I lost track of time

0	1	2	3	4
○	○	○	○	○

I found it challenging

0	1	2	3	4
○	○	○	○	○

I found it impressive

0	1	2	3	4
○	○	○	○	○

I was deeply concentrated in the game

0	1	2	3	4
○	○	○	○	○

I felt frustrated

0	1	2	3	4
○	○	○	○	○

It felt like a rich experience

0	1	2	3	4
○	○	○	○	○

I lost connection with the outside world

0	1	2	3	4
○	○	○	○	○

I felt time pressure

0	1	2	3	4
○	○	○	○	○

I had to put a lot of effort into it

0	1	2	3	4
○	○	○	○	○

I felt like I was looking at my own hand

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

I felt like I had control of the controller I was moving

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Even when the 'other' was present, I still felt alone in the virtual game room

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt like there was someone else in the virtual game room with me

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt like the 'other' was aware of my presence in the virtual game room

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I liked the other player

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I would like to play the game longer with the other player

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel the other player is reliable

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I fell the other player is honest

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel the other player is sociable

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel the other player is friendly

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel the other player is sympathetic

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel the other player is trustworthy

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

How much did you behave during this interaction as if the interaction was real?

	1	2	3	4	5	6	7	
Not at all the Same	○	○	○	○	○	○	○	The Same

How much were your physical responses(heart-rate/sweating etc) during the interaction the same as if you were interacting in real life?

	1	2	3	4	5	6	7	
Not at all the Same	○	○	○	○	○	○	○	The Same

How much did you have thoughts ‘ I know this is virtual’ but then find yourself behaving as if you were interacting in real life?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Always

How much were your emotional responses to the interaction as if it was occurring in real life?

	1	2	3	4	5	6	7	
Not at all the Same	○	○	○	○	○	○	○	The Same

How much did you feel the virtual body was your body?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

How much did you feel that the virtual body was another person's body?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

When you were in the virtual game room, how strong was the feeling that you were dissociated from your body (as if yourself and your body were in different locations)?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

How responsive was the environment?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

How much did the visual aspects of the environment involve you?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

How natural did your interactions with the environment seem?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

Rate your sense of being in the virtual game room on a scale of 1-7 where 7 is how you would normally feel in a environment.

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

To what extent were there times during the game where the virtual game room was reality to you?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Always

Thinking back to the virtual game room. How much do you think of it as a place you visited?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

During you experience playing the game, which was strongest on the whole, your sense of being in the virtual game room or the office room?

- ◯ Virtual Game Room
- ◯ Office Room

During the experience did you feel like you were in the office or how much did the virtual game room overwhelm you?

	1	2	3	4	5	6	7	
Not at all	◯	◯	◯	◯	◯	◯	◯	Completely

Appendix B

AppendixB

B.1 AppendixB - Supplementary material for Experiment 2: The Impact of Self-Representation and Consistency in Collaborative Virtual Environments

Items:

- Ethics forms
- Questionnaires

B.1.1 Ethics Form and Questionnaires Study 1

Institutional Review Board

Application Form

Instructions:

1. CITI certification (www.citiprogram.org) must be completed for all team members at the time of application submission.
2. Complete all sections and required addenda. Submit one complete package via IRBNet.
3. Projects with funding/proposed funding must include a copy of the grant application or proposal.
4. Research may not begin until you have received notification of IRB approval.
5. Handwritten and incomplete forms cannot be accepted.

1. Study Title: **The impact of the self-avatar between players within a social virtual environment**

2. Study Investigators

A. Principal Investigator (*must be faculty/staff and meet PI Eligibility, University Policy 4012*)

Name: **Tara Collingwoode-williams** Department: **Game Design**

Phone: **202 945 8429** E-mail: **tcollin6@gmu.edu**

B. Co-Investigator/Student Researcher

Name: Department:

Phone: E-mail:

C. Are there additional team members? No ☒ Yes ☐ *If yes, complete Addendum J to list additional team members*

D. Do any investigators or team members have *conflicts of interest* related to the research?

No ☒ Yes ☐ If yes, explain

3. Study Type: ☒ Faculty/Staff Research ☒Doctoral Dissertation ☐ Masters Thesis ☐ Student Project (**Specify** ☐ Grad or ☐ Undergrad) ☐ Other (Specify)

4. Complete Description of the Study Procedures

A. Describe the aims and specific purpose of the study: **The aim of this study is to investigate the effect of different levels of immersion with the self-avatar on collaborative social interaction within a virtual space**

B. Provide a COMPLETE description of the study procedures in the sequence they will occur including the amount of time each procedure will *take (attach all surveys, questionnaires, standardized assessment tools, interview questions, focus group questions/prompts or other instruments of data collection)*: **The particiapant will be asked to read, understand and sign a Consent Form. If they sign it the study will continue with their participation. They will be told they can withdraw at any time without giving any reasons. The participant will be asked to complete some demographic questions, so that we can try to understand their responses during the study. Part 1: Participants will be helped into VR kit and play 'Build-a-Block' with another player in multiplayer virtual environment(See attached 'Build-a-Block' information sheet). They will see an image of the sequence they must build in a certain amount of time. If both player touch the same block it will be taken away. There will be 10 sets to build. Each set they will be given back the blocks taken away. During this time, participants will be videotaped. Following this game participants will then fill out a questionnaire on their experience (See attached 'Questionnaire1'). Part 2: Participants will take part in a bonus level**

of the game which is a modified Trust Game(see 'Trust Game information sheet'). After this, the participants will be thanked for their time and released.

C. Describe the target population (age, sex, ethnic background, health status, etc.): **The target population is to be a mixed female/male group of varying ages.**

1. Summarize the inclusion/exclusion criteria for participation in the study: **The target population are faculty and students from George mason from ages 21+**

2. Are there any enrollment restrictions based on gender, pregnancy, race or ethnic origins? ☐Yes ☒No If yes, please describe the process and reasons for restriction(s):

3. Do any researchers listed on the application have a relationship to any of the participants that could unduly influence them to participate (including a teacher/student relationship)? ☒Yes ☐No If yes, please describe the relationship and how any possibility of undue influence will be managed: **There is a possible teacher/student relationship between participants and PI.**

4. Estimated number of subjects (may use a range): **40-60**

5. Estimated amount of total participation time per subject: **30 minutes**

D. Where will the study occur (*list all study sites and collaborators*)? **Virginia serious Games Institute Office**

E. Describe other approvals that have been/will be sought prior to study initiation (facility authorizations, biosafety review, IRB approval from collaborating institutions, approval from public school system IRBs, etc.): **IRBs approval**

5. Recruitment and Consent

A. Describe the processes used for selecting subjects and the methods of recruitment including when, how, and by whom the subjects will be recruited (***attach all recruitment materials including flyers, emails, SONA posting, scripts, etc. and please include the IRBNet number of the project and the PI's name on all recruitment documents***)? **To recruit participant, I will be sending an email(see Attached 'Email') and a flyer advertisement which i will hang around campus (see attached 'Flyer')**

B. Describe the consent process including how and where the consent will take place, who will conduct the consent process, information that will be discussed with and distributed to subjects, and how participants will indicate consent even if a waiver of signature is being requested below (*attach all consent documents*): **The consent form will be given at the beginning of the experimental process. This will be given by the lead researcher. The participant will be given an information sheet that will explain the proceedings of the experiment and then once any questions have been answered they will fill the consent form and then the demographic questionnaire.**

C. Is a waiver of <u>signature</u> on the Informed Consent being requested? ☐Yes ☒No

If yes, complete the following:

1. This waiver is being sought because (*check one*):

☐ The only record linking the subject and the research would be the consent document AND the principal risk would be potential harm resulting from a breach of confidentiality.

☐ The research presents no more than minimal risk of harm to subjects AND involves no procedure for which written consent is normally required outside of the research context.

2. Explain why the waiver of signature is being requested:

6. Privacy & Confidentiality

A. How will the researchers protect the *privacy* of the participants and the *confidentiality* of the data obtained? **The data will be anonymous and the participants will be given ID numbers which will be used to link them to the data. The video, images and audio recordings will be used only within the bounds of the research and will be stored on a harddrive only accessable by the PI.**

B. What individually identifiable information will be collected as part of the study data and who will have access to that information? **The participants will be recorded**

C. When will identifiable information/the identification key be destroyed (if applicable)? P*lease note that when feasible, the IRB recommends that personal identifiers be destroyed as soon as possible, though research data must be stored for 5 years.* **After 5 years.**

D. Where will the data be stored (*Copies of records must be stored on Mason property—for example, in the PI's office*)? **Will be stored in the PI's office under lock and key.**

E. How long will the data be stored (*data must be retained for at least 5 years after the study ends*)? **5 years.**

F. What, if any, are the final plans for disposition/destruction of the data? **The documents will be shredded and the digital copies will be wiped from the harddrive**

G. Will results of the research be shared with the participants? ☒Yes ☐No If yes, describe how this will be accomplished: **Results can be shared with the participants if requested through email.**

H. Will individually identifiable information be shared with anyone outside of the research team (*If yes, please explain and be sure to include this information in the consent form*)?
☐Yes ☒No If yes, please explain:

I. Does the research involve possible disclosure by participants of intent to harm themselves or others or possible disclosure of child abuse or neglect? (*If yes, please explain and be sure to include this information in the consent form*)?
☐Yes ☒No If yes, please explain:

7. Risks

A. Summarize the nature & amount of risk if any (*include side effects, stress, discomfort, physical risks, psychological and social risks*): **Participants may feel discomfort from the use of the virtual reality equipment. Participants may be stressed by the tasks they are asked to complete.**

B. Estimate the probability if any (e.g. not likely, likely, etc.) that a given harm may/will occur and its severity: **not likely**

C. What procedure(s) will be utilized to prevent/minimize any potential risks? **The participants will be told that if they wish to stop at any point during the experiment they need to say 'STOP' and they will be helped out of the Virtual Reality equipment. Participants will be shown an area where they can rest and drink water after experiement if they need sometime to calm and collect themselves.**

8. Benefits

A. Describe any probable benefits (if any) of the research for the subject(s) (*Do not address compensation in this section*): **Experiencing multiplayer Virtual Reality**

B. Describe the benefits to society and general knowledge the study is likely to yield: **By taking part in this experiment, participants will be helping in forwarding research in this budding and exciting field which could go on to support development of training and game based social virtual environments**

9. Financial Information

A. Is there any internal or external funding or proposed funding for this project? ☐Yes ☒No

If yes, funding agency and OSP # (if external funding) ***(attach grant application)***

B. Are there financial costs to the subjects? ☐Yes ☒No If yes, please explain:

C. Will subjects be paid or otherwise compensated for research participation? ☐Yes ☒No

If yes, please respond to the following questions:

1. Describe the nature of any compensation to subjects (cash, gifts, research credits, etc.):
2. Provide a dollar amount/research credit amount, if applicable:
3. When and how is the compensation provided to the subject?
4. Describe partial compensation if the subject does not complete the study: **none**
5. If research credit, what is the non-research alternative to research participation? **n/a**

10. Special Topics

A. Will the study involve minors? ☐Yes ☒No
If yes, complete addendum A

B. Will the study involve prisoners? ☐Yes ☒No
If yes, complete addendum B

C. Will the study specifically target pregnant women, fetuses, or neonates? ☐Yes ☒No
If yes, complete addendum C

D. Will the study involve FDA regulated drugs (other than the use of approved drugs in the course of medical practice)? ☐Yes ☒No
If yes, complete addendum D

E. Will the study involve evaluation of the safety or effectiveness of FDA regulated devices? ☐Yes ☒No
If yes, complete addendum E

F. Will false or misleading information be presented to subjects (deception)? ☐Yes ☒No
If yes, complete addendum F

G. Will participants be audio or videotaped? ☒Yes ☐No
If yes, complete addendum G

H. Will the research involve other potentially vulnerable participants (e.g. disabled or addicted individuals, populations engaging in illegal behavior)? ☐Yes ☒No
If yes, complete addendum H

I. Will the research be conducted outside of the United States? ☐Yes ☒No
If yes, complete addendum I

11. Investigator Certification

I certify that the information provided in this project is correct and that no other procedures will be used in this protocol. I agree to conduct this research as described in the attached supporting documents. I will request and receive approval from the IRB for changes prior to implementing these changes. I will comply with all IRB policies and procedures in the conduct of this research. I will be responsible for ensuring that the work of my co-investigator(s)/student researcher(s) complies with this protocol. I understand that I am ultimately responsible for the entire conduct of this research.

SVI Experiment Questionnaire 1

1. **I felt like I was looking at my own hand**
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

2. **I felt like I had control of the hand I was moving**
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

3. **Even when the 'other' was present, I still felt alone in the virtual game room**
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

4. **I felt like there was someone else in the virtual game room with me**
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

5. **I felt like the 'other' was aware of my presence in the virtual game room**
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

6. **I liked the other player**
   Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

7. **I would like to play the game longer with the other player**
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

8. **I feel the other player is reliable**
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

9. **I fell the other player is honest**
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

10. **I feel the other player is sociable**
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

11. **I feel the other player is friendly**
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

12. **I feel the other player id sympathetic**
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

13. **I feel the other player is trustworthy**
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Agree								Strongly Disagree

14. **How much did you behave during this interaction as if the interaction was real?**
Mark only one oval.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

15. **How much were your physical responses(heart-rate/sweating etc) during the interaction the same as if you were interacting in real life?**
Mark only one oval.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

16. **How much did you have thoughts ‘ I know this is virtual’ but then find yourself behaving as if you were interacting in real life?**
Mark only one oval.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

17. **How much were your emotional responses to the interaction as if it was occurring in real life?**
Mark only one oval.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

18. **How much did you feel the virtual body was your body?**
Mark only one oval.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

19. **How much did you feel that the virtual body was another person's body?**
Mark only one oval.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

20. **When you were in the virtual game room, how strong was the feeling that you were dissociated from your body (as if yourself and your body were in different locations)?**
Mark only one oval.

1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯

21. **How responsive was the environment?**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

22. **How much did the visual aspects of the environment involve you?**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

23. **How natural did your interactions with the environment seem?**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

24. **Rate your sense of being in the virtual game room on a scale of 1-7 where 7 is how you would normally feel in a environment.**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

25. **To what extent were there times during the game where the virtual game room was reality to you?**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

26. **Thinking back to the virtual game room, do you think of it as images you saw or a place you visited?**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

27. **During you experience playing the game, which was strongest on the whole, your sense of being in the virtual game room or the office room?**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

28. **During the experience do you feel like you were in the office or did the virtual game room overwhelm you?**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

SVI Pilot Study Questionnaire

Rate scale where: 1(Completely Disagree) - 5(Completely Agree)

1. **1. I felt content**
   Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

2. **2. I felt skillful**
   Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

3. **3. I thought it was fun**
   Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

4. **4. I was fully occupied with the game**
   Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

5. **5. I felt happy**
   Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

6. **6. It gave me a bad mood**
   Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

7. **7. I thought about other things**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

8. **8. I found it tiresome**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

9. **9. I felt competent**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

10. **10. I thought it was hard**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

11. **11. I forgot everything around me**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

12. **12. I felt good**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

13. **13. I was good at it**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

14. **14. I felt bored**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

15. **15. I felt successful**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

16. **16. I felt imaginative**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

17. **17. I felt that I could explore things**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

18. **18. I enjoyed it**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

19. **19. I was fast at reaching the game's targets**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

20. **20. I felt annoyed**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

21. **21. I felt pressured**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

22. **22. I felt irritable**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

23. **23. I lost track of time**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

24. **24. I felt challenged**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

25. **25. I found it impressive**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

26. **26. I was deeply concentrated in the game**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

27. **27. I felt frustrated**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

28. **28. It felt like a rich experience**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

29. **29. I lost connection with the outside world**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

30. **30. I felt time pressure**
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

In this next section, rate scale where: 1(Completely Disagree) - 7(Completely Agree)

31. **31. I liked the other player**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

32. **32. I would like to play the game longer with the other player**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

33. **33. I feel the other player Is reliable**
Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

34. **34. I feel the other player Is honest**

Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

35. **35. I feel the other player is sociable**

Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

36. **36. I feel the other player is friendly**

Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

37. **37. I feel the other player is sympathetic**

Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

38. **38. I feel the other player is trustworthy**

Mark only one oval.

1	2	3	4	5	6	7
⬭	⬭	⬭	⬭	⬭	⬭	⬭

INFORMATION SHEET FOR PARTICIPANTS

Thank you for participating in our study. Please read through this information sheet and feel free to ask any questions. The experimenters will answer any general questions; however the specific aspects regarding this study cannot be discussed with you until the end of the session. The whole study will take about _20 minutes_.

This particular study will be broken in to two parts. In the first part you will be asked to play a game of 'build-a-block' with another player and then fill in a questionnaire 1. During the second part you will be asked to complete a questionnaire 2 on the experience.

Please ask any questions that come to mind. Read and sign the **Consent Form**.

Information that we collect will never be reported in a way that specific individuals can be identified. Information will be reported in a statistical and aggregated manner, and any verbal comments that you make, if written about in subsequent papers, will be presented anonymously.

PROCEDURES

You will be asked to read, understand and sign a **Consent Form**. If you sign it the study will continue with your participation. **Note that you can withdraw at any time without giving any reasons.**
You will be asked to complete some questions on paper, so that we can try to understand your responses during the study.

Part 1:
You will play 'Build-a-Block' with another player. You will see an image of the sequence you must build in a certain amount of time. If both player touch the same block it will be taken away. There will be 10 sets to build. Each set you will be given back the blocks taken away. During this time, you might be videotaped. You will then fill out questionnaire 1.

Part 2:

You will take part in a bonus level of the game, then fill in questionnaire 2.

Thank you for your participation. Please do not discuss this study with others for about **three months**, since the study is continuing.
Any other questions?

Please note that you may (or may not) find the situation that is depicted within the experience stressful. If at any time you do not wish to continue participating in the experiment remember that you are free to withdraw without being required to give reasons.

In case you have any enquiries regarding this study in the future, please contact:

Tara Collingwoode-williams, VSGI Research Associate, tcollin6@gmu.edu.

Build-a- Block – Information Sheet

In this game will take place within a virtual game room. You will be shown an image of a sequence you must build with your teammate. This must be done as quickly and efficiently as you can. If both players touch a block it will disappear but with each sequence the blocks will be refreshed. You must do this until the timer runs out. If you have any questions about the how to play the game please ask the experimenter before the game begins.

Note: Please keep your torso as still as possible in your seat and only move your arms.

Trust Game – Information Sheet

To analyze trust the participant feels towards the confederate, once the player finishes the game they will take part in a trust exercise. The participant is rewarded with 100 points. They will be offered a chance to share some, all or nothing of this amount with the confederate. Every time points are sent to another player it is doubled by the experimenter. The confederate will then be given the same option. The amount the participant gives will be recorded. Example:

1. A gives 20 of the 100 points to B. (A = 80 B= 20)
2. This is doubled and given to B (A= 80,B = 40)
3. B can then send back an amount of the received money to A. B sends 20 (A = 80,B = 20)
4. This is doubled and given to A (A = 120, B = 20)

In this scenario B can also choose to keep all the points given. (B = 40, A= 80). This exercise tests the amount of trust A has of B. This exercise is based off of (Glaeser, Laibson, Scheinkman, & Soutter, 2000) Trust Game with a small modification of adding the doubling each turn. There will only be one turn as to gather the initial amount given by the participant.

Told to participant:

You have been rewarded with 100 points! You are now offered a chance to share some of this amount with your teammate. Every time points are sent to another player it is doubled by the experimenter. Your teammate will then be given the same option. By doing this you have the chance to increase you final point. How much will you give?

INFORMED CONSENT FORM

Project ID Number:

RESEARCH PROCEDURES

This research is being conducted to study the different levels of immersion during collaborative gaming in virtual environments. If you agree to participate, you will take part in the following procedure.

The whole study will take about *20 minutes*.

PROCEDURES

You will be asked to complete some questions on paper, so that we can try to understand your responses during the study.

Part 1:
You will play 'Build-a-Block' with another player. You will see an image of the sequence you must build in a certain amount of time. If both player touch the same block it will be taken away. There will be 10 sets to build. Each set you will be given back the blocks taken away. During this time, you might be videotaped. You will then fill out questionnaire 1.

Part 2:

You will take part in a short bonus level of the game.

RISKS

Please note that you may (or may not) find the situation that is depicted within the experience stressful. If at any time you do not wish to continue participating in the experiment remember that you are free to withdraw without being required to give reasons.

BENEFITS

There are no benefits to you as a participant other than to further research in Social Virtual Reality

CONFIDENTIALITY

The data in this study will be confidential. (Include a description of the specific procedures in place in your research project to maintain the confidentiality of the data. Information that we collect will never be reported in a way that specific individuals can be identified. Information will be reported in a statistical and aggregated manner, and any verbal comments that you make, if written about in subsequent papers, will be presented anonymously. No identifiers or names will be written on surveys taken.

PARTICIPATION
Your participation is voluntary, and you may withdraw from the study at any time and for any reason. If you decide not to participate or if you withdraw from the study, there is no penalty or loss of benefits to which you are otherwise entitled. There are no costs to you or any other party.

There will be refreshments available to all that participate after the completion of the experiment.

CONTACT
This research is being conducted by Tara Collingwoode-Williams, research associate at the Virginia serious Games Institute at George Mason University. She may be reached at tcollin6@gmu.edu for questions or to report a research-related problem.You may contact the George Mason University Institutional Review Board office at 703-993-4121 if you have questions or comments regarding your rights as a participant in the research.

This research has been reviewed according to George Mason University procedures governing your participation in this research.

CONSENT

Please read and answer the following questions carefully:

Have you read the information sheet about this study? YES/NO
Have you had an opportunity to ask questions about the procedure? YES/NO
Have you received satisfactory answers to all your questions? YES/NO
Have you received enough information about this study? YES/NO

Do you understand that your personal information will not be shared and your data will be anonymized? YES/NO

Do you understand that you are free to withdraw from this study
at any time and without giving a reason for withdrawing? YES/NO

Do you agree to take part in this study? YES/NO

We would like to videotape you during the experiment, and take pictures. This will be used for behavioral/communication data analysis purposes only and will be kept entirely confidential

Do you agree to be pictured/videotaped?
YES/NO

I have read this form, all of my questions have been answered by the research staff, and I agree to participate in this study.

____
Name

____
Date of Signature

B.1.2 Ethics Form and Questionnaires Study 2

Ethical Approval Form (EAF1)

CONFIDENTIAL

GOLDSMITHS COLLEGE University of London

Research Ethics Committee

NAME OF APPLICANT: Tara Collingwoode-Williams

DEPARTMENT: Computing Department

This form should be completed in typescript and returned to the Secretary of the Research Ethics Committee, for any research project, teaching procedure or routine investigation involving human participants or animals to be undertaken in the College or by or upon Goldsmiths College staff outside the College.

1. **Title of proposed project:** The Impact of the Self-Avatar on Collaborative gaming within a Social Virtual Environment

2. **Brief outline of the project, including its purpose:**

The purpose of this research is to understand the effect of the Self-Avatar on trust and productivity in a collaborative social virtual environment use9r case. Previous research has already brought to our attention that the appearance of an avatar can have an effect on user trust and social acceptance (Roth et al, 2016). Additionally, there has also been research highlighting the impact of the Self-Avatar on memory retention and cognitive load(Steed, 2016).
Steed more recently conducted research looking at the impact of the Self avatar on trust and collaborative and competitive settings(Steed, 2017), however in this case, each pair had the same setup of immersion and avatar appearance. As we have entered into a period of a diverse virtual reality ecosystem, it's important that we account for the varied immersive setups each afford and how this would affect social experiences in virtual reality. In this experiment, we look at the impact of the Self-Avatar on trust, productivity and social presence in an incongruent, collaborative social virtual setting - Incongruent in this case meaning the mismatch of avatar representation between users. We narrowed our investigation into focusing on these two factors; having an avatar[Self-Avatar] and facing an avatar[Consistency]. The results will help to highlight the areas of focus in future research and development in terms of providing successful social virtual interaction.

3. **Proposed starting date:**

August 15th 2019

4. **If external grant funding is being secured, does the research need ethical approval prior to the initiation of that funding?**

N/A

5. **Has the project been approved by an Ethics Committee external to the College? If so please specify.**
(NB for projects so approved, applicants may if they wish submit a copy of that application, but should sign the back of the form and return it as specified above)

This experiment has been approved by the George Mason University IACUC

6. **Please provide an ethical self-evaluation of the proposed research. Reference should be made to the ESRC Research Ethics Framework , to professional guidelines (such as provided by the BPS, the BSA or the SRA) or to guidelines by government (e.g. GSR) on ethical practice and research. You may wish to provide your response on a separate sheet.**

- When the participant arrives, the examiner will reiterate to the user that the experiment is completely voluntary and they should feel free to withdraw at any point during the experiment
- The participant will be given appropriate information about the nature of the experiment and be well informed of what is expected of them
- The participant will be told that their data will be anonymised and that it will not be shared to any third party outside those running the experiment.
- The participant will be shown to a quiet place where they can recuperate and drink water at any point during or after the experiment.
- After evaluation the results will be emailed to the participants if they request it

7. **State the variables to be studied, topics to be investigated, procedures to be used and/or the measurements to be made. (Please attach a separate sheet if necessary)**

This study will use virtual reality and HTC vive to investigate the impact of the Self Avatar in a collaborative social virtual environment, with consistent and inconsistent conditions of avatar representations between users (i.e. avatar with/without + gesture). This is to shed light on the effect of the diverse ecosystem of virtual reality products on social presence, productivity and trust in a collaborative setting and potentially support development in creating successful social virtual environments in both entertainment and education.

Two independent variables that are being controlled:

- Self-Avatar/ No Self Avatar
- Consistent/Inconsistent

Which equivalates into four conditions.

	Consistent	Inconsistent
Self	Self + Avatar (C1)	Self + No Avatar (C2)
No - Self	No Self + No Avatar (C4)	No Self + No Avatar (C3)

C1:

- *Participant A has body and hand movement*
- *Participant B has body and hand movement*

C2:

- *Participant A has body and hand movement*
- *Participant B has just hand movement with virtual hands*

C3:

- *Participant A has just hand movement with virtual hands*
- *Participant B has body and hand movement*

C4:

- *Both no body. Just hand movement with virtual hands.*

Six dependent variables being measured:

Collected with Questionnaire:

- Social presence
- Game Experience
- Trust

Collected in Real-time

- Reaction time (productivity)
- Arm movement
- Gaze

There are two independent variables to be manipulated during this experiment. The first is the self-avatar (SELF). The participant will either have a full body gender matched avatar to control or they will have no avatar and just have control of the game controller. The second independent variable is the consistency (CONSISTENCY). Participants will either be faced with a another partcipant matching their immersion or not matching, meaning the participant with an avatar will either face a confederate with an avatar or without an avatar, and the same would be for the participant without an avatar.

Trust will be measured through a questionnaire along with social presence and game experience. Other dependent variables such the reaction time, or how long taken to complete the game task in each level, gaze and arm movement will be captured in real-time during the experiment session.

VR Study procedure:
GREET

Participant A will be taken in to the office and briefed on the task and the hardware. This will involve explaining to the participant the health warnings and guide for safe use in line with the exercises following (i.e remain seated, only use arm and head movement). They will then be asked to fill in a demographic questionnaire which includes a standard psychological profiling questionnaire to fill out, BIG FIVE PERSONALITY INVENTORY - SHORT FORM(Rammstedt et al, 2007), as well as some basic demographic information.

Participant B will first be asked to fill in the demographic questionnaire, and then after Participant A has been briefed, Participant B will be brought into the office and briefed.

TRUST EXERCISE
Both Participants will then take part in a Day-trader game. This will be done in silence and seated. (See ‘Daytrader game’ sheet).

TRAINING
Both Participants will be helped into the HTC Vive. They will then get the opportunity to learn how to play the game with a ‘demo round.’ In this round, Participants will be asked to build a shape together - this will not be timed or included in analysis.

Participants will not continue until BOTH understand:
How to use the Vive controllers to pick up blocks
How to use the Vive controllers to change level

MAIN TASK
The Participants will once again be reminded of the instructions before they begin the main task. They will be encouraged to speak to one another and strategize on how they will complete the task efficiently. They will have 10 minutes to complete 10 levels of ‘Block build’ (See ‘Block Build Game’ sheet). Participants will complete the task in either of the four conditions (C1, C2, C3, C4). Participants will complete this task sitting down. During this time, participants will be videotaped.
Note: Participants will be asked to keep their torso still as they play.

QUESTIONNAIRE
Once the task has been completed, Participant B will be taken to another room. Once both Participants are out of VR, they will be asked to complete a questionnaire on a laptop/tablet. This questionnaire will consist of :
Social Presence questionnaire
Co-presence Questionnaire
Game Experience Questionnaire
This section will be completed seated.

TRUST EXERCISE
Both Participants will then take part in a Day-trader game. This will be done in silence and seated. (See ‘Daytrader game’ sheet)

DEBRIEF
Participants will be debriefed, paid and released. The HTC Vive headset foam will be wiped with a cloth and the other touched equipment with an antibacterial wipe after each participant. This session will take roughly 45 minutes.

We have three hypothesis:
H1 Participant with inconsistent immersion condition (i.e. C2 and C3) will feel less co-presence.

H2 Participant with consistent condition (i.e. C1 and C4) will feel more trust towards other participant.

H3 Participants will have a faster reaction time when with self-avatar (i.e C1 and C4)

8. **Specify the number of and type of participant(s) likely to be involved**
Gender: Female/Male
Number: Approximately 40
Age: 18+
Background: Range of ethnic background, does not suffer from epileptic seizures, seizures, loss of awareness, fainting, or severe dizziness.

9. **State the likely duration of the project and where it will be undertaken.**

The experiment will take roughly 45 minutes and will take place in the VR lab in 25 St James Building

10. **State the potential adverse consequences to the participant(s), or particular groups of people, if any, and what precautions are to be taken.**

N/A

11. **State any procedures which may cause discomfort, distress or harm to the participant(s), or particular groups of people, and the degree of discomfort or distress likely to be entailed.**

Potential side effects (nausea or disturbed vision). Participants may feel discomfort from the use of the virtual reality equipment. Participants may be stressed by the tasks they are asked to complete.
The participants will be told that if they wish to stop at any point during the experiment, they need to say 'STOP' and they will be helped out of the Virtual Reality

equipment. Participants will be shown an area where they can rest and drink water after experiment if they need some time to calm and collect themselves.

12. **State how the participant(s) will be recruited. (Please attach copies of any recruiting materials if used).**

The students will be recruited through word of mouth and email and poster.

Text :

VR Experiment!

Call for participants!

Love playing games?
Interested in Virtual Reality?
I'm a PhD student conducting research on Social Interaction within Virtual Reality Games and I'm inviting **YOU** to participate and take part in this exciting study!
Participation in this research includes taking part in a fun interactive game within virtual reality using the HTC VIVE, then you will be asked to take a follow up questionnaire on the experience. This should take no more than 45 minutes of your time and there will be delicious refreshments available for you to enjoy after you are done.
Once you take part, you will be rewarded with £5!
If you have any questions or would like to participate in this research, I can be reached at:
tc.williams@gold.ac.uk

Individuals who are sick, fatigued, under the influence of intoxicants/drugs, not feeling generally well, or with epileptic seizures, seizures, loss of awareness, fainting, or severe dizziness will be excluded from the study

You must be 18 or older to participate.

Thank you,
Best,

Tara Collingwoode-Williams

13. **State if the participant(s) will be paid, and if so, provide details and state reasons for payment.**

The participants will be paid £5 for their time. This is an incentive due to the long length of the experiment.

14. **State the manner in which the participant(s) consent will be obtained (if written, please include a copy of the intended consent form).**

The participants will be given a consent form to sign before the experiment takes place

14a. Will the participant(s) be fully informed about the nature of the project and of what they will be required to do?

The participants will be fully informed about what they will have to do during the experiment. However, they will not be told the nature of the experiment until after it is completed as this may affect results.

14b. Is there any deception involved?

No

14c. Will the participant(s) be told they can withdraw from participation at any time, if they wish?

Yes

14d. Will data be treated confidentially regarding personal information, and what will the participant(s) be told about this?

Yes. The participants will be told their data will be anonymose and not shown to any third party outside the experiment.

14e. If the participant(s) are young persons under the age of 18 years or 'vulnerable persons' (e.g. with learning difficulties or with severe cognitive disability), how will consent be given (i.e. from the participant themselves or from a third party such as a parent or guardian) and how will assent to the research be asked for?

N/A

15. **Will the data be confidential?**

Yes

15a. Will the data be anonymous?

Yes

15b. How will the data remain confidential?

Participants will have ID numbers and on the computer, data files will only be referred to through ID numbers. These numbers will be assigned upon scheduling of the participant(ID001, ID002, ID003…)
There will be no computer record that associates the ID numbers with identifying information, only written in a book kept under lock and key by the Researcher in the PhD office on Goldsmiths grounds. The video, images and audio recordings will be used only within the bounds of the research and will be stored on a password protected harddrive that will under lock and key and kept by the Researcher in the PhD office on Goldsmiths grounds.

15c. How long will the data be stored? And how will it be eventually destroyed?

The data will not be deleted; however the data will be anonymised and hardcopies linking the data to participants identifying information will be destroyed after a year.

16. **Will the research involve the investigation of illegal conduct? If yes, give details and say how you will be protected from harm or suspicion of illegal conduct?**

No

17. **Is it possible that the research might disclose information regarding child sexual abuse or neglect? If yes, indicate how such information will be passed to the relevant authorities (e.g. social workers, police), but also indicate how participants will be informed about the handling of such information were disclosure of this kind to occur. A warning to this effect must be included in the consent form if such disclosure is likely to occur.**

No

18. **State what kind of feedback, if any, will be offered to participants.**

Participants will be debriefed after the experiment and can ask any questions if they wish. We will also provide email feedback if requested of their performance and experiment results.

19. **State the expertise of the applicant for conducting the research proposed.**

PhD student specialising in Virtual Reality

20. **In cases of research with young persons under the age of 18 years or ‘vulnerable persons’ (e.g. with learning difficulties or with severe cognitive disability), or with those in legal custody, will face-to-face**

interviews or observations or experiments be overseen by a third party (such as a teacher, care worker or prison officer)?

N/A

21. **If data is collected from an institutional location (such as a school, prison, hospital), has agreement been obtained by the relevant authority (e.g. Head Teacher, Local Education Authority, Home Office)?**

N/A

22. **For those conducting research with young persons under the age of 18 years or 'vulnerable persons' (e.g. with learning difficulties or with severe cognitive disability), do the investigators have Criminal Records Bureau clearance? (Ordinarily unsupervised research with minors would require such clearance. Please see College *Code of Practice on Research Ethics*, 2005).**

N/A

23. **Will research place the investigators in situations of harm, injury or criminality?**

No

24. **Will the research cause harm or damage to bystanders or the immediate environment?**

No

25. **Are there any conflicts of interest regarding the investigation and dissemination of the research (e.g. with regard to compromising independence or objectivity due to financial gain)?**

No

26. **Is the research likely to have any negative impact on the academic status or reputation of the College?**

No

ALL APPLICANTS

Please note that the Committee should be notified of any adverse or unforeseen circumstances arising out of this study.

Signature of Applicant **Date**

TO BE COMPLETED BY HEAD OF DEPARTMENT

Please note that the College Research Ethics Committee should be notified of any adverse or unforeseen circumstances arising out of this study or of any emerging ethical concerns that the Head of Department may have about the research once it has commenced.

Has there been appropriate peer review and discussion of the ethical implications of the research in the department (i.e. with yourself as Head of Department or the Departmental Research Ethics Committee or Research Committee)?

Yes/No (Please circle)

Are the ethical implications of the proposed research adequately described in this application?

Yes/No (Please circle)

Signature of Head of Department **Date**

Build-a- Block – Information Sheet

This game will take place within a virtual game room. You will be shown a sequence you must build with your teammate. This must be done as quickly and efficiently as you can. With each sequence, you must use the same blocks to complete the task. You must do this until the timer runs out. If you have any questions about the how to play the game please ask the experimenter before the game begins.

Note: During play, please keep your torso as still as possible in your seat and only move your arms.

DayTrader Game - Information Sheet

The Daytrader Game is a social dilemma task in which the short-term interests of the individuals conflict with the longterm interests or goals of the group. We chose this social dilemma scenario because it has been used in several previous studies of computer- and video-mediated communication [1, 2], and it provides measures of trust that have been tested for reliability and validity.

Our use of the Daytrader Game was inspired by previous work [1,2,3]. The game involved three sets of five rounds. For each set of the Daytrader Game, each participant was given 30 credits that they could either keep or put into a pool that was shared between the two participants. At the end of the round, credits that they chose to keep doubled in value, while the credits in the shared pool tripled and were then split evenly between the two participants. At the end of each set of five rounds, the participant earning the most credits in that set received a 300 credits bonus. This bonus had the effect of giving a extra profit to the participant who contributed less than his or her partner. If both participants earned the same amount, they both received the bonus.

Trust Game – Information Sheet

To analyze trust the participant feels towards the confederate, once the player finishes the game they will take part in a trust exercise. The participant is rewarded with 100 points. They will be offered a chance to share some, all or nothing of this amount with the confederate. Every time points are sent to another player it is doubled by the experimenter. The confederate will then be given the same option. The amount the participant gives will be recorded. Example:

1. A gives 20 of the 100 points to B. (A = 80 B= 20)
2. This is doubled and given to B (A= 80,B = 40)
3. B can then send back an amount of the received money to A. B sends 20 (A = 80,B = 20)
4. This is doubled and given to A (A = 120, B = 20)

In this scenario B can also choose to keep all the points given. (B = 40, A= 80). This exercise tests the amount of trust A has of B. This exercise is based off of (Glaeser, Laibson, Scheinkman, & Soutter, 2000) Trust Game with a small modification of adding the doubling each turn. There will only be one turn as to gather the initial amount given by the participant.

Information to participant:

You have been rewarded with 100 points! You are now offered a chance to share some of this amount with your teammate. Every time points are sent to another player it is doubled by the experimenter. Your teammate will then be given the same option. By doing this you have the chance to increase you final point. How much will you give? You can only give once.

Pre-Questionnaire

* Required

1. **Participant ID**

____

2. **1. What is your gender?** *

Mark only one oval.

- ( ) Male
- ( ) Female
- ( ) Rather not say

3. **2. What is your age?** *

____

4. **3. I see myself as someone who …** *

Mark only one oval per row.

	Disagree Strongly	Disagree a little	Neither Agree nor Disagree	Agree a Little	Agree Strongly
… is reserved	( )	( )	( )	( )	( )
… is generally trusting	( )	( )	( )	( )	( )
… tends to be lazy	( )	( )	( )	( )	( )
… is relaxed, handles stress well	( )	( )	( )	( )	( )
… has few artistic interests	( )	( )	( )	( )	( )
… is outgoing, sociable	( )	( )	( )	( )	( )
… tends to find fault with others	( )	( )	( )	( )	( )
… does a thorough job	( )	( )	( )	( )	( )
… gets nervous easily	( )	( )	( )	( )	( )
… has an active imagination	( )	( )	( )	( )	( )

Post VR Questionnaire AV

[redacted]

Participant ID

Your answer

I felt Content

0	1	2	3	4
○	○	○	○	○

I felt skillful

0	1	2	3	4
○	○	○	○	○

I was interested in the game's story

0	1	2	3	4
○	○	○	○	○

I thought it was fun

0	1	2	3	4
○	○	○	○	○

I was fully occupied with the game

0	1	2	3	4
○	○	○	○	○

I felt happy

0	1	2	3	4
○	○	○	○	○

It gave me a bad mood

0	1	2	3	4
○	○	○	○	○

I thought about other things

0	1	2	3	4
○	○	○	○	○

I found it tiresome

0	1	2	3	4
○	○	○	○	○

I felt competent

0	1	2	3	4
○	○	○	○	○

I thought it was hard

0	1	2	3	4
○	○	○	○	○

It was aesthetically pleasing

0	1	2	3	4
○	○	○	○	○

I forgot everything around me

0	1	2	3	4
○	○	○	○	○

I felt good

0	1	2	3	4
○	○	○	○	○

I was good at it

0	1	2	3	4
○	○	○	○	○

I felt bored

0	1	2	3	4
○	○	○	○	○

I felt successful

0	1	2	3	4
○	○	○	○	○

I felt imaginative

0	1	2	3	4
○	○	○	○	○

I felt that I could explore things

0	1	2	3	4
○	○	○	○	○

I enjoyed it

0	1	2	3	4
○	○	○	○	○

I was fast at reaching the game's targets

0	1	2	3	4
○	○	○	○	○

I felt annoyed

0	1	2	3	4
○	○	○	○	○

I felt pressured

0	1	2	3	4
○	○	○	○	○

I felt irritable

0	1	2	3	4
○	○	○	○	○

I lost track of time

0	1	2	3	4
○	○	○	○	○

I found it challenging

0	1	2	3	4
○	○	○	○	○

I found it impressive

0	1	2	3	4
○	○	○	○	○

I was deeply concentrated in the game

0	1	2	3	4
○	○	○	○	○

I felt frustrated

0	1	2	3	4
○	○	○	○	○

It felt like a rich experience

0	1	2	3	4
○	○	○	○	○

I lost connection with the outside world

0	1	2	3	4
○	○	○	○	○

I felt time pressure

0	1	2	3	4
○	○	○	○	○

I had to put a lot of effort into it

0	1	2	3	4
○	○	○	○	○

I felt like I was looking at my own hand

	1	2	3	4	5	6	7	
Strongly Agree	○	○	○	○	○	○	○	Strongly Disagree

I felt like I had control of the controller I was moving

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Even when the 'other' was present, I still felt alone in the virtual game room

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt like there was someone else in the virtual game room with me

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt like the 'other' was aware of my presence in the virtual game room

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I liked the other player

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I would like to play the game longer with the other player

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel the other player is reliable

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I fell the other player is honest

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel the other player is sociable

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel the other player is friendly

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel the other player is sympathetic

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel the other player is trustworthy

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

How much did you behave during this interaction as if the interaction was real?

	1	2	3	4	5	6	7	
Not at all the Same	○	○	○	○	○	○	○	The Same

How much were your physical responses(heart-rate/sweating etc) during the interaction the same as if you were interacting in real life?

	1	2	3	4	5	6	7	
Not at all the Same	○	○	○	○	○	○	○	The Same

How much did you have thoughts ‘ I know this is virtual’ but then find yourself behaving as if you were interacting in real life?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Always

How much were your emotional responses to the interaction as if it was occurring in real life?

	1	2	3	4	5	6	7	
Not at all the Same	○	○	○	○	○	○	○	The Same

How much did you feel the virtual body was your body?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

How much did you feel that the virtual body was another person's body?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

When you were in the virtual game room, how strong was the feeling that you were dissociated from your body (as if yourself and your body were in different locations)?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

How responsive was the environment?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

How much did the visual aspects of the environment involve you?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

How natural did your interactions with the environment seem?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

Rate your sense of being in the virtual game room on a scale of 1-7 where 7 is how you would normally feel in a environment.

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

To what extent were there times during the game where the virtual game room was reality to you?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Always

Thinking back to the virtual game room. How much do you think of it as a place you visited?

	1	2	3	4	5	6	7	
Not at all	○	○	○	○	○	○	○	Completely

During you experience playing the game, which was strongest on the whole, your sense of being in the virtual game room or the office room?

- ◯ Virtual Game Room
- ◯ Office Room

During the experience did you feel like you were in the office or how much did the virtual game room overwhelm you?

	1	2	3	4	5	6	7	
Not at all	◯	◯	◯	◯	◯	◯	◯	Completely

Appendix C

AppendixC

C.1 AppendixC - Supplementary material for Experiment 3: Delivering Bad News: Using Embodiment as Tool of Self Evaluation for Medical Communication Training

Items:

- Ethics forms
- Questionnaires
- Script

C.1.1 Ethics Form, Questionnaires Study 1, Script

NOTE TO APPLICANTS: IT IS IMPORTANT FOR YOU TO INCLUDE ALL RELEVANT INFORMATION ABOUT YOUR RESEARCH IN THIS APPLICATION FORM AS YOUR ETHICAL APPROVAL WILL BE BASED ON THIS FORM. THEREFORE ANYTHING NOT INCLUDED WILL NOT BE PART OF ANY ETHICAL APPROVAL.

YOU SHOULD READ THE ETHICS APPLICATION GUIDELINES AND HAVE THEM AVAILABLE AS YOU COMPLETE THIS FORM.

APPLICATION FORM

SECTION A APPLICATION FOR ETHICAL REVIEW: HIGH RISK

Date of Submission:	Proposed Data Collection Start Date:
UCL Ethics Project ID Number: 0884/023	Proposed Data Collection End Date: 31/01/2020

Is this application for continuation of a research project that already has ethical approval? *For example, a preliminary/pilot study has been completed and this is an application for a follow-up project? If yes, please provide the information requested below.*

Project ID for the previous study: N/A

Full Name: Caroline Fertleman	Position Held: Professor of Paediatric Education
Name and Address of Department: Faculty of population health sciences, UCL GOS Institute of Child Health, 30 Guildford Street, London, WC1N 1EH	Email: c.fertleman@ucl.ac.uk Telephone: 020 7288 3275 Fax: N/A

Declaration To be Signed by the Principal Researcher

I have met with and advised the student on the ethical aspects of this project design *(applicable only if the Principal Researcher is not also the Applicant).*

I understand that it is a UCL requirement for both students & staff researchers to undergo Disclosure and Barring Service (DBS) Checks when working in controlled or regulated activity with children, young people or vulnerable adults. The required DBS Check Disclosure Number(s) is: N/A as only research with non vulnerable adults

I have obtained approval from the UCL Data Protection Officer stating that the research project is compliant with the General Data Protection Regulation 2018. My Data Protection Registration Number is: All data stored at Goldsmiths

I am satisfied that the research complies with current professional, departmental and university guidelines including UCL's Risk Assessment Procedures and insurance arrangements.

I undertake to complete and submit the 'Continuing Review Approval Form' on an annual basis to the UCL Research Ethics Committee.

I will ensure that changes in approved research protocols are reported promptly and are not initiated without approval by the UCL Research Ethics Committee, except when necessary to eliminate apparent immediate hazards to the participant.

I will ensure that all adverse or unforeseen problems arising from the research project are reported in a timely fashion to the UCL Research Ethics Committee.

	I will undertake to provide notification when the study is complete and if it fails to start or is abandoned.

SIGNATURE: **DATE:** 12/12/2018

[redacted]

Full Name: Caroline Fertleman

Position Held: Professor of Paediatric Education

Name and Address of Department: Faculty of population health sciences, UCL GOS Institute of Child Health, 30 Guildford Street, London, WC1N 1EH	Email: c.fertleman@ucl.ac.uk Telephone: 020 7288 3275 Fax: N/A

Full Name:

Position Held:

Name and Address of Department:	Email: Telephone: Fax:

[redacted]

a) Sponsor: ☐ **UCL** ☐ **Other institution**
If your project is sponsored by an institution other than UCL please provide details:

b) Other Organisations: If your study involves another organisation, please provide details. *Evidence that the relevant authority has given permission should be attached or confirmation provided that this will be available upon request.*

c) Funding: What are the sources of funding for this study and will the study result in financial payment or payment in kind to the department or College? *If study is funded solely by UCL this should be stated, the section should not be left blank.*

[redacted]

	A. I have discussed this project with the principal researcher who is suitably qualified to carry out this research and I approve it. **I am satisfied that *[please highlight as appropriate]*:** **(1) Data Protection registration:** **has been satisfactorily completed** **has been initiated** **is not required** **(2) a risk assessment:** **has been satisfactorily completed** **has been initiative** **(3) appropriate insurance arrangements are in place and appropriate sponsorship [funding] has been approved and is in place to complete the study. ☐ Yes ☐ No** **(4) a Disclosure and Barring Service check(s):** **has been satisfactorily completed** **has been initiated** **is not required** *Links to details of UCL's policies on the above can be found at: http://ethics.grad.ucl.ac.uk/procedures.php* ****If any of the above checks are not required please clarify why below.**

PRINT NAME: Caroline Fertleman

SIGNATURE: **DATE:** 20/12/2018

SECTION B DETAILS OF THE PROJECT

****It is essential that Sections B1 and B2 are completed in simple understandable lay language that a non-expert could understand or you risk your project being rejected**

B1	**Please provide a brief summary of the project in simple lay person's prose outlining the intended value of the project, giving necessary scientific background.** *(max 500 words)*. Virtual reality has already been credited as an effective tool for training in the medical field. Studies over the years have used this medium as a way to gauge the ability of GPs to deny patients unnecessary antibiotic medicine(Pan et al., 2016), to investigate the correlation between cognitive load and the ability to identify cues of child abuse during consultations(Pan et al., 2018a) and as a means to identify significant attributes of verbal and non-verbal behaviour which effect realistic communication in virtual reality(Biocca & Harms, 2002; Lindblom, 2015; Nowak & Biocca, 2003; Pan, Gillies, & Slater, 2015). Previous research has shown evidence that it is possible for users to express the same behaviour towards virtual patients as they do with patient actors(Johnsen et al., 2005). Additionally, we also know that virtual patients are able to elicit real emotions of stress, joy, fear and confusion from the user(Lok et al., 2006). Therefore, we can summarize that arguably virtual consultations can provide a trustworthy reflection of behaviour and communication skills towards patients as a consultation experience with an actor. But what virtual reality can also provides that is impossible to implement in real life, is the opportunity to see and experience this reflection from another person's perspective. What we wish to investigate during this experiment is whether this virtual ability to evaluate performance from another perspective, can be used as a tool for improving medical communication skills.

Research has shown us how important virtual characters are in investigating social presence in virtual reality, social presence in this case meaning the “feeling that one has some level of access or insight into the other’s intentional, cognitive, or affective states,”(Biocca & Nowak, 2001). Recent studies have highlighted the positive effect that the visibility of the avatar has on social presence. Croes believes that the reduction of visibility in social interactions will lead participants to feel less self aware, more anonymity and more inclined to stick to a task oriented conversation(Adriana & Croes, 2016). Research has shown that the level of immersion quality does not have linear positive impact on social presence, however what needs to be investigated is the single factors and how each influence different user cases. The second part of this experiment is an exploratory segment which will look into whether the presence or absence of the self-avatar can affect the participants interpersonal relations with an angered parent.

Attach any questionnaires, psychological tests, etc. (a standardised questionnaire does not need to be attached, but please provide the name and details of the questionnaire together with a published reference to its prior usage).

B3

Where will the study take place (please provide name of institution/department)?
If the study is to be carried out overseas, what steps have been taken to secure research and ethical permission in the study country? Is the research compliant with Data Protection legislation in the country concerned or is it compliant with the General Data Protection Regulation 2018?

The ICH, will host the virtual reality simulation technology and act as the site for testing the simulation.

B4

Have collaborating departments whose resources will be needed been informed and agreed to participate?
Attach any relevant correspondence.

Yes

B5

How will the results be disseminated, including communication of results with research participants?

The study results will be collated and written up for publication in the medical education and artificial intelligence literature. We will provide a short summary of the research findings, which will be disseminated to the participants.

B6

Please outline any ethical issues that might arise from the proposed study and how they are be addressed. *Please note that all research projects have some ethical considerations so do not leave this section blank.*

The main ethical issue which may arise relates to the very small risk from exposing participants to the potential psychological distress of interacting with angry and stressed virtual avatar parents, which may be traumatic and distressing for staff when this occurs in the real-world situation. At present in clinical education, simulation routinely attempts to train staff for difficult and emotionally challenging conversations using trained actors to deliver a facsimile of the conversational participant, who presents the emotionally challenging part of the conversation. Whilst there is often some role-play guidance around the parameters of this simulation, the content of the conversation is entirely ad-hoc and dependent on the actor, and has the potential to become very emotionally challenging.

In the context of this study, the virtual reality avatar has a pre-defined set of potential responses, which have been designed with clinicians to represent a range of possible replies; however there is reduced risk to the participants in that the responses are finite and controlled compared to the current standard of using actors.

In addition, the ethical risk of putting participants into the virtual reality simulation is mitigated by the fact that rehearsing communication skills in a simulated environment is psychologically safer than being exposed to these interactions in the real clinical environment without having prior preparation.

Finally, the researchers who debrief the simulation will facilitate discussion of any emotional components of the simulation which arise, and will be able to provide support for participants if they feel distressed or wish to explore any additional emotional context which arises, and there will be opportunity to signpost further support should the need arise.

SECTION C DETAILS OF PARTICIPANTS

C1

Participants to be studied

C1a. Number of volunteers:	40 (to be confirmed)
Upper age limit:	65
Lower age limit:	22

C1b. Please justify the age range and sample size:

Around 20 participants will be required to adequately assess the virtual reality simulation. We will postgraduate doctors and nurses between the ages of 21 - 65 with the majority being around 21-40.

C2

If you are using data or information held by a third party, please explain how you will obtain this. You should confirm that the information has been obtained in accordance with the General Data Protection Regulation 2018.

N/A

C3

Will the research include children or vulnerable adults such as individuals with a learning disability or cognitive impairment or individuals in a dependent or unequal relationship? ☐ **Yes** ☐ **No**

How will you ensure that participants in these groups are competent to give consent to take part in this study? *If you have relevant correspondence, please attach it.*

C4

Will payment or any other incentive, such as gift service or free services, be made to any research participant?

☐ **Yes** ☐ **No**

If yes, please specify the level of payment to be made and/or the source of the funds/gift/free service to be used.

Please justify the payment/other incentive you intend to offer.

C5	**Recruitment** (i) Describe how potential participants will be identified: Postgraduate nurses and medical staff studying at UCL and working at Great Ormond Street Hospital will be offered the opportunity to participate in the research. (ii) Describe how potential participants will be approached: Participants will be approached via e-mail (iii) Describe how participants will be recruited: By expressions of interest in response to an e-mail advertising the study and posters put up in the ICH. *Attach recruitment emails/adverts/webpages. A data protection disclaimer should be included in the text of such literature.*

C6	**Will the participants participate on a fully voluntary basis?** ☐ **Yes** ☐ **No** **Will UCL students be involved as participants in the research project?** ☐ **Yes** ☐ **No** *If yes, care must be taken to ensure that they are recruited in such a way that they do not feel any obligation to a teacher or member of staff to participate.* **Please state how you will bring to the attention of the participants their right to withdraw from the study without penalty?** As part of the e-mail information and the participant information sheet.

C7	**CONSENT** **Please describe the process you will use when seeking and obtaining consent.** Participants will be supplied with a patient information sheet explaining the study and the process. They will be invited to do the virtual reality simulation at a mutually convenient time, where the researcher will again explain the process of the simulation and explain what will happen and be clear that there are no negative consequences from non-participation, and offer the opportunity to consent to the study. *A copy of your participant information sheet(s) and consent form(s) must be attached to this application. For your convenience proformas are provided in Appendix I. These should be filled in and modified as necessary.* In cases where it is not proposed to obtain the participants informed consent, please explain why below.

C8	**Will any form of deception be used that raises ethical issues? If so, please explain.** No

C9	**Will you provide a full debriefing at the end of the data collection phase?** ☐ **Yes** ☐ **No** If 'No', please explain why below.

C10	**Information Sheets And Consent Forms: Appendix I** **A poorly written Information Sheet(s) and Consent Form(s) that lack clarity and simplicity frequently delay ethics approval of research projects.** The wording and content of the Information Sheet and Consent Form must be appropriate to the age and educational level of the research participants and clearly state in simple non-technical language what the participant is agreeing to. Use the active voice e.g. "we will book" rather than "bookings will be made". Refer to participants as "you" and yourself as "I" or "we". An appropriate translation of the Forms should be provided where the first language of the participants is not English. If you have different participant groups you should provide Information Sheets and Consent Forms as appropriate (e.g. one for children and one for parents/guardians) using the templates provided in Appendix I. Where children are of a reading age, a written Information Sheet should be provided. When participants cannot read or the use of forms would be inappropriate, a description of the verbal information to be provided should be given. Where possible please ensure that you trial the forms on an age-appropriate person before you submit your application.

SECTION D: DATA STORAGE AND SECURITY

D1	**Will the research involve the collection and/or use of personal data?** ☐ **Yes** ☐ **No** **If yes, is the research collecting or using:** **sensitive personal data as defined by the General Data Protection Regulation 2018 (racial or ethnic origin / political opinions / religious beliefs / trade union membership / physical or mental health / sexual life / commission of offences or alleged offences), and/or** **data which might be considered sensitive in some countries, cultures or contexts?** **If yes, state whether explicit consent will be sought for its use and what data management measures are in place to adequately manage and protect the data.** There will be no collection of the above data. The data will be anonymised and held securely.
D2	<u>**During the Project**</u> **(including the write up and dissemination period)** **State what types of data will be generated from this project** (i.e. transcripts, videos, photos, audio tapes, field notes, etc). Virtual reality 'transcript videos' of the interaction can be generated from the virtual reality platform and stored for analysis. A transcript or video of the debrief feedback will be kept, as well as copies of the questionnaire feedback. Other data includes, movement data tracked from the headset however this is anonymous data, nothing collected will be able to identify the participant. **How will data be stored, including where and for how long?** This includes all hard copy and electronic data on laptops, share drives, usb/mobile devices. Copies will be stored on secure personal computers and password-protected by the researcher. **Who will have access to the data, including advisory groups and during transcription?** Only the researcher will have access to the data.

D3	**Will personal data be processed or be sent outside of the European Economic Area (EEA)*?** **If yes,** please confirm that there are adequate levels of protection in compliance with the General Data Protection Regulation 2018 and state what arrangements are below. ***Please note** that if you store your research data containing identifiable data on UCL systems or equipment (including by using your UCL email account to transfer data), or otherwise carry out work on your research in the UK, the processing will take place within the EEA and will be captured by Data Protection Regulation. No

D4	**<u>After the Project</u>** **What data will be stored and how will you keep it secure?** After the experiment the data will be stored on two password protected hard drives and locked away by the researcher. **Where will the data be stored and who will have access?** The data will be stored on a secured, password-protected and encrypted USB **Will the data be securely deleted?** **If yes,** please state when will this occur:

D5	**Will the data be archived for use by other researchers?** ☐ **Yes** ☐ **No** If **Yes**, please describe provide further details including whether researchers outside the EEA will be given access.

SECTION E: DETAILS OF RISKS AND BENEFITS TO THE RESEARCHER AND THE RESEARCHED

E1	**Please state briefly any precautions being taken to protect the health and safety of researchers and others associated with the project (as distinct from the research participants).** The study will take place in a clinical simulation centre, which is already using virtual reality simulation. The virtual reality simulation equipment will be provided by the clinical simulation centre and will be PAT-tested in line with their local policies to ensure it is safe to use.

E2	**Will these participants participate in any activities that may be potentially stressful or harmful in connection with this research?** ☐ **Yes** ☐ **No** If **Yes**, please describe the nature of the risk or stress and how you will minimise and monitor it. The simulation has a very low risk of causing psychological distress in the participants from interacting with an angry and stressed virtual avatar parent, as we know this can be traumatic and distressing for staff when this occurs in the real-world situation. The risk of putting participants into the virtual reality simulation is mitigated by the fact that rehearsing communication skills in a simulated environment is psychologically safer than being exposed to these interactions in the real clinical environment without having prior preparation. The researchers who debrief the simulation will facilitate discussion of any emotional components of the simulation which arise, and will be able to provide support for participants if they feel distressed or wish to explore any additional emotional context which arises, and there will be opportunity to signpost further support should the need arise. There is a small risk of the Virtual Reality equipment inducing motion sickness. Participants will be excluded if they are unable to tolerate the simulation due to visually-induced motion sickness when using virtual reality technology, or if they have been informed by a medical professional for any reason not to use virtual reality technology. If participants experience these symptoms during the simulation they will be offered the opportunity to withdraw from the study.

E3	**Will group or individual interviews/questionnaires raise any topics or issues that might be sensitive, embarrassing or upsetting for participants?** If **Yes,** please explain how you will deal with this. No
E4	**Please describe any expected benefits to the participant.** The participants will benefit from being able to practice simulated conversations around difficult and challenging parental interactions prior to first experiencing these interactions in the clinical environment, in a safe virtual environment, under the supervision of clinical education researchers, and simulation faculty, which will enable them to safely practice and improve their communication skills. Training in dealing with difficult communication scenarios is often not possible due to the expense and time-input associated with running these events with simulated actors, and therefore research participants are otherwise unlikely to experience this training.

E5	**Specify whether the following procedures are involved:** **Any invasive procedure(s)** ☐ **Yes** ☐ **No** **Physical contact** ☐ **Yes** ☐ **No** **Any procedure(s) that may cause mental distress** ☐ **Yes** ☐ **No** Please state briefly any precautions being taken to protect the health and safety of the research participants. As per section B6.

E6	**Does the research involve the use of drugs?** ☐ **Yes** ☐ **No** If **Yes**, please name the drug/product and its intended use in the research and then complete Appendix II N/A **Does the project involve the use of genetically modified materials?** ☐ **Yes** ☐ **No** If **Yes**, has approval from the Genetic Modification Safety Committee been obtained for work? ☐ Yes ☐ No If **Yes**, please quote the Genetic Modification Reference Number: N/A

E7	**Will any non-ionising radiation be used on the research participant(s)?** ☐ **Yes** ☐ **No** If **Yes**, please complete Appendix III.

CHECKLISTAre you using a medical device in the UK that is CE-marked and is being used within its product indication? ☐**Yes** ☐ **No**

If Yes, please complete Appendix IV.

Documents to be Attached to Application Form (if applicable)	**Tick if attached**
Section B: Details of the Project	
Questionnaire(s) / Psychological Tests	☐
Relevant correspondence relating to involvement of collaborating department/s and agreed participation in the research i.e. approval letters to gatekeepers seeking permission to do research on their premises/ in their company etc.	☐
Section C: Details of Participants	

Parental/guardian consent form for research involving participants under 18 ☐

Participant/s information sheet ☐

Participant/s consent form/s ☐

Advertisement ☐

Appendix I: Information Sheet(s) and Consent Form(s) ☐

Appendix II: Research Involving the Use of Drugs

Relevant correspondence relating to agreed arrangements for dispensing with the pharmacy ☐

Written confirmation from the manufacturer that the drug/substance has has been manufactured to GMP ☐

Proposed volunteer contract ☐

Full declaration of financial or direct interest ☐

Copies of certificates: CTA etc…☐

Appendix III: Use of Non-Ionising Radiation ☐

Appendix IV: Use of Medical Devices ☐

Updated 17.10.2017

UCL RESEARCH ETHICS COMMITTEE
OFFICE FOR THE VICE PROVOST RESEARCH

20th August 2019

Professor Caroline Fertleman
Institute of Child Health
UCL

Cc: Simon Blackburn

Dear Professor Fertleman

Notification of Ethics Approval with Provisos
Project ID/Title: 0884/023: Breaking bad news: a virtual reality communications training project for staff working in healthcare

Further to your satisfactory responses to the Committee's comments, I am pleased to confirm in my capacity as Joint Chair of the UCL Research Ethics Committee (REC) that your study has been ethically approved by the UCL REC. Ethical approval has been granted until **31st January 2021.**

Ethical approval is subject to the following conditions:

Notification of Amendments to the Research
You must seek Chair's approval for proposed amendments (to include extensions to the duration of the project) to the research for which this approval has been given. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing an 'Amendment Approval Request Form'
http://ethics.grad.ucl.ac.uk/responsibilities.php

Adverse Event Reporting – Serious and Non-Serious
It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator (ethics@ucl.ac.uk) immediately the incident occurs. Where the adverse incident is unexpected and serious, the Joint Chairs will decide whether the study should be terminated pending the opinion of an independent expert. For non-serious adverse events the Joint Chairs of the Ethics Committee should again be notified via the Ethics Committee Administrator within ten days of the incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Joint Chairs will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.

Final Report
At the end of the data collection element of your research we ask that you submit a very brief report (1-2 paragraphs will suffice) which includes in particular issues relating to the ethical implications of the research

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Tel: +44 (0)20 7679 8717
Email: ethics@ucl.ac.uk
http://ethics.grad.ucl.ac.uk/

i.e. issues obtaining consent, participants withdrawing from the research, confidentiality, protection of participants from physical and mental harm etc.

In addition, please:

- ensure that you follow all relevant guidance as laid out in UCL's Code of Conduct for Research: https://www.ucl.ac.uk/srs/file/579
- note that you are required to adhere to all research data/records management and storage procedures agreed as part of your application. This will be expected even after completion of the study.

With best wishes for the research.

Yours sincerely

Professor Michael Heinrich
Joint Chair, UCL Research Ethics Committee

Instructions for GOSH Pilot

<u>Brief:</u>

Thank you for your participation in this pilot study. During this session, you will be seeing Emily and her 3-year-old son, Sam. Sam has primary immunodeficiency and needs long term immunoglobulins therapy. He was scheduled to have a PICC line inserted today.

You will need to inform Emily, that her son's PICC line surgery must be postponed due to Dr David Kahn, the interventional radiologist, being called into an emergency procedure for another child.

The doctor she has been dealing with, Dr Deidre Lacy is not available to consult with her presently, and you are the only qualified staff on the floor at the moment to see her. You will need to **reschedule the surgery for tomorrow.** Present in the ward will be both the mother and her toddler.

Please treat this as you would a normal consultation.

Thank you.

Post-Questionnaire

[redacted]

* Indicates required question

Your answer

I felt like I had control of the body was moving

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt like the virtual body was my body

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I wanted to maintain a sense of distance between us.

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I tried to create a sense of closeness between us.

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I was interested in talking to my interaction partner.

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt nervous talking to my interaction partner

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt anxious talking to my interaction partner

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt stressed talking to my interaction partner

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

My interaction partner was intensely involved in our interaction.

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

My interaction partner communicated coldness rather than warmth.

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

My interaction partner created a sense of distance between us.

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

My interaction partner seemed detached during our interaction.

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

My interaction partner made our conversation seem intimate.

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

My interaction partner created a sense of closeness between us.

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

How involving was the experience?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

How intense was the experience?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you feel like you were inside the environment you saw/heard?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you feel immersed in the environment you saw/heard?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you feel surrounded by the environment you saw/heard?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you feel able to assess your partner’s reactions to what you said?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent was this like a face-to-face meeting?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent was this like you were in the same room with your partner?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did your partner seem “real”?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you feel you could get to know someone that you met only through this system?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

1. Did you find it difficult to give advice to Emily? *

○ Yes

○ No

1a. Why/Why not? *

Your answer

5. How realistic did the interaction feel? *

	0	1	2	3	
Not at all realistic	○	○	○	○	Very Realistic

What made the scenario so realistic? *

Your answer

6. What particular aspect of the interaction did you think were unrealistic? *

Your answer

7. What particular aspect of the conversation made the scenario realistic? *

Your answer

8. How realistic did the virtual environment feel? *

	0	1	2	3	
Not at all realistic	○	○	○	○	Very Realistic

9. What particular aspects of the virtual environment did you think were unrealistic? *

Your answer

10. What made the virtual environment so realistic? *

Your answer

11. Do you think such virtual environments have potential as a training tool? *

- Yes
- No
- Maybe

12. Who do you think would most benefit from this type of training? *

- Medical Students
- FY1's
- FY2/SHOs/GPVTS
- Specialist Registrar
- GPs/Consultants/SAS doctors
- All of the Above

13. Do you have any further comments or suggestions? *

Your answer

ACTOR SCRIPT GUIDE

Bold words – Angry/Frustrated

A) – multiple choice prompt

A.1) – multiple choice dialogues

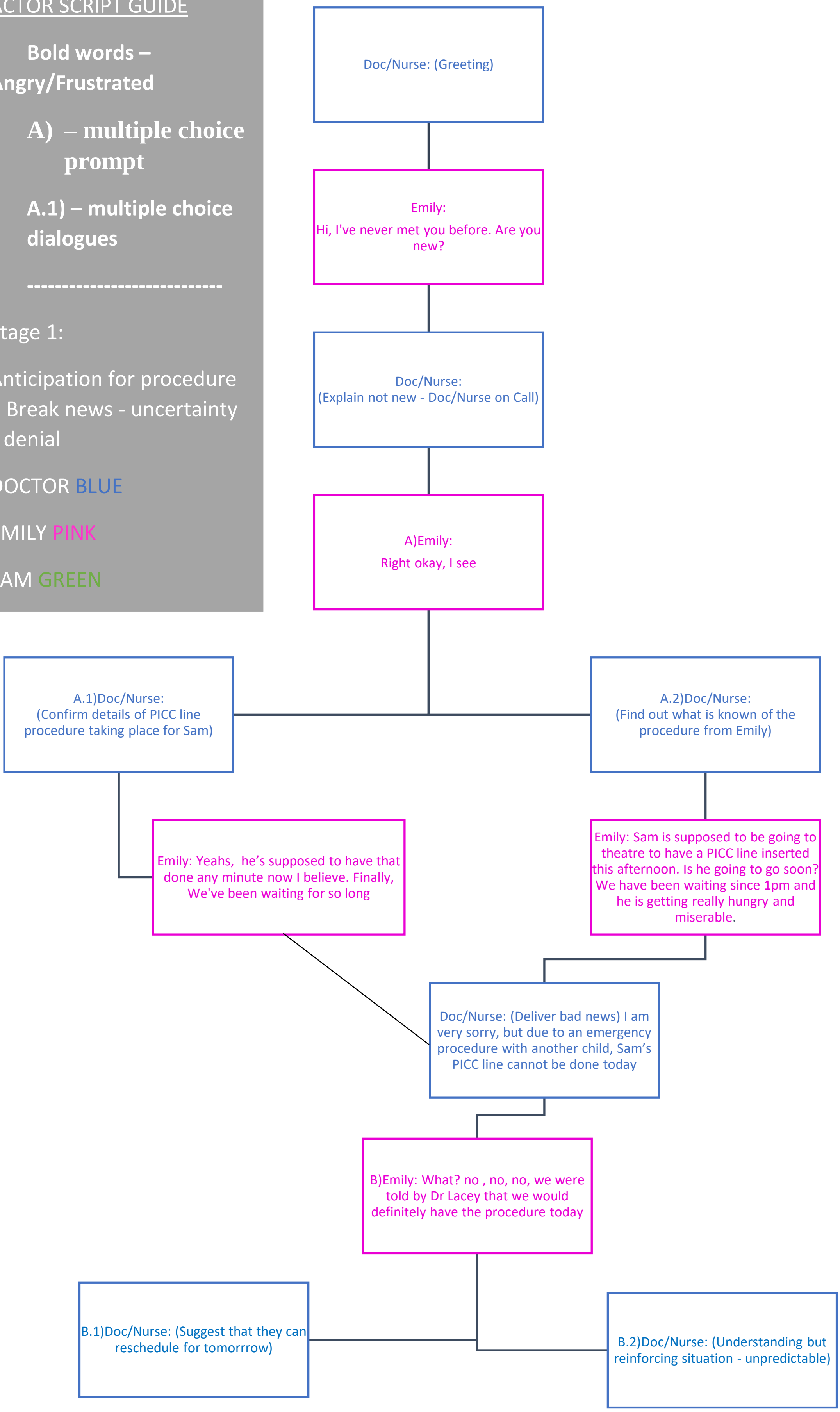
Stage 1:

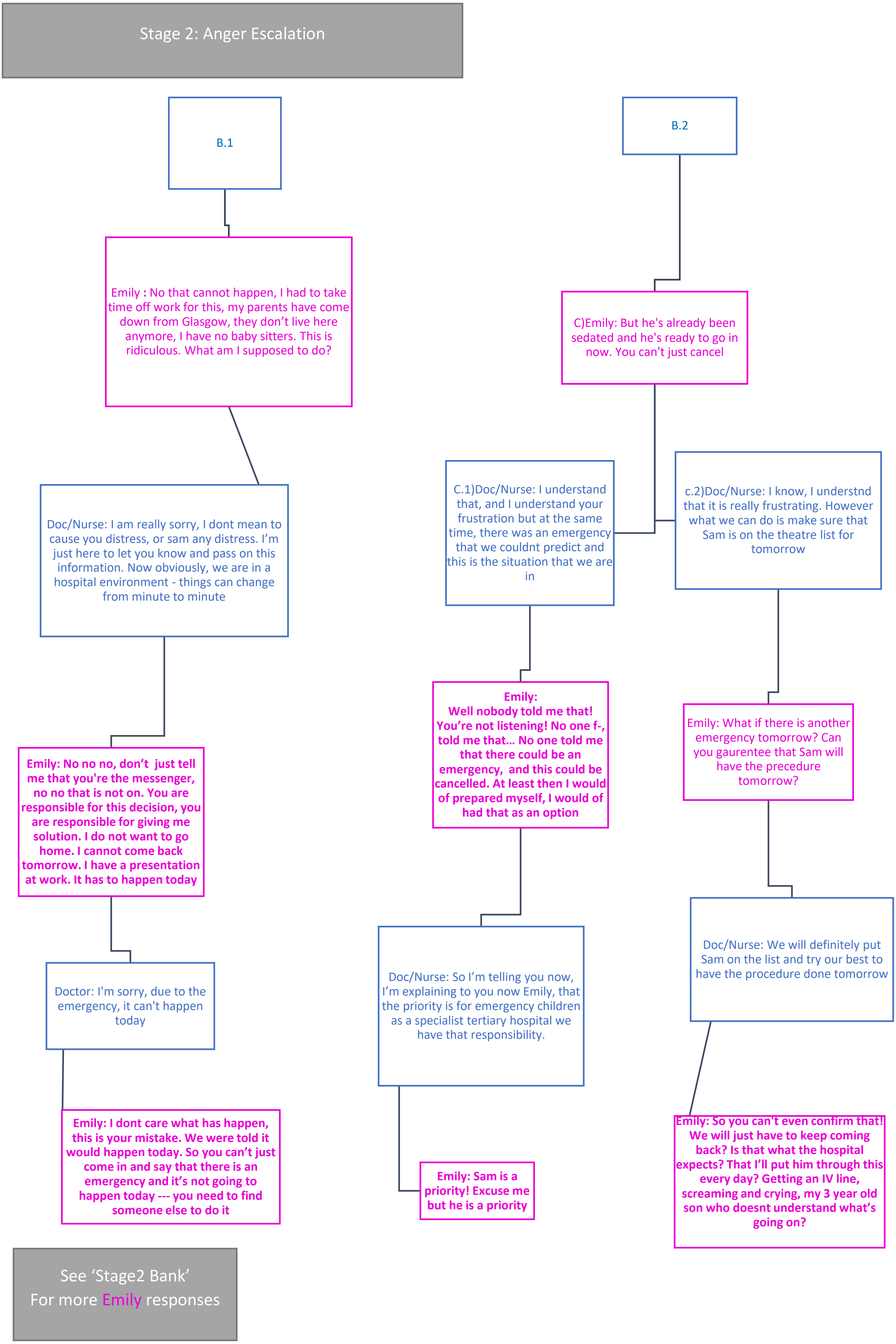
Anticipation for procedure + Break news - uncertainty / denial

DOCTOR BLUE

EMILY PINK

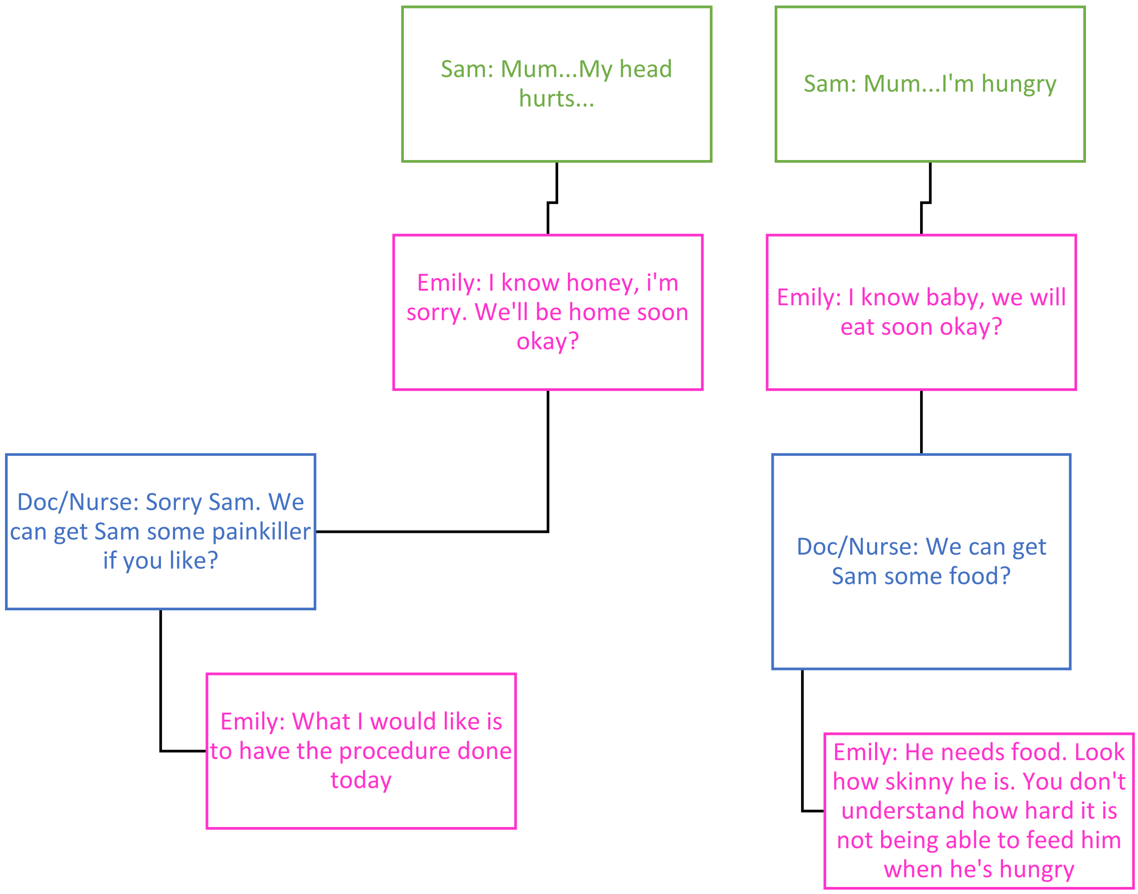
SAM GREEN





Stage 2: Anger Escalation
B.1
Emily : No that cannot happen, I had to take time off work for this, my parents have come down from Glasgow, they don't live here anymore, I have no baby sitters. This is ridiculous. What am I supposed to do?
Doc/Nurse: I am really sorry, I dont mean to cause you distress, or sam any distress. I'm just here to let you know and pass on this information. Now obviously, we are in a hospital environment - things can change from minute to minute
Emily: No no no, don't just tell me that you're the messenger, no no that is not on. You are responsible for this decision, you are responsible for giving me solution. I do not want to go home. I cannot come back tomorrow. I have a presentation at work. It has to happen today
Doctor: I'm sorry, due to the emergency, it can't happen today
Emily: I dont care what has happen, this is your mistake. We were told it would happen today. So you can't just come in and say that there is an emergency and it's not going to happen today --- you need to find someone else to do it
B.2
C)Emily: But he's already been sedated and he's ready to go in now. You can't just cancel
C.1)Doc/Nurse: I understand that, and I understand your frustration but at the same time, there was an emergency that we couldnt predict and this is the situation that we are in
Emily: Well nobody told me that! You're not listening! No one f-, told me that... No one told me that there could be an emergency, and this could be cancelled. At least then I would of prepared myself, I would of had that as an option
Doc/Nurse: So I'm telling you now, I'm explaining to you now Emily, that the priority is for emergency children as a specialist tertiary hospital we have that responsibility.
Emily: Sam is a priority! Excuse me but he is a priority
c.2)Doc/Nurse: I know, I understnd that it is really frustrating. However what we can do is make sure that Sam is on the theatre list for tomorrow
Emily: What if there is another emergency tomorrow? Can you gaurentee that Sam will have the precedure tomorrow?
Doc/Nurse: We will definitely put Sam on the list and try our best to have the procedure done tomorrow
Emily: So you can't even confirm that! We will just have to keep coming back? Is that what the hospital expects? That I'll put him through this every day? Getting an IV line, screaming and crying, my 3 year old son who doesnt understand what's going on?
See 'Stage2 Bank'
For more Emily responses

Stage 2.5: Sam


Sam: Mum...My head hurts...
Emily: I know honey, i'm sorry. We'll be home soon okay?
Doc/Nurse: Sorry Sam. We can get Sam some painkiller if you like?
Emily: What I would like is to have the procedure done today
Sam: Mum...I'm hungry
Emily: I know baby, we will eat soon okay?
Doc/Nurse: We can get Sam some food?
Emily: He needs food. Look how skinny he is. You don't understand how hard it is not being able to feed him when he's hungry

STAGE 2 BANK

Longer answers:

Emily: I don't even know If I can come here tomorrow. I'm sorry, my parents have just moved to Glasgow, and they had to take a plane down yesterday to babysit my other kids today I have no other babysitter. I'm a single mum, I have no one else to babysit. I've had to take a day off work, which is incredibly difficult for me. So I don't even know if I'll be able to come tomorrow.

Emily: Nobody told me about that. Nobody said that there might be an emergency and he won't be able it get it done. It's what he's been waiting for, it's what he needs. He's also sick, I know it's not an emergency like some kids, but he's also very sick.

Emily: I'd like you to be more proactive, and give me some solutions, because all you've done is come in delivering bad news and then what, going off? It's like tick on the list. Like, okay I've told that parent.

Emily: No, this is not on. How will it benefit my son to go through another half day without eating? He is already so skinny and it's hard for him to put on weight. I was told he would be seen today and that he can't eat until after the procedure. He is so hungry. How can you put him through that again?

Emily: I can't come back tomorrow; I have a presentation at work to do tomorrow. I can't, it's in front of all of my bosses. I can't just call up and say oh you know what I can't come in today, you know that procedure thing that my son was meant to have today, that I took the day off for, its actually happening tomorrow so I can't come in tomorrow and do that presentation, for our clients. What are they supposed to say to their clients? It's one of our top clients and I'm presenting to them? They are flying in from America!

Shorter answers:

Emily: My mum is not all that well at the moment, she's flown all the way from Glasgow to look after my two kids

Emily: This is happening today - I am not going home today

Emily: I don't care about the other patients I'm sorry, I just care about my son

Emily: Are you saying that my child is not a priority?

Emily: My boss will not care. I'm probably going to get fired. I'm going to get fired because of your mistake

Emily: This has messed up so many things for me this week I can't even tell you

Emily: No you don't understand that. Do you understand that kind of pressure?

Emily: I was told that this was urgent, that this procedure is urgent for Sam. Is it not urgent?

Emily: What works best for me is that it happens today

Emily: I am not going home today - who's going to look after my kids when I come back here

Emily: Well then someone can do it. Because we are not going home today

Emily: Someone has taken his slot! So, he can take someone else's slot today!

Emily: You apologising isn't going to fix the situation!

Emily: Don't tell me to calm down. This is your fault!

Emily: Can you get a babysitter for my kids? Can you get me a day off work? I didn't think so!

Emily: That's not good enough!

General short answers and connection words/phrases:

Emily: Excuse me?

Emily: This is ridiculous…

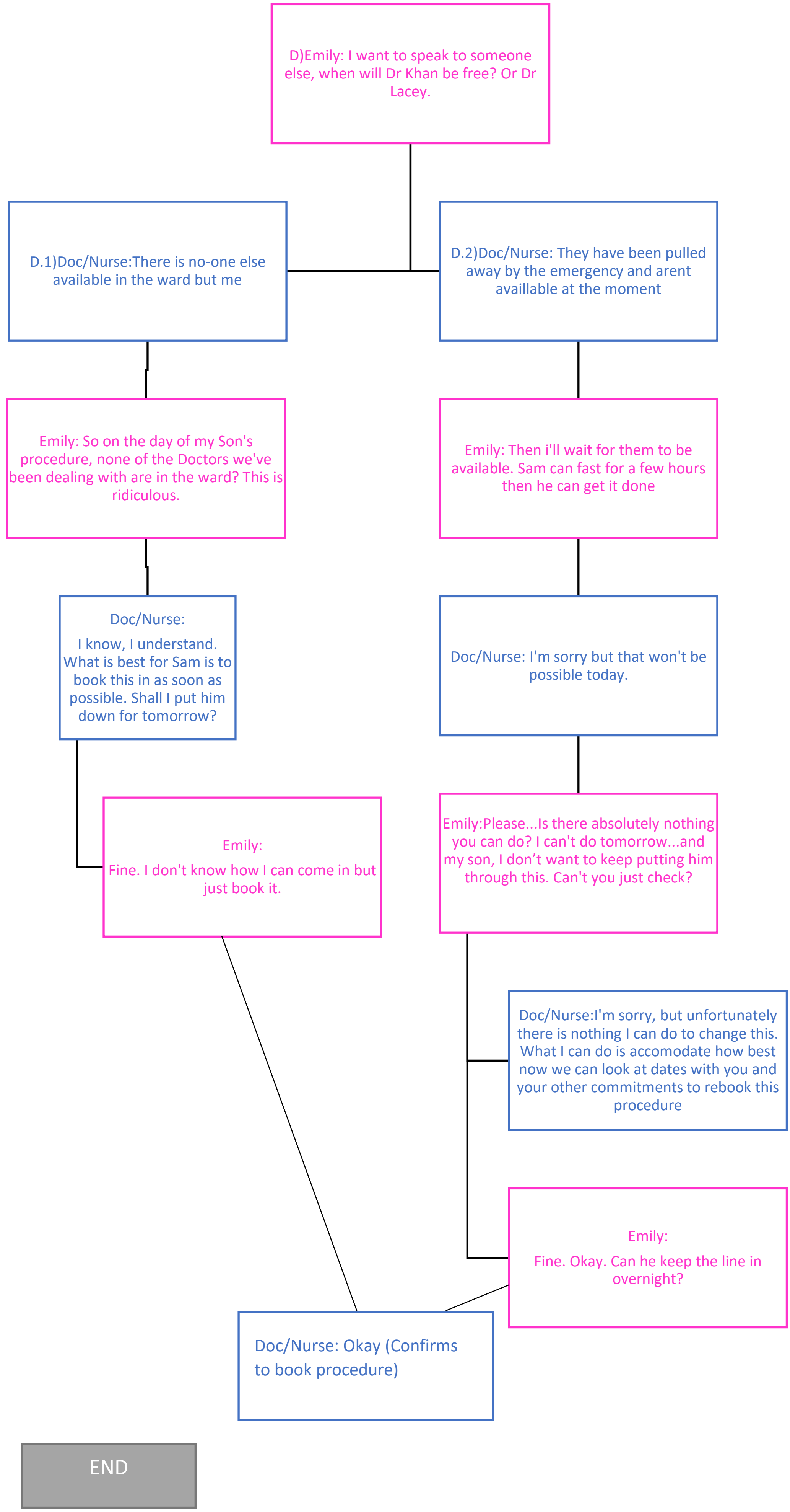
Emily: No

Emily: Yes

Emily: I don't care…

Emily: You're not listening…

Stage 3: Shut down – Parent accepts rescheduling



C.1.2 Questionnaires Study 2

Pre-Questionnaire

[redacted]

* Indicates required question

Participant ID

Your answer

1. What is your gender? *

- ◯ Male
- ◯ Female
- ◯ Rather not say

2. What is your age? *

Your answer

3. Please describe your role? (GP, Consultant, etc) *

Your answer

3a. Which year did you qualify? *

Your answer

3b. How many months(not annual leave) have you had off since qualifying? *

Your answer

3c. What category do you belong to? *

- F2
- GPVTS
- GP
- Other:

4. I see myself as someone who ... *

	Disagree Strongly	Disagree a little	Neither Agree nor Disagree	Agree a Little	Agree Strongly
... is reserved	○	○	○	○	○
... is generally trusting	○	○	○	○	○
... tends to be lazy	○	○	○	○	○
... is relaxed, handles stress well	○	○	○	○	○
... has few artistic interests	○	○	○	○	○
... is outgoing, sociable	○	○	○	○	○
... tends to find fault with others	○	○	○	○	○
... does a thorough job	○	○	○	○	○
... gets nervous easily	○	○	○	○	○
... has an active imagination	○	○	○	○	○

5. Please indicate how often the following statements occur: *

	Never	Almost Never	Sometimes	Fairly Often	Very Often
In the last month, how often have you been upset because of something that happened unexpectedly?	○	○	○	○	○
In the last month, how often have you felt that you were unable to control the important things in your life?	○	○	○	○	○
In the last month, how often have you felt nervous and "stressed"?	○	○	○	○	○
In the last month, how often have you felt confident about your ability to handle your personal problems?	○	○	○	○	○
In the last month, how often have you felt that things were going your way?	○	○	○	○	○
In the last month, how often have you found that you could not cope	○	○	○	○	○

with all the things that you had to do?

In the last month, how often have you been able to control irritations in your life?	○	○	○	○	○
In the last month, how often have you felt that you were on top of things?	○	○	○	○	○
In the last month, how often have you been angered because of things that were outside of your control?	○	○	○	○	○
In the last month, how often have you felt difficulties were pilling up so high that you could not overcome them?	○	○	○	○	○

6. Please indicate how much you agree/disagree with the following statements: *

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
In general when someone praises doctors, it feels like a personal compliment	○	○	○	○	○	○	○
In general when someone criticizes doctors, it feels like a personal insult	○	○	○	○	○	○	○
When I talk about doctors I say 'we' rather than 'they'	○	○	○	○	○	○	○
Medicine's successes are my successes	○	○	○	○	○	○	○
if a story in the media criticized doctors, I would feel embarrassed	○	○	○	○	○	○	○

7.Have you undertaken any continuing professional development courses in the last 12 months? *

- ◯ Yes
- ◯ No

Pre-VR: [5-Item Assessment] **Resident Evaluation/Self-Evaluation**

Self-Assessment regarding Skills involving Difficult Conversations using 7-Point-Likert Scale

[redacted]

* Indicates required question

ID *

Your answer

This issue is appropriate for my level of training *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I am trained to discuss this issue with patients *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I feel nervous discussing this issue with patients *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I am able to answer questions about this issue *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I am skilled at this difficult conversation *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

VRMCT: Post VR Survey

21-point checklist extracted from the guidelines for disclosure of adverse events developed by the CPSI and published by the CMPA

[redacted]

* Indicates required question

Participant ID *

Your answer

Check those that apply. During the consultation with Emily I... *

- [ ] Introduced myself
- [ ] Introduced the topic of discussion
- [ ] Used plain language
- [ ] Expressed regret
- [ ] Determined what Emily knows
- [ ] Presented the facts
- [ ] Avoided placing blame
- [ ] Allowed time for Emily to express feelings
- [ ] Was professional
- [ ] Avoided barriers
- [ ] Spoke at a comfortable rate
- [ ] Used appropriate body-language
- [ ] Focused on the patients needs
- [ ] Was attentive
- [ ] Allowed time for reflection
- [ ] Checked for understanding
- [ ] Summerized the meeting
- [ ] Arranged a follow up

VRMCT: Post VR Survey

[redacted]

* Indicates required question

Resident Evaluation/Self-Evaluation

I have successfully discussed this issue with Emily *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

This issue was appropriate for my level of training *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I am trained to discuss this issue with Emily *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt nervous discussing this issue with Emily *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I was able to answer questions about this issue with Emily *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I was skilled at this difficult conversation with Emily *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

VRMCT: Post VR Survey

[redacted]

* Indicates required question

BBN Skills Scaled Items - 6 item self reflect

When consulting with Emily about important issues, how good/bad were you at...

Verbally responding to Emily's emotion: *

	1	2	3	4	5	
no verbal response to her emotion or responses hampered my relationship with the physician, e.g., said something I found off-putting	○	○	○	○	○	consistent verbal acknowledgment of her emotions that almost always felt natural and tailored to her needs).

Nonverbally responding to Emily's emotions. *

	1	2	3	4	5	
nonverbal response to her emotion or nonverbal actions hampered her relationship with me, e.g., inappropriate touch, uncomfortable silence, distracted body language, no eye contact;	○	○	○	○	○	consistent verbal acknowledgment of her emotions that almost always felt natural and tailored to her needs).

Overall, how would you rate your communication with Emily? *

	1	2	3	4	5	
I communicated in a way that was detrimental to our relationship	○	○	○	○	○	I consistently said/did things that she found helpful and responses/actions that almost always felt natural and tailored to her needs).

You demonstrated that you were able to recognize the impact of this moment on Emily. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

You were able to convey the information clearly and provide guidance on how Emily should proceed. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

During the conversation, you were able to notice how Emily was doing and switch back and forth between providing information/guidance and acknowledging the impact of the news on her and her son. *

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly Agree

VRMCT: Post VR Survey

[redacted]

* Indicates required question

Embodiment and Social Presence

I felt like I had control of the body that was moving *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt like the virtual body was my body *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I tried to create a sense of closeness between myself and Emily *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I was interested in talking to Emily. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt nervous talking to Emily. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I felt stressed talking to Emily. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Emily was intensely involved in our interaction. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Emily created a sense of distance between us. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Emily seemed detached during our interaction. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Emily created a sense of closeness between us. *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

How involving was the experience? *

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

How intense was the experience? *

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you feel like you were inside the environment you saw/heard? *

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you feel immersed in the environment you saw/heard?

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you feel surrounded by the environment you saw/heard? *

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you feel able to assess Emily's reactions to what you said? *

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent was this like a face-to-face meeting? *

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent was this like you were in the same room with Emily? *

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did your Emily seem “real”? *

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you feel you could get to know someone that you met only through this system? *

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

To what extent did you Did you find it difficult to give advice to Emily? *

	1	2	3	4	5	6	7	
Not at All	○	○	○	○	○	○	○	Very Much

Why? *

Your answer

How realistic did the interaction feel? *

	1	2	3	4	5	6	7	
Not at all realistic	○	○	○	○	○	○	○	Very Realistic

How realistic did the virtual environment feel? *

	0	1	2	3	
Not at all realistic	○	○	○	○	Very Realistic

What made the scenario feel realistic? *

Your answer

What particular aspect of the conversation made the scenario realistic? *

Your answer

What made the virtual environment feel realistic? *

Your answer

What particular aspect of the interaction did you think were unrealistic? *

Your answer

What partic lar aspects of the virtual environment did you think w re unrealistic? *

Your answer

Appendix D

AppendixD

D.1 AppendixD - Additional Work Attached

Items:

- Evaluating Quality Experience through Participant Choices
- A Study of Professional Awareness Using Immersive Virtual Reality: The Responses of General Practitioners to Child Safeguarding Concerns

D.1.1 A Study of Professional Awareness Using Immersive Virtual Reality: The Responses of General Practitioners to Child Safeguarding Concerns

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ORIGINAL RESEARCH
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A Study of Professional Awareness Using Immersive Virtual Reality: The Responses of General Practitioners to Child Safeguarding Concerns

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The art of picking up signs that a child may be suffering from abuse at home is one of those skills that cannot easily be taught, given its dependence on a range of non-cognitive abilities. It is also difficult to study, given the number of factors that may interfere with this skill in a real-life, professional setting. An immersive virtual reality environment provides a way round these difficulties. In this study, we recruited 64 general practitioners (GPs), with different levels of experience. Would this level of experience have any impact on general practitioners' ability to pick up child-safeguarding concerns? Would more experienced GPs find it easier to pick up subtle (rather than obvious) signs of child-safeguarding concerns? Our main measurement was the quality of the note left by the GP at the end of the virtual consultation: we had a panel of 10 (all experienced in safeguarding) rate the note according to the extent to which they were able to identify and take the necessary steps required in relation to the child safeguarding concerns. While the level of professional experience was not shown to make any difference to a GP's ability to pick up those concerns, the parent's level of aggressive behavior toward the child did. We also manipulated the level of cognitive load (reflected in a complex presentation of the patient's medical condition): while cognitive load did have some impact upon GPs in the "obvious cue" condition (parent behaving particularly aggressively), this effect fell short of significance. Furthermore, our results also suggest that GPs who are less stressed, less neurotic, more agreeable and extroverted tend to be better at raising potential child abuse issues in their notes. These results not only point at the considerable potential of virtual reality as a training tool, they also highlight fruitful avenues for further research, as well as potential strategies to support GP's in their dealing with highly sensitive, emotionally charged situations.

Keywords: immersive virtual reality, virtual patient, medical training, professional awareness, child safeguarding, expertise, cognitive load, naturalistic decision making

INTRODUCTION

Aside from having to grasp an ever-growing body of medical knowledge, today's general practitioners (GPs) need to be equipped with a wide set of practical and social skills. While some of those skills can be taught pretty straightforwardly, others are harder to inculcate without the benefit of experience and role models. The ability to pick up signs that a child may be suffering from abuse at home is one of those skills that cannot easily be taught. The clearly non-cognitive underpinnings of this skill made it an ideal focus point for this study, which, at a more abstract level, is driven by an endeavor to develop a better understanding of the non-cognitive aspects of professional expertise. To become a professional indeed requires a process of habituation, whereby one comes to internalize "the way things are done." Aside from its cognitive elements, the latter typically encompasses a mix of intuitive understandings and both reflective and unreflective habits. These non-cognitive, deeply internalized aspects of expertise can be what distinguishes the merely competent from the truly brilliant: just as experienced firemen seem able to sense when to evacuate a building that is about to collapse, some healthcare providers seem able to sense when something is amiss with a child even in the absence of any concerns expressed by the child and/ or her carer.

In the UK, all GPs are entrusted with the responsibility to identify potential child abuse issues and keep record of any concerns they may have (General medical council, 2012), given their position as primary point of contact for families with healthcare concerns. Beyond the specific child protection training provided in the context of continuous education - all GPs have to obtain level 3 safeguarding competency (Royal College of Paediatrics Child Health, 2014), undergraduate education about child protection has only been included in the medical school curriculum relatively recently. It is mentioned in the American literature as early as 1996 (Dorsey et al., 1996), but, as an example, in UCL Medical School it was only formally included from 2005. A variety of teaching styles is used, often mirroring postgraduate training, but delivered appropriate for the learners' level of knowledge, exposure and experience (Hann and Fertleman, 2016). A qualitative study at UCL of medical students' experience of child protection teaching by Yiannis Ioaunnou concluded "*these students have placed great emphasis on emotional aspects of the subject. They have commented on their uncertainty of their own role in these situations and concern about managing emotions that might be experienced*" (Ioannou, 2008).

Emphasis on the impact of emotions on the processes that are constitutive of morally-loaded judgments is far from new. The dominant, dual-process theory highlights the interaction between cognitive processes on one hand, and emotional and intuitive processes on the other. Cognitive load manipulation experiments have long been relied on to throw light on these interaction modalities. They have largely contributed to corroborating the now widely influential "dual system" theory (Kahneman, 2011), which highlights a dichotomy between two different ways in which we may apprehend a given situation: while System 1 produces fast, instinctive and emotional answers, System 2 stands for slower, deliberative modes of thought. The latter are meant to supervise System 1's fast, emotional and/or intuitive answers. When cognitive load disrupts System 2's supervising role, intuitions and emotions are given free(er) rein. This can prove problematic and lead to an increase in erroneous judgments (Gilbert, 1989; Menaker et al., 2006; Pawar et al., 2017) particularly so when those judgments proceed from simplifying heuristics rather than a skill learned from experience.

The "naturalistic decision making" tradition (NDM), which owes its name to an endeavor to study how people "actually" make decisions under conditions (like high stakes or team dynamics) that are not easily replicated in the laboratory (Klein, 2008; Zsambok and Klein, 2014) has focused on the latter, skilled type of intuition. Initially developed from an attempt to analyze the way fireground commanders make decisions under conditions of uncertainty and time pressure (which hamper System 2's ability to systematically evaluate a set of options), naturalistic decision making has since studied many professions-specific examples of what it refers to as "skilled" intuitions. Acquired through extensive experience in an environment that allows for systematic, constructive feedback, those skilled intuitions are contrasted to those that arise from quick, simplifying heuristics that are never put to the test. (Crandall and Getchell-Reiter, 1993) for instance studied the intuitions that allow nurses in a neonatal intensive care unit to detect life-threatening infections even before blood tests came back positive. These intuitions draw upon tacit, rather than explicit knowledge: the nurses' remarkable ability was acquired through extensive experience, rather than any formalized training based on a set of rules or principles. Henceforth we will refer to the above as the "skilled intuition effect."

While the Naturalistic Decision Making tradition is widely acknowledged as having the potential to contribute in a substantial way to our understanding of the factors that impact upon professional judgment, it is often criticized due to its having to study professional judgment "*in situ,*" with the lack of controllability this entails. In this respect, reliance on immersive virtual reality to study ecologically valid professional judgments -albeit in a controlled environment- has great potential as an added "tool" at the disposal of all those seeking to gain a better understanding of the factors that impact upon professional judgment (within or without the Naturalistic Decision Making tradition), since it allows for those factors to be controlled and replicated with a high degree of precision.

Using virtual humans in the field of medical training is not new. For instance, early work by Johnsen et al. (2007) showed a significant correlation between medical students' performance with a virtual and a human patient, and (Raij et al., 2007) showed that medical students were able to elicit the same information from the real and virtual human (although showing less interest and poorer attitude toward the latter). More recently, virtual patients have been used in training for mental health assessment (Foster et al., 2015; Washburn et al., 2016), empathetic communication (Kleinsmith et al., 2015), and identifying gender bias in diagnosis (Rivera-gutierrez et al., 2014). In these studies, typically, human participants interacted with virtual patients via text or voice, and the virtual patients were animated and programmed to react toward the participants in a realistic way. For a summary of different types of virtual patients see (Talbot et al., 2012; Kononowicz et al., 2015).

Our approach emphasizes the ecological validity of the GP-virtual patient interaction: our use of immersive virtual reality allows the participants to interact with 3D, human-sized and realistically animated virtual patients. Participants are able to interact with these virtual characters in the most natural way using their voice and gestures, and the virtual characters respond appropriately, using a wizard-of-oz method where an experimenter selects the reaction from a command window. Similar approaches have been used in previous work including therapy for social anxiety (Pan et al., 2012), study of bystander reactions to a violent incident (Slater et al., 2013), and more recently training for GPs to resist the unreasonable demand to prescribe antibiotics (Pan et al., 2016).

This study was designed to test whether the level of professional experience—as well as cognitive load—have any impact upon a GP's ability to correctly identify (and devise some strategy to address) child safeguarding concerns. As one of the advantages of using virtual reality consists in its allowing for the accurate control of various factors in the GP-patient interaction, in this work we controlled the level of child abuse cues. The cues were made to be more obvious or more subtle by manipulating only the level of aggressiveness shown by the parent toward his son during the consultation. The behavior of the son remained the same in both conditions (obvious v. subtle cues). We wanted to test whether the more obvious cues from a "virtual parent" would make it easier for the GPs to identify child-safeguarding concerns and take appropriate actions. The design of the scenario itself (based on a real-life case study) was chosen because its most important child-safeguarding cues predominantly require perceptual awareness rather than cognitive engagement on the part of the GP. The medical condition of the parent, which was presented in a more or less complex set of letters (high v. low cognitive load conditions) from two cardiologists, was also based on a real-life case study and adapted with specialist advice to retain maximum plausibility.

Overall our research questions are as follows:

Research question 1: Does the degree of professional experience impact upon a GP's ability to identify and act upon child safeguarding concerns effectively?

Hypothesis 1: Highly experienced GPs will be more likely to pick up child-safeguarding concerns and act upon it more effectively (skilled intuition effect, discussed above).

Hypothesis 2: Highly experienced GPs will be better able to pick up subtle (as opposed to obvious) signs of child-safeguarding concerns than their inexperienced counterparts.

Research question 2: Does cognitive load affect a GP's ability to pick up signs of child-safeguarding concerns and act upon it effectively?

Hypothesis 3: Cognitive load will affect all GP's ability to pick up signs of child-safeguarding concerns and act upon it effectively.

Hypothesis 4: The impact of cognitive load will be greater on less experienced GPs.

MATERIALS AND METHODS

Ethics Statement

The study was approved by and carried out in accordance with the regulations of the Research Ethics Committee of UCL. Participants gave written informed consent on a form devised for this purpose that had been approved by the said Research Ethics Committee.

Scenario Details

Video link: http://www.panxueni.com/gpcave

Our previous work used the HMD system where participants (i.e., GPs or trainee GPs) were fully immersed in the virtual interactions with a head-mounted display (Pan et al., 2016). Many participants commented that they found not having access to a computer made the experience less real, as they always relied on a computer during their real-life consultations. This presented us with a challenge: as the HMD systems block the real world completely, it is not possible to be immersed in VR while having access to a real computer at the same time. It is also not possible to simulate a virtual computer inside the HMD because the HMD's display resolution remains too low. In order for the participants to have access to a real computer while being immersed in the virtual environment, a CAVE-like system was used.

A virtual consultation was created in Autodesk Maya using some assets downloaded from the Unity assets store. The layout is modeled based upon photographs we took of a GPs consultation room in the United Kingdom, with a few chairs, a medical bed behind a curtain, some medical information posters hanging on the wall, and a hand sterilizer next to the door. As shown in **Figure 1**, the configuration of the room is carefully designed to reflect NHS guidelines where the patients' seating area is not blocking the doctor's access to the exit door. The participant, who is either a GP or a trainee GP, also has a real desktop and laptop in front of them just like they would in a real consultation. On the laptop, they have access to notes related to their next patient, Mr. Christopher (Chris) Truman, including basic information (date of birth, gender, NHS number) and two expert consultation letters. The two letters both indicate that Mr. Christopher Truman needs an operation for his aortic stenosis but give different recommendations: one suggesting trans-catheter aortic valve implantation (TAVI) and the other one an open-heart surgery. There were two sets of these letters as part of the experimental condition (see Supplemental Material: consultation letters). On the laptop, the participant also has an area where they are free to type in their notes. Everything is supported by a very unsophisticated web-browser interface and participants were given time to familiarize themselves with it and to study the notes before their consultation.

As the VR scenario starts, the participant finds themselves sitting on their own in the consultation room, with the door ajar. A man approaches the room and asks politely if the participant is expecting to see a "Christopher Truman," and once confirmed,

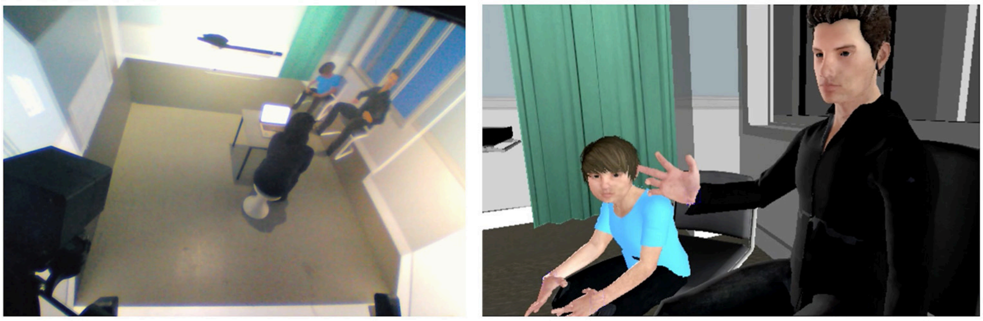

FIGURE 1 | Medical Doctor interacting with virtual patients in a CAVE-like system.

he apologizes that he has to bring his 6-year-old son with him. He then enters the room with his son, Tom, following him.

Chris sits down and becomes very upset with Tom when he realizes that, instead of sitting on the chair properly, Tom is staring at the chair. At this point Chris appears to have lost his patience. He aggressively gestures toward Tom to sit down (without touching Tom's body), and Tom flinches. Chris then apologizes for being bad tempered blaming his poor health, and the consultation carries on (see Supplemental Material: Video).

Chris explains that he needs to understand the options he has in order to make a quick decision to secure the surgery slot he has been offered. Typically, the participant and Chris would spend between 3 and 5 min discussing his options: open-heart surgery which is more risky but a permanent solution, or TAVI which is a less risky procedure but only a temporary solution. Toward the end of their discussion, Chris asks the participant to clarify what is the worst that could happen if he went for the open-heart surgery and is shocked to discover that he could die.

While Chris is deep in his thoughts, Tom interrupts and says that he wants to go to the toilet. Chris ignores Tom. Tom repeats his demands with a raised voice which makes Chris very upset. He shouts at Tom and tells him to hold on as he is having an important conversation.

At this point Chris's phone rings. It is clearly a phone call he has been waiting for. He quickly picks it up with and walks out of the room while talking on the phone, leaving the door closed behind him.

The moment Chris walks out of the room Tom looks visibly more relaxed. The participant has the opportunity to ask questions, they are free to ask anything but typically they would ask questions such as "What's your name?" "How old are you?" "Do you have any brothers or sisters?" As and when prompted by the participant, Tom answers these questions with short replies. If the participant chooses to ask questions related to Chris and how things are at home, Tom looks down or nods.

The opportunity for the participant to interact with Tom lasts 1 min—until Chris re-enters the room. He apologizes for having to pick up the important phone call from his brother. At the same time, he informs the participant that he has made up his mind and will go for the open-heart surgery. He then leaves the room with Tom. The participant is then left to type up their consultation notes on the laptop.

Design

The experiment has a 2 × 2 between group design with the two factors being: cognitive load (LOAD - two levels: high - H, low - L), and child abuse cue (CUE -two levels: obvious - O, subtle - S). In total, there are 4 conditions (HO, HS, LO, and LS). A power analysis was conducted for ANOVA assuming 80% power ($\alpha = 0.05$). This analysis suggested that in order to detect a large effect (partial $\eta^2 = 0.14$) with any of the cognitive load or child abuse cue factors (or an interactive effect), a total sample size of 52 would be needed. We recruited a total of 64 participants to take into account the fact that we did not know in advance the amplitude of the effect of our cognitive load manipulation.

In the high cognitive load version (HO and HS), the two letters were both very detailed and long and difficult to read; whilst in the low cognitive load version (LO and LS), they were both very brief and the key points were clearly highlighted with bullet points.

With the other factor, in the obvious cue version (HO, LO), the scenario was played out as descripted above; in the subtle cue version (HS, LS), the two points where Chris' became upset with Tom (after Chris sat down and realized Tom was still standing, and when Chris was interrupted by Tom who wanted to go to the bathroom), Chris behaved less aggressively (this manifests itself through his choice of words, tone of voice, and slightly less angry gestures -i.e., more gentle, less intimidating). In both conditions Tom behaved exactly the same. Our design and implementation for the child abuse cues were supervised by one of our co-authors (CF) who is also the senior co-author of "The Child Protection Practice Manual" (Hann and Fertleman, 2016). It is important to note that even in the subtle cue conditions, there are plenty of signs of child abuse: experts in this area would identify potential problems from the beginning when Tom walks in behind Chris as there is a clear, uncomfortable power dynamic, whereby Chris is dismissive of Tom. The GPs' concerns should be further confirmed when Chris ignores Tom's request to go to the toilet. There are also worrying signs when Chris talks about death in front of his son, and when Tom becomes visibly more relaxed as Chris leaves the room (most children would be more worried when a parent left them with a stranger).

Upon confirmation of their participation, participants were divided into two groups (GP, trainee GP) and within each group they were assigned to one of the four experimental conditions pseudo-randomly. This was to ensure that we had, as much as possible, an equal number of GPs and trainee GPs in each condition, and that the total number of participants in each condition was similar.

Materials

The experiment was conducted in a CAVE-like virtual reality system at UCL. A detailed specification of the technical setup follows. The system conforms with the most common setup for CAVE systems, with three back-projected vertical screens (front, left and right, each 3 × 2.2 m) and a front-projected floor screen filling the enclosed space (3 × 3 m). The simulation was run on a workstation with nVidia K5000 graphics, delivering quadbuffer stereo to drive 4 Christie Mirage DLP projectors, each of which projected to one of the 4 screens (refresh rate 96 Hz). The display resolution was 1,400 × 1,050 for each of the vertical screens and 1,100 × 1, 050 for the floor screen. The graphics quality achieved is state-of-the-art; incrementally better performance can be achieved with the more recent graphics hardware (e.g., nVidia K6000 or AMD FirePro, or with higher resolution (4K) projectors). However, for this simulation the difference would not likely be noticeable. Resolution issues in CAVE setups typically manifest when the user stands close enough to the screens that the individual pixels can be seen. For this experiment, participants were seated over 1 m away from the nearest screen. Participants wore active stereo glasses (Volfoni ActivEyes Pro) to view the stereo imagery. Active stereo (as opposed to polarizing lenses) is the preferred technology for immersive VR system since it is better at eliminating cross-talk between the left and right eye images. In particular, we chose the Volfoni glasses due to their large lens size (50 × 37 mm) so that the frames do not encroach on the user's field of view. The position and orientation of the glasses was tracked by a 6-camera ART TrackPack system. This is an IR marker-based optical tracking system with 100 Hz update rate, with the recorded position/orientation being used to render the virtual scene from the wearer's viewpoint. ART TrackPack is widely used in CAVE setups due to its high accuracy over the full volume of the CAVE and the requirement for the user to wear only lightweight passive markers (attached to the glasses). The VR scenario was programmed in Unity3D and compiled with the MiddleVR middleware in order to run in the CAVE. Events were triggered by an experimenter through a control panel, which is set up on a separate desktop machine connected to the VR application machine via an internal network.

Procedures

Sixty-four participants were recruited for the study. All were General Practitioners (GPs) or trainee GPs. They all visited the CAVE lab at UCL.

Before the study, participants read the information sheet which informed them that the study was designed to test whether virtual reality equipment can be used to simulate a realistic clinical consultation environment, and that they would be interacting with 3D avatars who are programmed to act as patients in a clinical setting. They then signed the consent form and completed a set of questionnaires, including demographics questions and other personality.

Participants were then guided to sit on a stool in front of a desk in the CAVE and to familiarize themselves with the interface. They were verbally informed that they would have a consultation with virtual patients, and that they should behave as they would during a real consultation. They were shown the laptop on the desk, which allowed them to read and type in notes. Other than the stool, desk, and laptop, which were real, everything else was computer generated 3D graphics. Participants were asked to inform the experimenter when they were ready. They were asked to put the shutter glasses on and the curtain behind them was closed.

At that point the participants witnessed the following 3D virtual scenario:

Christopher shows up by the door and asks the Doctor if he is in the right room, and whether he can bring in his son Tom with him. The consultation then starts as described in "Scenario Details". After Christopher and Tom leave the room, the screen goes dark and the participant completes the post-consultation notes on the (real) laptop provided.

Afterwards the participants were asked to watch the video recording of their behavior during the virtual consultation and to provide a running commentary of their thoughts and feelings during the consultation. This commentary was also recorded. Finally, participants completed further questionnaires concerning their decisions during the consultation and the usefulness of Virtual Reality as a training tool. All participants were paid for their time (£20 store vouchers), as well as awarded with continuing professional development (CPD) points for completing 1-h training. At the end of the experiment all the participants received a certificate showing that they had undertaken an hour of level 3 safeguarding training.

Response and Explanatory Variables

The main concern of this study is the extent to which the medical doctors are able to not only identify potential safeguarding issues, but also act effectively and timely. Hence our key measurement, in this quantitative analysis, focuses on the doctor notes left on the laptop immediately after the consultation.

In order to quantify our response variable, 10 raters were recruited to rate the post-consultation notes from all 64 participants independently. The raters were chosen from a wide variety of backgrounds, all experienced in safeguarding, and received formal teaching and training in this area. They were completely blind to the difficulty of the scenario cues or the level of complexity of the medical interview and had no demographic information about the participants. They had not been recruited to undertake the study themselves nor could they tell from the consultation notes who had written them.

Notes from all 64 participants were evaluated by those raters with a visual analog scale (VAS) score ranging from 0 (not notion of safeguarding) to 100 (fully demonstrates safeguarding concerns). We also collected some demographic data on the raters. They are salaried GPs, GP trainees, one GP lecturer, two pediatricians, and the two clinical medical students (both completed an intercalated BSc in pediatrics and child health). It took each rater about 1 h to score these responses, and they received a personalized certificate of level 3 safeguarding training if they were a working professional or a certificate of appreciation if they were a medical student.

The average of the 10 ratings was used as the response variable "NOTE." The latter reflects the 10 raters' assessment of the extent to which the post-consultation notes suggested both an appropriate awareness of the child-safeguarding issues at stake and the development of some strategy to address those concerns. The recruitment of 10 (rather than one or two) raters reflects our awareness of the fact that this assessment is necessarily subjective and open to contestation. When dealing with such a sensitive, context-dependent situation, there is no single correct answer. Each strategy to address the possible child safeguarding concerns will not only reflect different value choices and priorities. They will also translate different assumptions under conditions of uncertainty (new patients with unknown background due to unavailability of personal notes etc.). The latter assumptions and value choices are not easily captured in a quantitative analysis, and will be the focus of a subsequent, qualitative analysis publication that takes into account the participants' post-immersion written and oral comments.

In an endeavor to collect as much pertinent data as possible, several explanatory variables were collected for analysis of covariance, given their documented impact on professional performance. These covariates were: years of experience (Dror, 2011; Dror et al., 2011), personality (Barrick and Mount, 1991), stress level (Dollard et al., 2003), and professional identification (Hekman et al., 2009). Hence, prior to the experiment, participants completed a questionnaire where they were asked whether they were a GP or a trainee GP, and how many years of experience they had since they qualified as a trainee GP. Thus our key explanatory variable -professional experience- was calculated using the GPs' year of qualification, taking into account months of career breaks. We also collected data on their personality using the 10-item NEO "big five" personality inventory (Rammstedt and John, 2007) covering Extraversion, Agreeableness, Conscientiousness, Neuroticism and Openness. GPs also completed the Perceived Stress Scale (PSS) (Cohen et al., 1983), which measures exhaustion and disengagement from work, as well as a 5-item Professional Identification Scale (PIS) (Hekman et al., 2009), which measures the extent to which individuals identify with their profession and their colleagues.

RESULTS

Participants

Out of the 64 participants who attended our study, one has to be excluded due to technical issues. In total, we have 63 participants (37 GPs and 26 Trainee GPs), with age range 25-59, and 37 out of them were female. Overall, they have a mean and standard error of 10.7 ± 1.1 years of post-qualification experience as a general practitioner (see Supplementary Material: participant details).

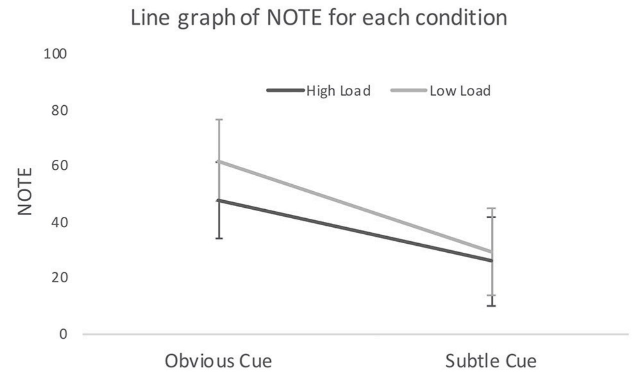

FIGURE 2 | Line graph with 95% CI of NOTE, presented with different conditions.

Note

The mean and standard error of NOTE (determined by our panel or raters, see section Response and Explanatory Variables) were 41.1 ± 4.13 (see **Figure 2**). A two-way ANOVA was conducted in SPSS version 24 (IBM, 2016), with the dependent variable being NOTE, independent variables being CUE and LOAD. There is no interaction effect of LOAD and CUE [$F_{(1,\,62)} = 0.53$, $p = 0.468$]. CUE has a significant [$F_{(1,\,62)} = 12.68$, $p = 0.001$] effect with NOTE in the obvious cue condition being higher (mean ± standard error: 54.2 ± 5.2) than NOTE in the subtle cue condition (27.6 ± 5.6), indicating that in the obvious cue condition, the notes were deemed to translate a better awareness of child-safeguarding concerns (as well as an adequate strategy to address those concerns). LOAD was not significant [$F_{(1,\,62)} = 1.35$, $p = 0.249$], suggesting no difference in NOTE between the high cognitive load (mean ± standard error: 37.3 ± 5.5) and low cognitive load conditions (45.0 ± 6.1).

Professional Experience

In order to address Research Question 1 about the GP's experience and their ability to pick up child child-safeguarding concerns, we analyzed the impact of participants' professional experience on the value of NOTE. We performed two-sampled t-test and correlation analysis with MATLAB R2017a (MathWorks, 2018) where Pearson correlation coefficients and two-tailed p-values were calculated. No difference was found between GP and trainee GPs (two sample t-test, $p = 0.48$), neither was there a correlation between NOTE and years of experience ($R = -0.05$, $p = 0.69$). This indicates that there is no relationship between the GPs' experience and the quality of their notes. When years of experience was used as a covariate in our ANOVA analysis with SPSS, the effect of CUE (subtle vs. obvious) remains significant [$F_{(1,\,62)} = 12.304$, $p = 0.001$], with no other effect found [years of experience: $F_{(1,\,62)} = 0.018$, $p = 0.893$].

Perceived Stress Scale (PSS) and Professional Identity Scale (PIS)

When PSS was used as a covariate, CUE remained significant [$F_{(1,\,62)} = 11.77$, $p = 0.001$], and PSS had a significant effect

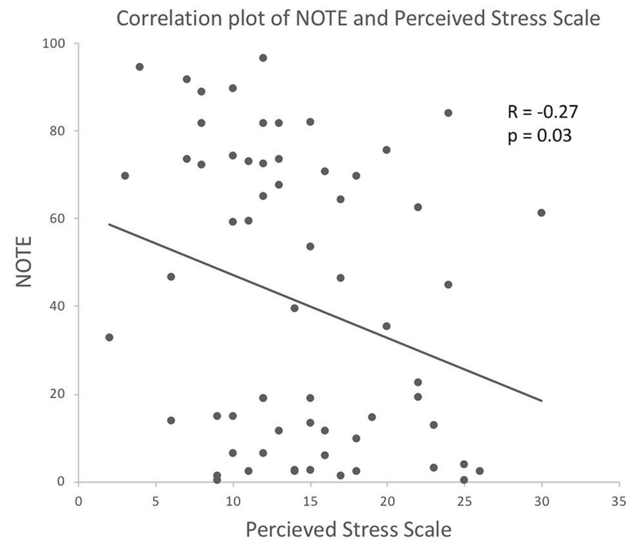

FIGURE 3 | Correlation between NOTE and Perceived Stress Scale.

[$F_{(1, 62)} = 4.02$, $p = 0.050$]. Correlation analysis of PSS and NOTE suggested a negative correlation [$R = -0.27$, $p = 0.03$], which indicates that the more stressed the participants perceived themselves to be before the experiment, the lower the quality of their notes was rated in relation to child safeguarding issues (see **Figure 3**).

On the other hand, PIS does not seem to explain any of the variances. When PIS was used as a covariate, CUE remain significant [$F_{(1, 62)} = 13.82$, $p = 0.000$], with no other effects found [PIS: $F_{(1, 62)} = 2.55$, $p = 0.12$].

Personality

Amongst the NEO big-five factor personality variables, there was a significant positive correlation between NOTE and Agreeableness ($R = 0.25$, $p = 0.05$), Extraversion ($R = 0.35$, $p = 0.005$), and a negative correlation between NOTE and Neuroticism ($R = -0.41$, $p = 0.008$). No other personality traits were significantly correlated with NOTE (Conscientiousness: $R = -0.14$, $p = 0.29$; Openness: $R = 0.16$, $p = 0.21$). This suggested that those whose notes received higher marks were more agreeable, extraverted, and less neurotic (see **Figure 4**). Further, two-way ANOVA with each of the five personality traits as a covariate also confirmed that Agreeableness, Extraversion, and Neuroticism had an effect on NOTE [Agreeableness: $F_{(1, 62)} = 4.75$, $p = 0.033$; Extraversion: $F_{(1, 62)} = 9.02$, $p = 0.004$; Neuroticism: $F_{(1, 62)} = 13.20$, $p = 0.001$] but not Conscientiousness or Openness [Conscientiousness: $F_{(1, 62)} = 0.29$, $p = 0.59$; Openness: $F_{(1, 62)} = 0.89$, $p = 0.35$].

Observations and Comments

Our video (http://www.panxueni.com/gpcave) shows some typical interaction during our virtual consultation. It was clear from the videos that all the doctors were actively engaged in the conversation and took it seriously and reacted toward it as if it were real.

In the post-experimental questionnaire, we asked participants to comment on those aspects which contributed to the realism of their consultation experience. Among the realistic aspects, participants listed: non-verbal cues, tone of voice, patient's concerns, the commonality of the scenario (i.e., "*patients seeking support making difficult decisions*"), the responses and questions (from Chris), interaction between Chris and his son, "Him answering his phone in the middle!," the room "*did look like a generic consulting room.*" Among the unrealistic aspects, participants listed: pauses between replies, lack of facial expressions, the inability to examine the patients, and that "*there was much less equipment than in a normal GP consultation room.*"

The participants were encouraged to leave comments about their experience—some found it stressful and challenging:

> *"Impressed, evoked a sense of discomfort within me which is difficult to do in an artificial setting."*
>
> *"Challenging (in a positive way), fun and educational. Thanks, I'm glad I participated."*
>
> Many pointed out that this could be a useful tool for training, especially for medical students, here are some examples from many related comments we received:
>
> *"It was a challenging scenario and I would have done it differently but it was interesting to watch how I acted knowing it felt wrong and I was able to reflect on it and consider how I would improve if I had to do it again"*
>
> *"definitely has potential as a training tool, particularly with regards to difficult consultations/breaking bad news etc."*
>
> *"I can see how this may lower the stakes for a medical student doing consultation skills training for the first time. When I first did it I had actors and all my peers were watching on video link from the next room - it was terrifying mainly because they were real people acting very convincingly so it felt like it really mattered - plus I was being observed. This (VR) could have a role in easing med students into training in consultation skills perhaps without being observed, but as a private tool to carry out consultations and then watch yourself back and observe. Then could progress to actors with a little more confidence?"*
>
> *"An excellent opportunity to learn/experience key scenarios and reflect/observe consultation style afterwards".*

DISCUSSION

The most significant effect from our results was the safeguarding cue: those who had the less obvious cues were rated less effective in raising child protection issues in their post-consultation notes than those who had the more obvious cues. The result supports our hypothesis 2. This is encouraging as it indicates that our manipulation was successful: our virtual reality scenario and character animation were realistic in portraying the potential child abuse between the adult and child virtual characters during the consultation. It is important to note that we have manipulated only Chris' behavior and not Tom's: Chris was more violent and abusive in both his verbal and non-verbal language, however Tom behaved in exactly the same way (i.e., withdrawn in general, ducked his body when Chris got physically close, acted as if he was relieved when Chris left the room). A common recommendation in child abuse training is for practitioners to use the cues from the child rather than the adult to spot potential

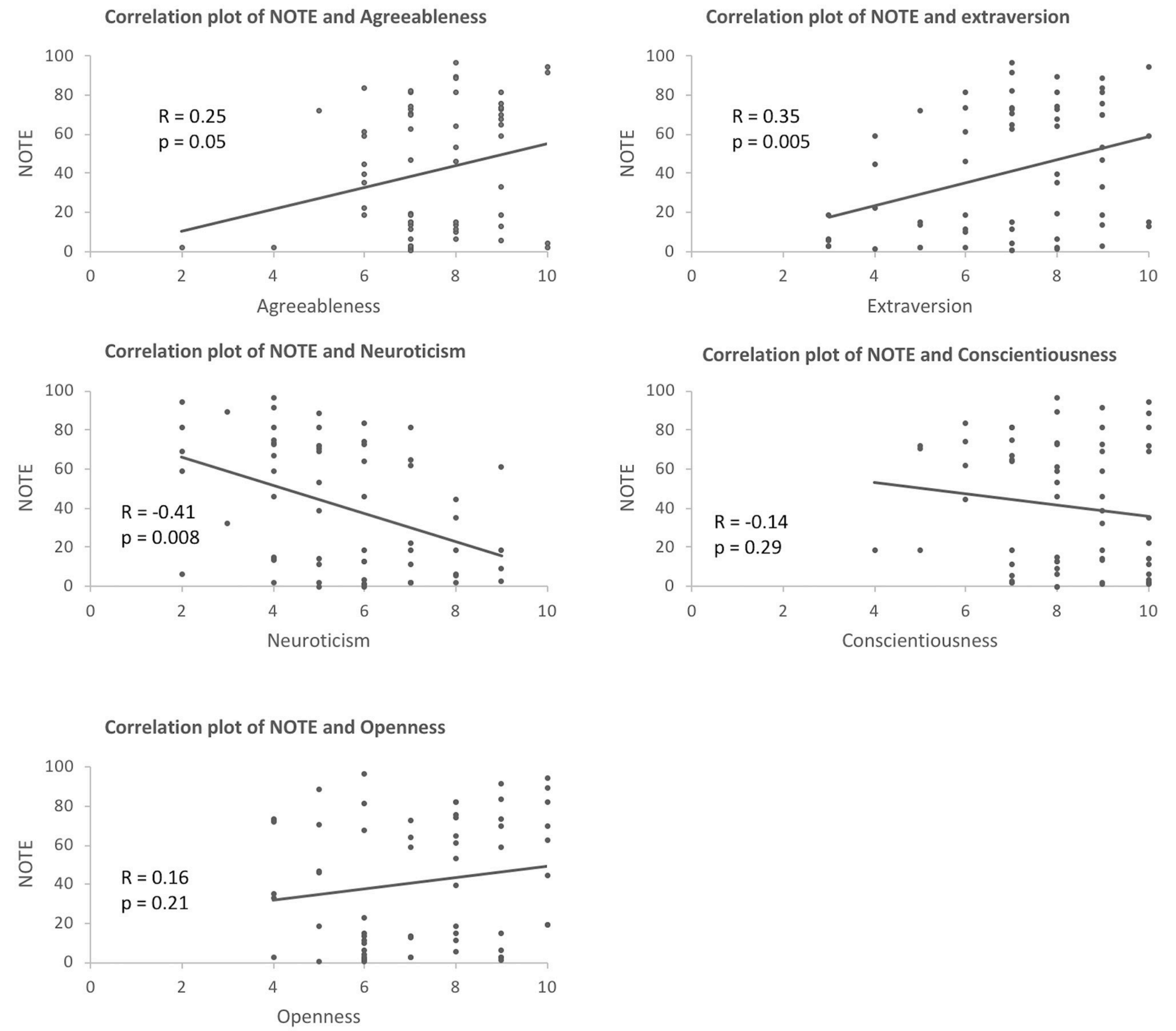

FIGURE 4 | Correlation between NOTE and the five personality traits (agreeableness, extraversion, neuroticism, conscientiousness, and openness).

child abuse issues (as the adult's behavior is likely to adapt to the presence of professionals). However, our results suggest that, in practice, the adult's own behavior may play a key role in the Doctors' response.

Contrary to our expectation, our other manipulation (cognitive load) did not have a significant effect on participants' ability to notice child-safeguarding concerns, whether these participants were very experienced or not. This result contravenes Hypotheses 3 and 4: we expected GPs' situational awareness to be affected by cognitive load, and for the latter impact to be greater for less experienced GPs. Among the possible interpretations, one may point at a ceiling effect, since the cognitive load in both conditions was already relatively high. This is corroborated by the post-questionnaires results, where 56 out of 62 participants (post-questionnaire data from one participant out of the 63 was missing) reported that they found it was difficult to give advice to Chris.

This said, it is worth noting that, even if they fall some way short of significance, the load manipulation findings in the obvious cue condition are in line with hypothesis 3 and are consistent with the established literature: a higher cognitive load does impact upon GPs' ability to pick up child-safeguarding concerns. Had the effect of the difference between the two cognitive loads -high and low- been less subtle (the amplitude of this effect is difficult to determine a priori, in the absence of pilot data), our study may not have been underpowered. Future research relying on less subtle cognitive load manipulation (or greater sample size) is likely to yield significant results. If so, these results would be particularly important in terms of designing low-cost interventions aimed at improving the detection of child protection issues: it could lead to stricter guidelines when it comes to communication clarity between specialists and GPs, for instance.

As for our first research question: the participants' years of professional experience was not shown to have any effect on their ability to pick up child-safeguarding concerns. Among the possible interpretations of this result, one may point at the possibility that the skilled intuition effect (on which hypothesis 1 was based) was curbed by other factors. Among these, one may highlight the fact that less experienced GPs will have had recent and systematic training in child protection as part of their undergraduate degree (experienced GPs will have had some compulsory, continuous education training too, but the effect may not be the same). Another interesting factor that may have played a role is the desensitization that comes with repeated exposure to a particular stimulus. The possible interaction between these different factors could point at fruitful avenues for future research.

Interestingly, incidental results suggest that personal circumstances and personality traits play an important role in doctors' ability to identify child abuse issues. In particular, our results suggest that the quality of notes is negatively associated with both the participants' perceived level of stress and their level of neuroticism, while it is positively associated with their agreeableness and extraversion. In other words, those who are less stressed, less neurotic, more agreeable and extraverted tend to be better at raising the child abuse issues in their notes. It is also worth pointing out that among these traits, the effect of neurotic and extraversion is particularly strong (i.e., $p < 0.005$). One interpretation of these effects is that those who have better interpersonal skills in general experience the whole situation with Chris as less stressful and less cognitively demanding, which allows them to pay more attention to Tom.

This paper points at many potentially fruitful areas for future research. Further cognitive load manipulations in particular could prove insightful and lead to simple but high-impact public interventions, such as urging specialists to use an easy-to-read, bullet point based template for their letters to GPs. The incidental results, particularly those related to stress, would also warrant further studies aimed specifically at developing improved ways of supporting time-poor GPs who are confronted on a daily basis with emotionally charged, difficult situations. Most importantly, it is clear from the participants' comments that Immersive Virtual Reality has considerable potential as a training tool: while it is already extensively used for hands-on technical training (to master various surgery techniques for instance), its potential to train healthcare providers who are to face difficult social interactions (such as pushy patients demanding antibiotics, Pan et al., 2016) is still under-appreciated, given its advantages in terms of replicability and scalability. In the domains of mental health and pediatrics, where the use of actors can be particularly problematic, immersive virtual reality allows for a unique chance to apprehend difficult situations in a way that allows for both repetitive immersion and group discussions aimed at teasing out ethical quandaries.

This experiment also allowed to put together a wealth of qualitative data that will be analyzed in subsequent publications. Among other things, this will allow for a more fine-tuned and contextual understanding of the value choices and assumptions made by GPs under conditions of uncertainty. We will also seek to gain a better understanding of the potential which such a virtual experience may have as a continuing education tool within GPs' professional practice.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

AUTHOR CONTRIBUTIONS

XP made a substantial contribution to the conception and design of the work (involved in the initial design, wrote the script, helped with the ethics application), implementation (supervised and coordinated the implementation, directed the motion capture session, helped to get it to work in the CAVE), data acquisition (coordinated the recruitment and experiments), data analysis (conducted the data analysis and produced all the plots), and interpretation of data for the work, as well as drafting the manuscript (wrote section Results, the majority of section Materials and Methods and part of sections Introduction and Discussion). SD made a substantial contribution to the conception and design of the work (led the initial design, led the ethics application), data acquisition (coordinated the recruitment and addressed any concern from participants), interpretation of data for the work, and drafting the manuscript (wrote the majority of section Introduction and Discussion and a small part of section Materials and Methods). CF made a substantial contribution to the conception and design of the work (involved in the initial design and script writing, supervised the child abuse cues), data acquisition (supervised recruitment), interpretation of data for the work as well as drafting the manuscript (contributed to section Introduction and commented on the rest). TC-W, BC, and OD made substantial contribution to data acquisition (TC-W and BC conducted the experiment, OD was in charge of recruitment). AA, HB, and MG made substantial contribution to the conception and design of the work and implementation (HB and MG were involved in adapting the script to VR, design and implemented the user interaction; HB ran the motion capture session and implemented part of the animation; AA implemented the animation and programmed the interaction). DS made substantial contribution to the implementation and data acquisition of the work (supervised the implementation in the CAVE and technical issues during the data acquisition). PP made substantial contribution to the conception and design of the work (involved in the initial design and data analysis).

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SUPPLEMENTARY MATERIAL

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D.1.2 Evaluating Quality Experience through Participant Choices

2020 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)

Evaluating Virtual Reality Experiences Through Participant Choices

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ABSTRACT

When building virtual reality applications teams must choose between different configurations of the hardware and/or software aspects, and other factors, of the experience. In this paper we extend a framework for assessing how these factors contribute to quality of experience in an example evaluation. We consider how four factors related to avatar expressiveness affect quality of experience: Eye Gaze, Eye Blinking, Mouth Animation, and Microexpressions. 55 participants experienced an avatar delivering a presentation in virtual reality. At fixed times participants had the opportunity to spend a virtual budget to modify the factors to incrementally improve their quality of experience. They could stop making transitions when they felt further changes would make no further difference. From these transitions a Markov matrix was built, along with probabilities of a factor being present at a given level on participants' final configurations. Most participants did not spend the full budget, suggesting that there was a point of equilibrium which did not require maximizing all factor levels. We discuss that point of equilibrium and present this work as an extended contribution to the evaluation of people's responses to immersive virtual environments.

Index Terms: I.3.7—Computer Graphics—Three-Dimensional Graphics and Realism—Virtual Reality

1 INTRODUCTION

When constructing a virtual reality (VR) application teams typically have a choice between different configurations of the objective aspects of the design of the experience, or factors, relating to hardware and/or software. Moreover, there may be tradeoffs between these factors in terms of rendering performance, latency, cost of implementation and so on. For example, avatar facial expressions that are highly accurate may be computationally expensive, but in the end make no difference to the experience when compared to more simple facial expression representations.

Teams need a way to evaluate trade-offs between factors that differentially affect the experience. The challenge in doing so lies in that we currently lack a systematic method for assessing experience that does not rely on large multi-factor experiments that elicit participant preferences across all possible configurations of factors. The primary objective of this research is to extend a previously existing method for evaluating presence to inform hardware and/or software trade-off decisions. We illustrate the validity of the approach via a novel application and extension of the method in an avatar presentation context. We briefly review the concept of presence before describing in detail the methodology we adapt and extend.

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1.1 Presence

Presence was originally defined as the sense of 'being there' in the place depicted in VR. The concept was derived from its original use in telepresence systems, where people operating in a remote environment through a robot typically had the feeling that they were located 'there' [14]. It was adapted to the similar feeling of 'being there' that people had in VR – e.g. [11, 19–21, 28].

Presence is not the only criteria against which to judge the quality of a VR experience. For example, a participant can have a strong sense of presence, but be quite uninterested in or unconvinced by events that are unfolding. Garau et al. [9] found that participants interacting with virtual human characters would experience those characters more like people when they exhibited some minimal level of response to participant actions compared to treating those characters as part of a computer interface without such responses (see also Steed et al. [29]).

Slater [24] deconstructed presence into two different components: Place Illusion (PI), as the illusion of 'being there', and Plausibility (Psi) as the illusion that events in the virtual environment were actually occurring, in spite of full knowledge that this was just a simulated environment. For a recent review of the field see [22].

1.2 Method of assessment of participant responses

The standard method for evaluating presence is to use questionnaires [13, 27, 30]. Although these provide valuable information, especially in conjunction with behavioral and physiological measures [25], they nevertheless are difficult to interpret - they provide no universal measure since one participant's score of '5' out of a maximum of '7' might mean something completely different than another's. Additionally, answering '7' or at the high end of a scale has no consequences for the respondent, yet decisions that may have costly consequences may be made on that basis. Physiological measures also do not provide a universal solution, given their complexity and utility in a limited number of scenarios. Even if questionnaires or physiological measures alone were suitable, there is still the problem of the explosion of conditions necessary to run a factorial experimental design to test (e.g.) presence across all possible conditions. For example, suppose there were k factors each with just two levels; the factorial design would require 2^k conditions. There are ways to reduce this, through hierarchical designs, but this becomes infeasible for larger k and more than binary levels.

A method that potentially overcomes these methodological challenges was introduced in Slater et al. [26]. This method was based on an analogy with colorimetry, where in order to measure the subjective response to illuminated surfaces participants are never asked to judge how (e.g.) 'red' a color is, but to match their perception of a color produced through manipulation (by adjusting red, green and blue projectors). Carried out over many participants and patches of light, experimenters can calculate on average how much 'red', 'green' and 'blue' went into the makeup of any particular patch.

Similarly, participants in the method of Slater et al. [26] were able to independently manipulate the extent of field-of-view, properties of a virtual body, perspective condition, and illumination quality, in order to match a level of PI or Psi previously experienced with all factors at their 'highest' level. This approach led to the derivation

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of probabilities of how much each of these factors contributed to PI or Psi, without participants having to answer a questionnaire. As in colorimetry, they only had to judge whether a particular experience *matched* or not their experience of the system with all factors at their highest level. The 'matching' is an observable event (it is a fact that they matched) and not something on an ordinal scale, and obviates the problem of knowing the meaning of a score in a questionnaire.

We extend this approach and we use a much simpler criteria for the assessment of participant responses to a VR application: what makes the experience better? - whether they prefer the experience with a specific factor configuration compared to others, and to what extent they would be willing to 'pay' for this configuration.

To illustrate this alternative approach we describe an experiment that shows how a version of this method captures preferences in the context of a VR experience where participants were faced with a virtual human character giving a presentation about how to have a good conversation. Participants evaluated configurations of different levels of four factors relating to avatar facial behavioral realism: eye gaze, eye blinking, mouth animation, and facial microexpressions, and how they contribute to a better experience. Our goal is both to show how the method was improved in its application and analysis, and to present the findings with respect to the four factors above. The main contributions of this paper are:

- We extended a previously used method for evaluating VR experiences, modifying the goal that participants were given from matching previously experienced feelings of presence to "making the experience better". We included a virtual budget component that restricts the number of factors that participants can maximise. We discuss the benefits and limitations of the proposed approach, and suggest directions for future work.

- We present the experimental design, analysis and results of a study to illustrate the aforementioned extension of the method. The design of the study includes a placebo that serves to demonstrate the effectiveness of the approach. A knowledge transfer questionnaire aims to demonstrate that participants were capable of evaluating the factors whilst remaining engaged in the presentation.

In the next sections we give further background, followed by the experimental design, results, discussion and conclusions.

2 Background

2.1 Building a convincing virtual presenter

One of the most compelling experiences in VR is to have a face-to-face encounter with another avatar. This is different to seeing an image or video of a character on a 2D screen as participants share a virtual space. Such virtual interactions require social cues that are central to real face-to-face conversations. Significant research has been conducted to identify the factors that provide these social cues.

One notable factor highlighted by research is avatar behavioural realism. Behavioral realism refers to the extent to which the avatar behaves or moves like a human being [3]. It can be operationalized in the most simple terms by the absence or presence of non-verbal cues, which are a key component of face-to-face interactions. For example, Pan et al. [18] found that participants reported high levels of social presence when a virtual agent blushed after making a mistake during a presentation. Additionally, Bailenson et al. [4] found that virtual agents that mimicked the head movements of the participants were more persuasive and received higher positive trait ratings. Interestingly, the positive effect of behavioral realism is dependent on the understanding of the various factors and their implementation in different use cases. Bente et al. [5] found that having plausible gaze behaviour contributes to social presence but also found that when the duration of the eye contact was too long it led to negative responses from participants.

2.2 Eliciting participant preferences

The method introduced in Slater et al. [26] aims to find an optimal configuration amongst possible factors in a VR application. In the first use of the method, four factors were considered: illumination level (Gouraud shading, static global illumination, global illumination with real-time shadows), field-of-view (small, large), display type (simulated power wall, head-mounted display), and virtual body (none, static, real-time full motion-tracked body). Participants first experienced a scenario with all these factors at their maximum level, and were asked to concentrate on their sensation of either PI or Psi. Starting from a low level for each factor and under simple cost constraints, participants were able to increase one level at a time until they declared that their feeling of PI of Psi matched their original feeling. There were 36 possible configurations, and each change by the participant corresponded to a transition from one configuration to another. By counting the number of times that a change was made from configuration i to j, a 36×36 transition probability matrix (P) was constructed, where entry p_{ij} is the probability of transitioning to configuration j given that the participant was experiencing configuration i. From the transition matrix P, Markov Chain theory was used to compute the k-step transition probabilities (the probability of being in configuration j, k transitions after being in configuration i) [12]. The data also supported computation of the probabilities of choosing a 'match' (i.e. when the participant had stopped through matching their original feeling of PI or Psi) for each configuration. Hence, this method affords computation of interesting probabilities that represent how the 'average' participant behaves in terms of choosing a configuration that matches the level of PI or Psi.

Azevedo et al. [2] closely followed this method augmented with EEG measures of engagement and Azevedo [1] applied the method to auditory environments. Skarbez et al. [23] applied the method to Psi in the context of interaction with virtual characters. Bergstrom at al. [6] applied the method to unravelling how Psi may be influenced by different characteristics of sound rendering, and the responses of musicians to the participants, in the context of a virtual string quartet performance. Gao et al. [8] explored how different factors contributed to the believability of a virtual environment in the context of a rock climbing application. The study involved participants first experiencing a rock climbing environment at the highest levels of each factor: visual appearance of the rocks (3 levels), the appearance of the surrounding scene (from simple to complex, 3 levels), environment sound effects (from no sound to high level windy sound, 3 levels), and environment behavior (none to dynamic changes such as animated leaves, 2 levels). The windy sound and dynamic features were the most important contributors to believability in this setup, and the analysis of the transition matrix showed that to get to the windy sound, dynamics and rock appearance were the transitions that participants made.

Just as this method has been used for PI, Psi and believability, it can be used for any other type of response that is definable and identifiable by participants. The method does not assume an underlying quantitative scale, but only that participants are able to compare the effect of two different configurations and choose one over the other, or conclude that there is no difference in terms of their own experience between them.

In this paper we considered what is perhaps the most straightforward and understandable response by participants to changes in configuration. Given two configurations, we are only interested in the configuration that participants felt made the experience *better for them*. Like previous uses of this method we first let participants experience the 'best' possible configuration in a demo task but we did not then ask them to select changes to move towards that experience since we did not want to impose our notions of what constitutes a better experience. Rather, participants were free to move through the configuration space in any direction, their only criterion being whether they prefer the newly chosen configuration to the previous one. There are other differences with previous uses of this method detailed in the next section.

3 EXPERIMENTAL DESIGN

Participants experienced a pre-recorded avatar presenter delivering a 14-minute presentation, divided into two equivalent trials of seven minutes each, on "How to Have a Good Conversation" in a 1:1 setup in VR. This approach was selected to ensure maximum stimuli uniformity across participants. At fixed points during each trial, the presenter stopped and participants had the opportunity, should they choose to do so, to modify characteristics relating to the presenter through a user interface. The characteristics they were able to modify were the factor levels (described below). All participants were given the same fixed budget, and each transition to higher levels that participants made had an associated cost. We encouraged participants to spend the minimum budget required to achieve what they regarded as the best form of presentation. Note that the budget was virtual and in no way affected participant compensation.

We evaluated four factors related to avatar expressiveness in a 1:1 presentation scenario: Eye Gaze (EG), Eye Blinking (EB), Mouth Animation (MA) and Microexpressions (ME). This is denoted in a property vector of the form $S = [EG, EB, MA, ME]$. Each instance of the property vector was considered a configuration. Altogether there were a total of 81 possible configurations, detailed below:

(EG) Eye Gaze

- (EG = 0) Static centered eyes
- (EG = 1) Dynamic random gaze targeting
- (EG = 2) Dynamic saliency-based gaze targeting

(EB) Eye Blinking

- (EB = 0) None
- (EB = 1) Normal-distribution around mean frequency of 6 seconds
- (EB = 2) Normal-distribution around mean frequency of 6 seconds (note that this level was added as a placebo effect to ensure that participants were only moving to higher levels if this made the experience better for them)

(MA) Mouth Animation

- (MA = 0) None
- (MA = 1) Oculus Lipsync [16]
- (MA = 2) Oculus Lipsync with Action Unit Easing

(ME) Microexpressions

- (ME = 0) None
- (ME = 1) Random triggering of microexpressions
- (ME = 2) Linked to events from Oculus Lipsync and Eye Gaze

All of these factors are variations on the facial animation system built for the Oculus Avatar SDK, and described in detail in our Oculus Connect 6 talk [15]. The highest level in each category is representative of the behavior exhibited in the public release of the Oculus Avatar SDK (with the exception of EB = 2 as noted, which was used as a placebo in this experiment, but is triggered by events in the gaze and speech models related to times of higher blink probability in the Oculus Avatar SDK). The eye gaze model in EG = 1 and EG = 2 conditions both use a physiologically-based kinematic model to generate realistic human saccades, micro-saccades, and smooth pursuits. The difference between EG = 1 and EG = 2 is that the latter uses a saliency model to distribute gaze as opposed to distributing gaze randomly. The saliency model uses a number of factors to estimate the highest probability of where the user is looking, which includes head motion, the array of objects in the current field-of-view and their type, movement, and size, how long an object has been fixated on and ignored, and the normalized distribution of gaze eccentricity from the center. The factors of mouth animation are based on Oculus Lipsync in MA = 1, and our extensions to the animation model that feature in the Oculus Avatar SDK in MA = 2. Natively, Oculus Lipsync generates a probability over 15 visemes (including laughter), and the avatar rig can be set accordingly per-frame. In our animation extension in MA = 2, we further correspond these visemes to their component parts, based on FACS action units [7]. Each action unit has a custom onset and falloff curve, which results in significantly smoother and more natural appearance of mouth movements pertaining to speech. Finally, the microexpression factors operate as a secondary model ME = 2 and in the Oculus Avatar SDK; linked to characteristic events in the gaze and Lipsync models. For instance, an upward gaze may trigger a slight raising of the eyebrows, an end of speech may trigger a subtle smile, and head movement may trigger slight perturbations of the facial state. These microexpression models are designed to be extremely subtle; adding texture and nuance rather than semantic or emotional undertones to the avatar's performance. In this experiment, ME = 1 is a state in which these microexpressions are triggered randomly at a regular cadence, with no relation to the rest of the facial state.

The following restrictions were built into the system:

1. Participants were given a total budget of 7 in order to encourage them to think carefully about their transitions and avoid the possibility of choosing a maximal configuration [2,2,2,2] (which would not give us any meaningful information). The budget restriction reduced the total number of configurations being evaluated from 81 to 80.
2. The cost of moving to each subsequent higher factor level was equal to 1 budget unit.
3. Factors could only be increased by one level during each transition opportunity. For example, participants could not move from level 0 to level 2 on any of the factors without first making a transition to level 1. This ensured that participants had a chance to experience and assess the factors at all levels. It also reduced the amount of data that had to be collected to populate the Markov transition matrix as some of the transitions became impossible (transitions from level 0 to 2).
4. Participants were able to remove budget units spent (and recover total budget) from any factor each turn by reducing the level, but could not reallocate the budget recovered in the same turn. For example, if a factor was on level 2, participants were able to recover budget and bring the factor back to level 1 or level 0 in one turn. However, they could not reallocate that budget to another factor and increase from level 0 to level 2 on that same turn, respecting rule 3 described above.
5. At the end of each trial, participants were asked to confirm or modify their final configuration choice. This final confirmation turn had none of the previous restrictions in place to allow them to jump to their preferred final configuration.

Each of the trials randomly started in one of four low base configurations, in which three factors were at level 0 and one factor at level 1 ([0,0,0,1], [0,0,1,0], [0,1,0,0], [1,0,0,0]). Participants therefore began with the remainder six budget units to spend.

4 METHOD

4.1 Participants

A total of 55 participants (31 female, 24 male; average age 35.5 years, SD = 11.3) were recruited from the Oculus user base. All participants signed a consent form and the study was approved through Facebook Research Review. Two participants had no previous VR experience. Twenty participants were broadly classified as gamers (categorized as spending more than one hour gaming a week). Participants were paid £75.

4.2 Materials

The user study was conducted in a lab at Facebook London. An Oculus Rift Consumer Version 1, two Oculus Touch controllers and three Oculus sensors were used. The virtual environment was rendered at scale 1:1 in Unity 2018.2.18f1 at 90FPS in each eye on an Intel Core i7-7700 CPU @ 3.60GHz, with 16GB RAM and Nvidia GeForce GTX 1080 GPU running Windows 10.

The virtual environment consisted of an empty custom built room. A modified version of the Oculus Avatar SDK 1.35 [17] was used to render the presenter and generate the different factor levels. The participants' virtual hands were rendered in a non-human colour (blue) to remove any effect of skin-tone on performance in the task. The Oculus Touch trigger buttons were used to interact. A ray casting method was used in order to point at the user interface in the experience, with a blue reticle appearing upon collision with it. In order to account for handedness, participants were able to switch the interaction from the left or right controller using the X (left hand) or A (right hand) buttons.

The concept of the user interface for participants to make transitions was very simple and straightforward. Four rounds of usability testing with five participants each were completed to iterate on its design prior to the study. The resulting version consisted of a floating panel with a slider showing coloured discrete marks for each factor as well as for the budget at the top. A "plus" and "minus" button were displayed on either side for each factor slider, allowing participants to increase or decrease levels by selecting them. Each factor level increase or decrease would automatically update the budget bar to reflect the units taken or recovered, with a delayed animation to make this obvious for participants. The vertical order in which factors were presented in the user interface was counterbalanced across participants to avoid order effects (with each participant having the same counterbalanced order for the full duration of their session).

4.3 Metrics

There were two sets of dependent variables. The first was the final configuration that the participants chose. The second consisted of the transition data, which depicted the chronological changes made by a participant from configuration i to another configuration j across the two trials. We also included a post-trial questionnaire. This included a 16-question knowledge transfer questionnaire about the content that the pre-recorded presenter delivered. The facts required to correctly answer questions 1-7 were delivered during the presentation in trial 1, and questions 8-16 in trial 2. We also included a question asking participants to rank the factors in order of importance. The questionnaire was delivered outside of VR. Participants also completed a semi-structured interview.

4.4 User interface demo task

To familiarise participants with interaction in the virtual environment, we created a task where participants had to fill in a bar to continue onto a simplified version of the user interface by pointing at and selecting the "plus" button. If participants were in doubt as to how to interact, the experimenter would assist.

Participants were then shown the full user interface containing all factors and levels as part of a full user interface demo task. Here participants were able to experience what was possible within the system by manipulating the factor levels of the presenter. The goal of this task was to allow participants to familiarise themselves with the system and to feel comfortable interacting with the user interface. The budget was set such that the participant could test the configuration where all factors are set to their maximum level. The presenter was not the avatar from the main presentation task but rather a different avatar to encourage the practice of changing the factor levels. These would be the same factor levels that they would be able to modify on the presenter during the main task. The presenter spoke a short looped phrase to allow participants to see the effect of the changes they made. Participants were only able to advance to the next stage if they displayed understanding of how to interact with the user interface, understood the effect of the changes to the confederate avatar, and experienced the system at the highest configuration [2,2,2,2]. They were encouraged to think aloud to help the experimenter assess if they understood how the user interface operated. The confederate avatar for the demo task differed in both appearance and voice to the confederate in the main task. This was to prevent familiarity affecting the choices participants made.

Figure 1: Main task scene with the presenter and user interface.

4.5 Main task

In the main task, participants were faced with a virtual presenter who delivered a presentation to them about how to have a good conversation [10]. This presentation was adapted from an TEDx Creative Coast talk and was selected out of a series of talks in a pilot study because it elicited the highest engagement levels as evaluated via questionnaires.

Participants were reminded of the instructions for the main task and advised that from that moment on there may be options for the experience that they cannot always afford, meaning that going forward the budget restrictions described in Sect. 3 were applied. The main task was split into two 7-minute trials, with each trial corresponding to the first and second half of the presentation. At seven fixed, equally spaced times during the presentation, a dialog box prompt would appear giving the participant the opportunity to remain in the same configuration or make a transition to another configuration. If participants decided to make a change the full user interface would appear, as shown in Fig. 1. An extra dialog box would appear at the very end of each trial to allow participants to confirm or change their final configuration. Participants were not encouraged to think aloud during the main task to avoid any distraction from the presentation and the evaluation of factors. This task was designed to be completed with the participant standing.

4.6 Procedure

Participants were welcomed to the session and escorted to the lab. The experimenter introduced the hardware and the task. The experimenter helped the participant don the headset. After recentering to ensure that participants were facing the correct direction and that the virtual floor was at the correct height, they experienced the user interface demo task. After making sure that the participants understood how to interact with the system, they were reminded of the instructions and completed the main task. Upon completion of the first trial, the experimenter helped the participants remove the headset. The participant was then given a few minutes (no more than

5) to sit and rest, as well as to drink some water. The experimenter then helped participants don the headset. They were reminded of the task before starting the second trial. Participants were asked to stand throughout the main task of each trial. However, in the cases were participants expressed a need to sit down, a chair was provided. The chair was positioned in the same position the participants were asked to stand in and the application was then recentered to account for the height change, to ensure that the presenter's height would always match the participant's. One participant chose the sitting option. After both trials were completed, the experimenter helped the participants remove the headset and they were handed an iPad to answer the questionnaire described in Sect. 4.3. They were also offered water. The questionnaire was completed sitting down. They then discussed their experience with the facilitator.

5 RESULTS

5.1 Method of analysis

Participants completed two trials with each trial starting at different configurations. The results were analysed for each trial independently as well as combined, with all showing similar results. In addition to looking at the transitions from configuration to configuration (Transition Analysis), we also analyze the final configurations that participants chose after they had reached the configuration through following the transitions (Final Configuration Analysis). For Transition Analysis, we denote the set of 80 configurations that a participant could experience by C. Note that the budget restrictions made configuration [2,2,2,2] impossible to reach. The set of all possible transitions from configuration to configuration is therefore a subset of C. Each transition is of the form:

$$[EG_t, EB_t, MA_t, ME_t] \rightarrow [EG_{t+1}, EB_{t+1}, MA_{t+1}, ME_{t+1}]$$

denoting the transition from the configuration that a participant was in at time t, to the configuration at time $t+1$.

From the set of all such transitions we can build the probabilities π_{ij} that a participant in configuration $i \in C$ would next choose configuration $j \in C$. This gives us the $m \times m$ Markov transition matrix P, where $m = 80$ is the number of configurations. Fig. 2 shows, for example, the numbers of transitions for each factor separately. The full transition matrix is similar, but includes each of the 80 configurations, and thus is too complex to display.

P^k is the k-step transition matrix, with elements that give the probability that a participant in configuration i would be in configuration j, k steps later. Let u be a 1×80 vector where u_j are the initial probabilities of being in configuration $j \in C$ (i.e. the probability of being in a particular configuration). Then uP^k are the probabilities of being in the configurations after k transitions. All of the above follows from Markov Chain theory [12]. P is constructed from the 770 observed transitions (55 participants $\times$ 2 trials $\times$ 7 transitions).

Markov Chain theory requires that the probability of making a transition to any valid configuration is only dependent on the current configuration and not previous history. We follow this abstraction for the purpose of model building. Using the results of all transitions made by the participants we can estimate the transition matrix: the probability of a transition to a configuration given the current configuration. From the resulting transition matrix we can calculate the probabilities of being in the various configurations after the successive transitions within the set system and budget restrictions.

Suppose that the number of transitions from i to j is n_{ij}. Then the frequency estimate of the probability π_{ij} is $p_{ij} = n_{ij}/N_i$, where N_i is the total number in row i.

From the set of all transitions various other probabilities can be estimated, including the probabilities of each factor level being part of the the final configuration arrived at by participants. We can also compute the marginal probabilities that any particular factor at any level is included in any configuration.

After completing their final transition at the end of each trial participants could choose to make one more change. This was to act as a confirmation or not that they had ended in their desired configuration. Since this final confirmation choice was not regulated by the budget restriction (to allow them to jump onto their preferred configuration regardless or where they were), it is not included in the transition analysis.

Table 1: The four highest probability configurations (C) after each transition (k) with [0,0,0,0] as the starting configuration, and assuming that participants chose the transitions randomly. C is the property vector of the form $S = [EG, EB, MA, ME]$.

Transition	Configuration	Probability	
		Frequency	Random
1	0000	0.333	0.063
	0010	0.333	0.063
	0100	0.333	0.063
	0001	0.000	0.063
2	0010	0.271	0.030
	0100	0.214	0.030
	0000	0.120	0.030
	0110	0.114	0.030
3	0010	0.171	0.026
	0110	0.154	0.026
	0111	0.115	0.026
	0100	0.107	0.026
4	0110	0.146	0.026
	1111	0.128	0.026
	0111	0.126	0.026
	0010	0.101	0.026
5	1111	0.132	0.026
	0110	0.122	0.026
	0111	0.120	0.026
	1110	0.073	0.026
6	1111	0.126	0.026
	0111	0.106	0.026
	0110	0.096	0.026
	2111	0.068	0.013
7	1111	0.114	0.026
	0111	0.091	0.026
	2111	0.087	0.013
	0110	0.074	0.026

5.2 Transition analysis

We added one last transition at the end of each trial that would act as a "confirmation box". This was to allow participants to end each trial in their preferred configuration. Since this last transition was no longer regulated by the budget restriction (to allow them to jump onto their preferred configuration regardless or where they were), we must exclude this last transition from the transition analysis. We therefore calculate the transition probability matrix without the last transition from each trial (110 transitions).

The 55 participants completed a total of 7 transitions in each of the two trials leading to a total of 770 transitions. From this the count matrix N is computed, which represents the number of transitions from configuration to configuration. Note that, due to the nature of the transition restriction, N is a sparse matrix, with 226 non-zero cells (the 80 $\times$ 80 matrix has 6400 cells - the budget restriction reduces the number of valid cells to 4000).

Diving deeper into the question on sparsity, 184 out of the 226 non-zero matrix cells representing transitions were visited four times or less. Results also indicate that $366/770$ transitions were from and to the same configuration where $[EG_t, EB_t, MA_t, ME_t] = [EG_{t+1}, EB_{t+1}, MA_{t+1}, ME_{t+1}]$.

The configuration [0,0,0,0] has each of the four factors at their 'minimal' levels. For the purposes of analysis we ordered the con-

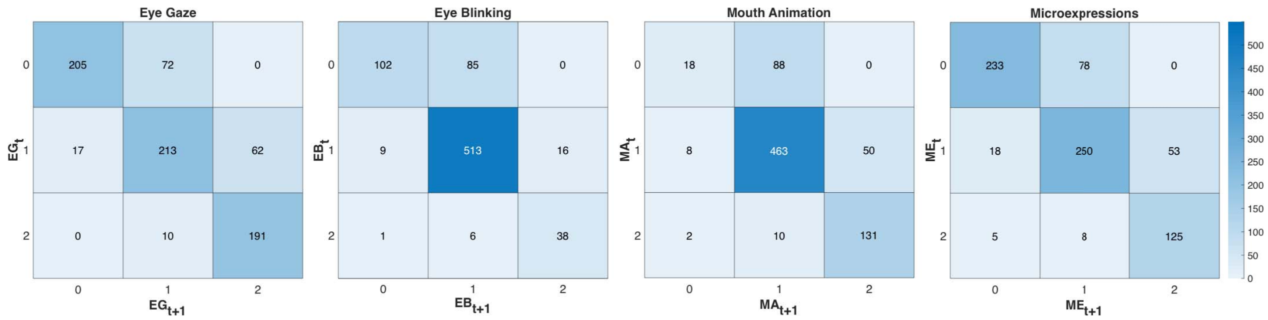

Figure 2: Markov transition matrices showing the number of times participants moved between factor levels.

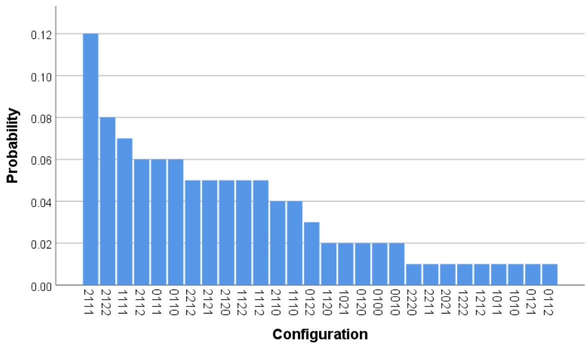

Figure 3: Distribution of final configurations across both trials.

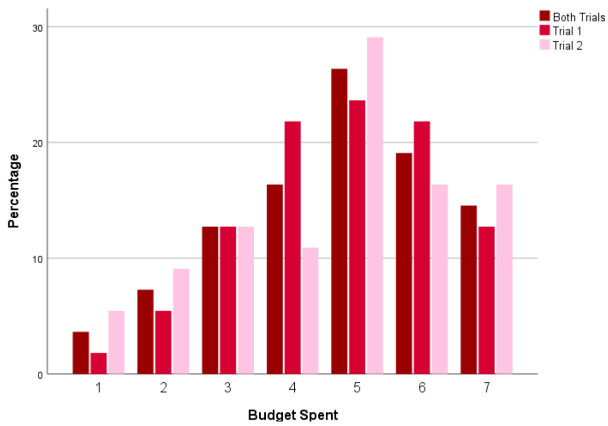

Figure 4: Distribution of budget spent for Trial 1, Trial 2 and both trials.

figurations so that [0,0,0,0] occupies the first place, and therefore the probability vector u = [1,0,0,..,0] (79 zeros) represents this as the starting configuration for a hypothetical participant. Now using $uP^k, k = 1,...,7$ we can find the probabilities for the four highest probability configuration transitions that were more likely to be chosen from this starting configuration. This is shown in Table 1. After the first transition the most likely configurations were the original starting one, or with change in Eye Gaze or Mouth Animation. By transition 5 the most likely configuration had each of the factors at level 1. Note that the probabilities seem to be low, but should be compared with the probabilities assuming individuals selected transitions randomly. Table 1 also shows the highest probability configurations in this case, taking into account that some transitions were impossible. Starting from other randomly chosen low base configurations results in similar transitions as for [0,0,0,0], but more transitions are needed to reach the same configuration.

5.3 Final configuration analysis

For any particular configuration we can estimate the probability of ending in that configuration $P(C|final)$. This is the number of times that participants ended in that configuration over the total number of final configurations, which is 55 participants × 2 trials = 110. The probability distribution is shown in Fig. 3. Overall, the group's most likely final configuration was [2,1,1,1]. Note that 81% of trials had an exact equivalence between the last transition and the confirmation transition (i.e. chosen through the confirmation UI after all the transitions had been completed) and 95% were one level away from their confirmed final configuration. A Wilcoxon signed-rank test showed no significant difference in the distribution of final configurations between the two trials ($Z = -0.115, p = 0.908$). Participants chose their responses non-randomly. If they had, then Fig. 3 should illustrate a fairly uniform distribution among the final configurations. If we carry out a Chi-squared test comparing the resulting distribution with the theoretical uniform distribution, then random choice is an inconceivable hypothesis ($\chi^2(27) = 68.182, p < 0.001$).

5.3.1 Marginal factor probabilities

Starting from [0,0,0,0] we can compute after k transitions the marginal probabilities of a factor being present at a given level (shown in Table 2). For example, after 4 transitions we can find the probability that (e.g.) Eye Gaze would be present at level 1. We consider this after 4 transitions and after 7 transitions. After 4 transitions Eye Blinking and Mouth Animation have the highest level 1 probabilities and these two have the greatest overall probability of having made at least one change. This is also true after 7 transitions. The strong result is that in the case of Mouth Animation there is a very high probability of there being at least one change, though the greater bulk of the probability is at level 1. This is followed by Eye Blinking where again, the greater probability is at a level 1 change. After 7 transitions there is not a lot of difference between Eye Gaze and Microexpressions. It is important to note that Eye Blinking at level 2 was the same as level 1, designed as a 'placebo' to understand if participants were following instructions as they were designed. This is reflected in Table 2, where the probabilities of EB being at exactly level 2 are always small in comparison to others.

5.4 Budget analysis

Participants were able to spend a maximum of seven budget units in each trial. Results show that the mean budget spent by participants across both trials was 4.7 with an *S.D.* of 1.6. Fig. 4 shows the

Table 2: Probability that the configurations after 4 and 7 transitions would contain the factor at the given level with the probability estimates.

		After 4 transitions				After 7 transitions			
		Level 0	Level 1	Level 2	At least Level 1	Level 0	Level 1	Level 2	At least Level 1
Frequency estimate	Eye Gaze	0.510	0.382	0.109	0.490	0.289	0.367	0.345	0.712
	Eye Blinking	0.272	0.685	0.043	0.728	0.104	0.819	0.077	0.896
	Mouth Animation	0.086	0.790	0.124	0.914	0.027	0.678	0.295	0.973
	Microexpressions	0.506	0.419	0.075	0.494	0.305	0.446	0.249	0.695

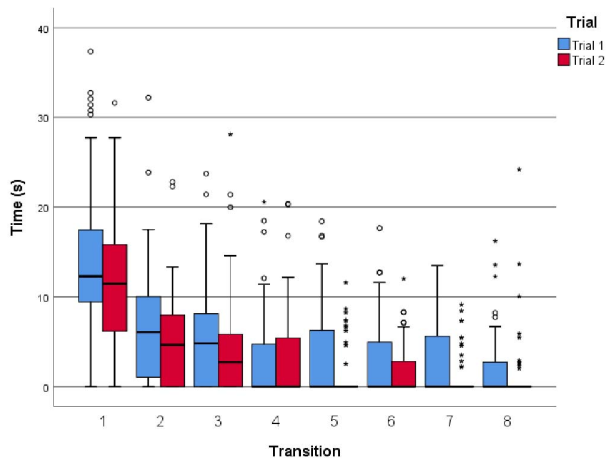

Figure 5: Time taken for participants to complete each of the eight transitions for each trial. Selecting "no change" was recorded as zero. Boxes represent the interquartile ranges (IQR). Whiskers represent either the extreme data points or extend to $1.5 \times IQR$. Outliers are shown by circles. Extremes are shown as asterisks.

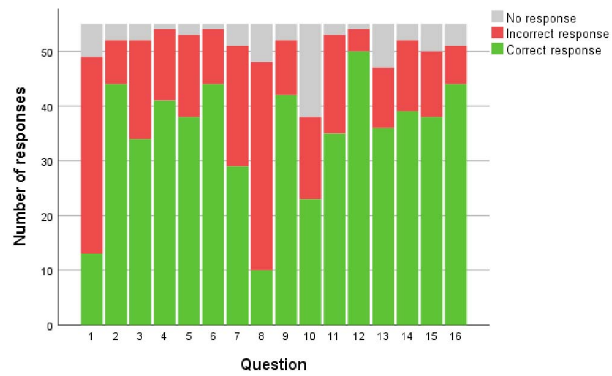

Figure 6: Stacked bar graph depicting participants' correct answers (green), incorrect answers (red) and blank answers (grey) for each of the knowledge transfer questionnaire questions.

distribution of budget spent. A Wilcoxon signed-rank test showed no statistically significant differences on budget spent between Trial 1 and Trial 2 ($Z = -0.801, p = 0.423$). A Mann-Whitney U test showed no statistically significant differences on budget spent based on gender ($U = 1278, p = 0.351$). A Mann-Whitney U test showed no statistically significant differences on budget spent based on gaming experience ($U = 277, p = 0.158$).

5.5 Transition times

The time taken by participants to complete each transition decreased over time and is shown in Fig. 5. A Wilcoxon signed-rank test with a Bonferroni correction applied showed that there were no significant differences between the two trials.

5.6 Questionnaire analysis

5.6.1 Factor ranking

Participants rated the factors from most to least important. Overall, Mouth Animation was ranked as most important, followed by Eye Blinking, then Eye Gaze and then Microexpressions. There was a significant difference in the distributions of importance rankings for each of the factors ($\chi^2(2) = 46.29, p < 0.001, df = 3$). Post hoc analysis with Wilcoxon signed-rank tests were conducted with a Bonferroni correction applied, resulting in a significance level set at $p < 0.008$. Median (IQR) perceived importance for Eye Gaze, Eye Blinking, Mouth Animation and Microexpressions were 3 (2 to 4), 2 (2 to 3), 1 (1 to 2) and 4 (3 to 4), respectively.

5.6.2 Knowledge transfer

A Kruskal-Wallis H test showed that there was no statistically significant difference in knowledge transfer score (total number of correct responses) based on final configuration ($\chi^2(2) = 21.664, p = 0.301, df = 19$). At a first glance at Fig. 6, we can see that the lowest correct responses came from Question 1 and Question 8. Interestingly, the content asked in these questions was located at the start of each trial. This could relate to participants settling into the experience and paying less attention to the presentation at the beginning of each trial.

5.7 Interview analysis

Interview responses were coded into the following themes:

Participants felt they had sufficient opportunities to assess the factors and believed that the configuration that they ended in was the best given the options available. This is important for us in validating that the number of opportunities offered to make transitions in our experimental design were sufficient.

Participants tended to mimic real-world behaviour, even though most reported that they knew they were facing a pre-recorded avatar. Some participants laughed, and others stepped back when they felt the presenter was too close.

Participants could articulate what their goals were in making the experience better. They reported that their goal was to make the presenter more 'real', 'natural', 'not mechanic', 'human', 'less distracting', 'comfortable', and 'life-like'.

The budget was sufficient to find a 'match'. By this we can conclude that the budget was sufficient.

Some participants had difficulty in interpreting ME levels. Unlike the other factors, ME changes were harder to pinpoint. This led to participants having varied notions on what the effect of this factor was and could explain the results.

6 Discussion

This work extends the methodology introduced in previous work [6, 23, 26] by:

- including a rigorous application of the budget concept,
- using a placebo effect to validate the design,

- proposing a new goal for participants to *make the experience better* where they no longer have to match the initially experienced sensation with all factors at their maximum level,
- allowing participants to move between configurations in any direction before confirming the final configuration, and
- removing the assumption that a given level of a factor is better than another.

For decades VR practitioners have been imposing measurements (e.g. presence) to evaluate quality of experience, but maybe participants have different criteria. Therefore, this approach introduces the idea that results are purely based on participant preferences rather than what teams or experimenters decide in advance is important.

However, the method still presents a number of limitations. On one hand, we do not know the extent to which the results from a study using the method generalise to other scenarios. We also do not yet understand what might be the maximum number of factors and levels for an evaluation using this method. The higher the number of factors and levels evaluated, the larger the Markov transition matrix that has to be populated with data, and the higher the cognitive workload for participants. Another limitation is that it relies on one particular analytical technique (Markov Chain theory - replicating the previous uses of the method). Given that participants were freely navigating through the different configurations during both trials, it is not possible to correlate a single configuration (e.g. the final configuration) for each participant to their knowledge transfer questionnaire score. However, there may be additional ways to approach the analysis that could yield novel insights.

In the study, we evaluated four factors relating to avatar facial behavioral realism: EG, EB, MA and ME. Participants were able to iteratively assess three levels for each of these factors in a 1:1 presentation delivered by a pre-recorded avatar. This allowed for the evaluation of 80 versions or configurations of the system (a virtual budget limited participants from reaching a configuration where all factor levels were maximised).

Overall, the group's most likely final configuration was [2,1,1,1] (Full Model Targeting Eye Gaze, Linear Eye Blinking, Oculus Lipsync Mouth Animation and Random Microexpressions). This is the configuration that we would recommend teams to implement in 1:1 presentation experiences that the scenario we evaluated is representative of and for the studied set of factors and levels. This is not to say that this combination is the 'best' in all circumstances, but is relative to this particular system and presentation type.

Most participants did not spend the full budget, suggesting that there were personal optimal configurations which did not require maximising all factor levels. This is consistent with theory denoted in previous works that have implemented this method [6, 23, 26]. We also found no significant differences in budget spent based on gender and gaming experience. We suggest gathering more granular background data around gaming experience to continue monitoring this result in future uses of this method.

The placebo effect included in factor EB worked well to help us verify that participants were completing the task as it had been designed (to only spend budget if it made the experience better for them) as the probability that participants would end in EB = 2 was low. The expectation was that participants would not end in level 2 for EB as there was no actual increased quality or value, but there was an increase in cost. The placebo effect actually allowed for participants to maximise all factor levels with the available budget. However, this effect was not observed given that most participants did not consume the full budget.

Results indicate that knowledge transfer was generally high but lower at the start of each trial. This is a good indication that participants were involved in the presentation and paying attention to the information that was delivered, beyond evaluating the different factors. Participants may have concentrated on settling into the task and evaluating options towards the beginning of each trial.

Overall, the time taken by participants to make transitions between levels decreased over time. This could indicate that, towards the end, participants had generally found their optimal configuration and decided not to make further changes, whereas towards the beginning there was more exploration and evaluation. This could also be attributed to fatigue; participants may have felt tired and therefore less engaged in the task and more focused on finishing quickly. Another possibility is that participants may have overcome the learning curve, and felt more confident in using the system to achieve the result they wanted. However, for this last potential reason we would have expected to see a significant difference between trials, which we did not observe.

Future work should further explore how different factors may contribute to quality of experience in other applications, extending the range of use cases evaluated. This information will be important to help teams define the best possible configurations for different VR applications, including future hardware that can support those configurations (e.g. face tracking technologies). Even though our goal with the proposed extended method was to model the average user based on the actions that participants took, future work could focus on studying individual differences. The community should equally continue to evaluate other factors and levels in the context of immersive social interactions, and in multi-user scenarios where avatars are driven in real-time.

Extensions to the method should explore other budget restrictions that will force participants into tighter evaluations and, conversely, scenarios in which the budget does allow for maximisation of all factors to understand whether a point of equilibrium can still be reached when there is no tension. Moreover, the budget could reflect real costs, for example, of implementation or production. Other suggestions include different configuration starting points for trials (i.e. completely random or configurations with high levels) to explore whether consistent points of equilibrium are reached. For larger data collection, the research method could also be run as an 'in the wild' study by embedding the experience in public applications and optionally allowing headset owners to voluntarily take part in them. This would allow for more sophisticated machine learning approaches to the data analysis.

7 Conclusions

This paper is based on the framework described in Slater et al. [26] that proposed a method for exploring the contributions of different factors to the illusion of Psi and PI in a VR application. Here we have shown how this work can be extended to account for other objective features of a VR experience relating to avatar-mediated non-verbal communication. Importantly, this method avoids the need for self-report. The only information it is based on is observable - participants chose to make transitions (or not).

We tackle this problem with a novel approach; to explore what participants choose to be acceptable rather than risk imposing preconceived notions of what makes for a better VR experience. In the study we looked at four factors. The results have shown that most participants did not spend the full budget, implying that there was an optimum point reached without having to maximize the factors.

It is important to note that these results should not be taken as an evaluation of the factors themselves but as an exploration of their implementation and influence on participants' preferences on obtaining a better VR experience strictly applied in the context explored. Above we mentioned that MA followed by EB were accepted overall at a minimum of level 1, but there was less agreement in what was the optimal level for EG and ME. This is not to say that EG and ME are not important: in this setup, this is the preference established by participants. This framework hopes to provide teams that are looking to build VR applications with a consistent tool to evaluate the impact of different factors on experience, as well as a way to understand the point of equilibrium across a range of use cases.

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