WHAT FACE WOULD YOU LIKE TO HAVE?

The Effects of an Avatar's Facial Features on Social Presence

MASTER'S THESIS :

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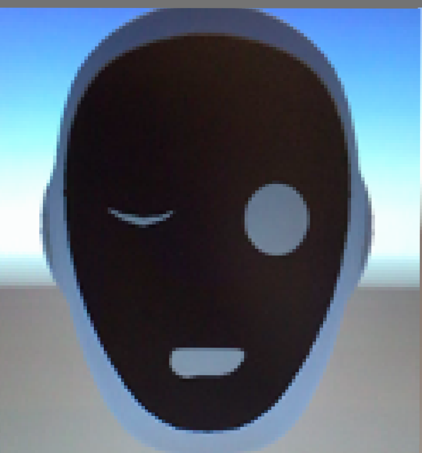
MSc Interaction Technology

UNIVERSITY
OF TWENTE.



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ABSTRACT

Introduction

Remote collaboration, wherein people can interact remotely via a robotic representation, is becoming increasingly prominent and yet, despite the development of commercial telepresence systems and robots for remote collaborative interactions, there has been little evaluation or discussion about the facial appearance of the collaborator's avatars, especially real-time facial tracked avatars.

Objective

This research investigates the effects of avatar facial features on social presence and users' perception in a physical space telepresence system.

Methods

We conduct a user study comparing the effects of avatar face appearance with two levels of anthropomorphism (low: abstract; high: stylised human), which includes two levels of expressiveness (low: only eye blinks + mouth up-down movements; high: realistic facial expressions) on Social Presence while performing a collaboration task.

Results and Conclusion

Twenty-nine participants are included. We find that females perceive more Copresence, Emotional Contagion and Aggregated Social Presence with high level of expressive avatars than low level of expressive avatars, indicating that females could be more receptive to higher expressiveness than males. Males perceive more Copresence with high-anthropomorphic avatars than females due to the lowest scores for high-anthropomorphic-low-expressive avatars by females. Females' lowest scores for high-anthropomorphic-low-expressive avatars might be because females are more sensitive and critical to the unexpectedness of avatars' behaviour according to their visual representation. The difference between low and high expressiveness is significant for high anthropomorphic avatars, implying Copresence is the lowest when a large mismatch exists between an avatar's appearance (anthropomorphism) and behavioural realism (expressions). However, the results show no significant difference within Anthropomorphism, Expression Modality and Sex individually and overall three-way interaction (Anthropomorphism*Expression Modality*Sex). We discuss these results and suggest guidelines for designing future avatar-mediated remote collaboration systems.

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LIST OF ABBREVIATIONS

COP	Copresence
PAE	Perceived attentional engagement
PEC	Perceived emotional contagion
PC	Perceived comprehension
PBI	Perceived behavioral interdependence
EVE	Low anthropomorphic avatar- Robotic face
RPM	High anthropomorphic avatar- Ready Player Me Human stylised face
LM	Low expressive modality
HM	High expressive modality
CMC	Computer-mediated communication
F2F	Face-to-Face
RQ	Research Question

1 INTRODUCTION

”Man is by nature a social animal”

Aristotle, Politika ca. 328 BC

The human being is a social animal. No matter from which background, culture or demographics we are from, humans have to communicate to meet their daily needs and function in society. Organisation and effective communication are impossible without being aware of others, and understanding actions [1]. Understanding actions means to share feelings or to learn through imitation. Social interaction shapes our perception and daily behaviour by attaching social meaning to spontaneous acts like gestures, facial expressions, intonations, to name a few [2]. One of the skills to have a meaningful social life is ’the ability to work within groups’. This ability can also benefit teamwork because groups are more intelligent than individuals. Research has found that face-to-Face groups are much smarter than those who communicate electronically [3]. This more smartness and effectiveness achieved as a group is because ninety per cent of our communication is non-verbal. The effectiveness of a group is not determined by their Intelligence Quotient(IQ). It is determined by how well they communicate and how often they take turns in conversation [3]. Therefore, social behaviour is crucial for artificial agents like social robots. Robots should be able to show similar verbal and non-verbal cues of emotional states and their social stance like humans through their voice, face, and other body parts.

1.1 Context and Motivation

This project is a part of iBotics; TNO and University of Twente initiate the independent innovation hub. It aims to develop knowledge and technology for value-adding Robotic solutions. iBotics participates in ANA Avatar XPRIZE [2], which focuses on developing a robotic system that will deploy the human presence to a remote location in real-time, leading to a more connected world. This robotic system can be achieved by creating synergy in multimodal telepresence, transporting the operator’s social and functional self to any fit-for-purpose avatar through a compelling combination of state-of-the-art social, visual, haptic, audio and olfactory technologies. The vision is that distance should not be a barrier to experiencing social connectedness and applying one’s skills and knowledge to make this world a better and safer place. The mission is to develop a system that enables the user to feel embodied and interact with a remote environment and its people as if physically present. This system would create a societal impact on healthcare, elderly homes, and safety and security.

Robot applications are taking a rapid transition from factory settings to people’s day to day lives. The institutions like museums, hospitals, airports and schools use robots to aid productivity. Depending upon the context and function, robots with human-like appearance provides a stronger sense of social presence [4] enabling richer social human-robot interaction and might improve acceptance. One way to improve people's acceptance of robots is to increase their familiarity. The familiarity can be increased by making the robot anthropomorphic (human-like). Anthropomorphism is the tendency to attribute human characteristics to non-lifelike artefacts. Developmental psychology studied the phenomenon of attributing intentions and animacy(the quality to be perceived as a living entity rather than an inert object) to simple shapes based on appearance and motion [5]. Humans tend to anthropomorphise non-humanlike objects in order to make them more familiar, explainable, or predictable [6]. This phenomenon of anthropomorphism plays a vital role in designing social robots, which is evident in the robot's appearance (form) and behaviour (e.g. movement), and interaction (e.g. modality) [7].

This project focuses on the facial expressions of avatars and their effects on social presence. However, why measure the social presence of the avatar? This document will shed light upon answering these questions in upcoming sections. The aim is to develop and investigate facial avatars to deliver social presence.

1.2 Background

Communication technology has become a part of our daily lives. Social media and online conferencing surround our lives. The COVID-19 has significantly prompted and accelerated the adoption of remote collaborative technologies of communication and video conferencing tools [8]. The use of Zoom, an online meeting platform, jumped from about 10 million users in December 2019 (pre-pandemic COVID 19) to more than 300 million users 5 months later [9]. However, video conferencing has several limitations, which is well known by the term "Zoom Fatigue". Zoom fatigue refers to tiredness, anxiety or worry resulting from overusing virtual conferencing platforms [10]. These negative effects arise because of the human nature of being wired for face-to-face or in-person conversation and meetings. Video-conferencing causes nonverbal overload, which potentially causes mental and physical fatigue [11]. VR technology aims to solve these problems related to on-screen video conferences.

The use of VR/AR technologies has also boosted education, remote collaboration and retail. "Overall, global spending on AR and VR headsets, software and services, including purchases by consumers, rose in 2020 to $12 billion, up to 50% from 2019."[1]. VR offers excellent benefits for the eye-contact by simply looking at the conversation partner's eyes. To address this problem of eye contact, remote collaboration and lack of presence, there is a need to incorporate and enhance the immersiveness through a compelling combination of state-of-the-art social, visual, haptic, audio and olfactory technologies.

Social VR can make us feel transported to a virtual world where we can interact with people in a shared virtual space. Avatars usually represent the people in shared virtual spaces. The immersiveness increases because of spatial sound effects and controllers' haptics. It gives a sense of embodiment as the physical body becomes the interface between users and their personalised avatars, making social VR more engaging, intimate, and fun.

The humanoid robots like Halodi's EVE [2] also help to give an immersive feeling to be in the environment where the robot is. EVE can be teleoperated with the VR technology where the operator can see what the cameras mounted on EVEs' head sees. Moreover, the body parts of EVE being tele-operable gives the operator a sense of embodiment. The challenge is to have more non-verbal cues, such as facial expressions.

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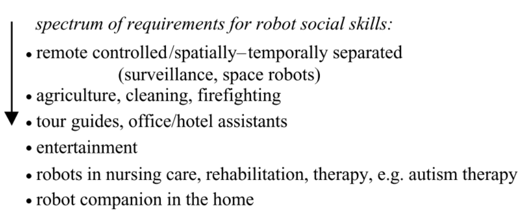
[1] https://www.forbes.com/sites/forbestechcouncil/2021/09/14/augmented-and-virtual-reality-after-covid-19/?sh=6bef908d2d97

[2] https://www.halodi.com/ever3

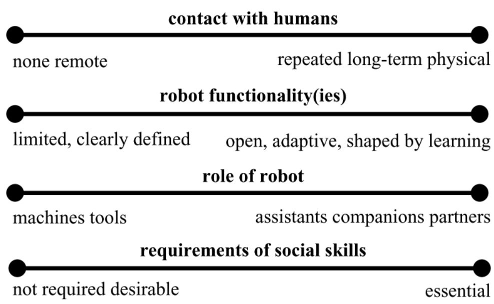
1.2.1 Social Robot

Social robots can be defined as *"an autonomous or semi-autonomous robot that interacts and communicates with humans by following the behavioural norms expected by the people with whom the robot is intended to interact"* [12]. Communication and interaction with humans are critical points of this definition. Humanoid service robots have been described as "the most dramatic evolution in the service realm" [13] because they differ from prior service technology and has more human-like interactions. The COVID-19 crisis has increased the inclination for robotic automation of frontline hospitality services such as hotels, tourism [14, 15]. It is expected that communication between robots and humans will change with the emerging technology. Significant advancement of technology integration is the ability of technology to engage customers on a social level. So, understanding how customers perceive such new human-like interaction technology is crucial [16]. The robots are designed according to the usefulness, functionality and domain where they will be used. Figure 1.1a shows a list of several application domains where increasing social skills is necessary. At one end of the spectrum, we see that robots do not need to be social (e.g. surveillance robots) unless they need to cooperate with humans or other robots.

In contrast, a robot delivering a cup of coffee to patients in hospitals has regular encounters with people. So within this domain, social skills contribute to making the interactions with the robot more convenient and acceptable for people. To determine which social skills are needed, the application domain and the nature and the frequency of contact with humans need to be analysed. According to [17], 1.1b Contact with humans ranges from none, remote contact (e.g. for robots operating in deep-sea environments) to repeated long-term contact possibly involving physical contact, as is the case (e.g. in assistive robots in nursing homes). The functionality of robots ranges from limited, clearly defined functionalities (e.g. as vacuum cleaning robots) to open, adaptive functions that might require robot learning skills (e.g. applications such as robot partners, companions or assistants). Social skills vary from not required (e.g. robots designed to operate in areas spatially or temporally separated from humans, e.g. on Mars or patrolling warehouses at night) to possibly desirable (even vacuum cleaning robots need interfaces for human operation) to essential for performance/ acceptance (service or assistive robotics applications). Therefore, it is essential to make use of socially acceptable functionality in a robotic system that removes the barrier between its intended purpose and people [18].

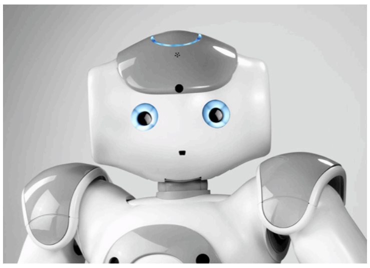


(a) Increasing requirements for social skills in different robot application domains [18]

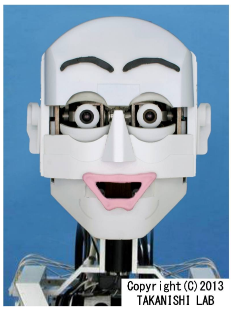


(b) Evaluation criteria for identifying social skill requirements for robots in various application fields

Figure 1.1: Requirements and evaluation criteria on social skills for robots in different application domains.



(a) NAO: Non-expressive robot



(b) Kobain-RIII: Expressive robot with actuators

(c) EVE: Expressive robot with projection display

Figure 1.2: Types of Humanoid Robot's Faces

1.2.2 Humanoid Robot Head and Face

Advancement in robotics is giving rise to the inclusion of robots in our day to day lives. Today robots assist people with various activities that are physically demanding, monotonous or helping people with mental disorders. Therefore, designing robots according to their needs is essential. For designing and classifying social robots, [19] proposes a framework which consists: Form, Modality, Social Norm, Autonomous, Interactivity. In this project's scope, we are focusing on facial modality representing an embodied person via an avatar. The head is an integral part of the body that informs the current emotional state via facial expressions. There is evidence that words are not needed to convey a particular emotion [20]. Therefore, a robot that represents a remote human needs to elicit appropriate facial expressions. This representation also helps establish an acceptable bond that enables social presence, and acceptance [21, 22, 23].

Face plays a vital role in nonverbal communication. For fifty years, facial expressions have received much attention from social scientists. According to some researchers, the face is a portal to one's internal mental state. The emotions are the reflection of biological events that produce changes in a person—one of those changes is movements of facial muscles which results in facial expressions [24, 25]. These changes in facial expressions are also correlated to physiological changes like heart rate or blood pressure [26]. During mediated communication, facial expressions are necessary to know about nonverbal reactions. Telephonic conversation serves the purpose of communication without any visual cues about others' faces. However, showing another person's face tends to be more effective when the goal of the interaction is social than when purely it is task-oriented [27].

There are two main humanoid robot heads classified as non-expressive or expressive face robot heads. Non-expressive face heads cannot show dynamically changing facial expressions. They mainly have sensors such as cameras and microphones to record or guide towards a goal (See Figure 1.2a). Expressive heads show dynamically changing facial expressions through several mechanisms; actuated facial traits(mechanical) (see Figure 1.2b); animated facial traits through displays; or the projection of the animated face onto a screen [28] (see Figure 1.2c).

1.2.3 Avatars

Avatars are virtual representations of their users that can be distinguished from agents by the source of control: avatars are controlled by real people, whereas computational algorithms control agents [29]. Avatars can either look or behave like the users they represent.

Figure 1.3: Apple Memojis: Avatars to match your personality and mood.

We live in the age of avatars. We see avatars on social media platforms, gaming and in animated movies. A social media platform, Snapchat use Bitmoji [3] while Apple uses Memoji [4]. Most major platforms, including Facebook, allow users to create their customised digital persona. The idea is to match users' personalities to a cartoon character that can express many moods and emotions. Moreover, with the help of avatars, we have the freedom to control the way we represent ourselves in digital space. Figure 1.3 shows a variety of avatars by which we can represent ourselves and express ourselves. Avatars enhance the communication apps we use to stay connected—to stay social—both practical and emotive.

Researchers have found that using avatars gives a greater sense of co-presence between participants [30, 31]. Co-presence is simply the sensation of being with another person simultaneously—a sense of shared connectedness. Suppose a text-based messenger incorporates the use of avatars. In that case, people feel like they are speaking to another person, even through simple actions like sending a quick expressive Memoji or Bitmoji.

1.2.4 Social Presence

The way avatars look and behave is essential because they elicit an experience of being with another person, called social presence(also referred to as co-presence). Social Presence was first conceptualised by [32]. It was defined as the salience of interactants and their interpersonal relationship during a mediated conversation. According to [32], intimacy and immediacy are the two core components of social presence. Intimacy refers to the feeling of connectedness that communicators feel during an interaction. Furthermore, immediacy is the psychological distance between the communicators. These two concepts are related to each other. Both intimacy and immediacy are determined by verbal and non-verbal cues like facial expressions, voice, and physical appearance [33].

There are many definitions of Social Presence in literature. For our convenience, we will consider the definition: "sense of being with another" [34] p.456 and is dependent on the perceived ease with which one can have "the access to the intelligence, intentions, and sensory impressions of another" [35] p.22. It is considered that Face-to-Face(F2F) is the gold standard for

[3] https://www.bitmoji.com
[4] https://support.apple.com/en-us/HT208986

social presence [36]. Research compares F2F communication with CMC to judge how successful a given system establishes social presence.

Establishing social presence is also dependent on the modality or specific technology affordances of a medium (e.g., immersive features). Certain affordances of a medium can increase or decrease social presence when all other circumstances are equal [37, 38, 39]. However, [40] argues, in contrast, these medium-centric views of social presence by proposing social information processing theory(SIPT). According to this theory, individuals can adapt to various communication media and achieve their communication goals accordingly, although it may take more time. From this point of view, the experience of social presence is highly subjective rather than the medium itself. Furthermore, this theory was expanded, saying that people who communicate via text-based CMC could achieve high levels of social presence than F2F by carefully selecting the aspects of their personality they wish to reveal, which is known as the hyperpersonal model of communication [41].

Both SIPT and the hyperpersonal model suggest that the level of social presence a medium can afford is not entirely determined by technology. It's vital to emphasise that neither viewpoint denies that media have fundamental disparities. For example, individuals are only given a limited timespan to communicate, a specific task type, to name a few. Likely, technological features such as immersive quality(technological capacity to deliver a vivid experience) will influence an individual's level of social presence. For our purpose, the ways a humanoid robot/avatar looks, express and moves are vital to know the level of social presence it has to deliver.

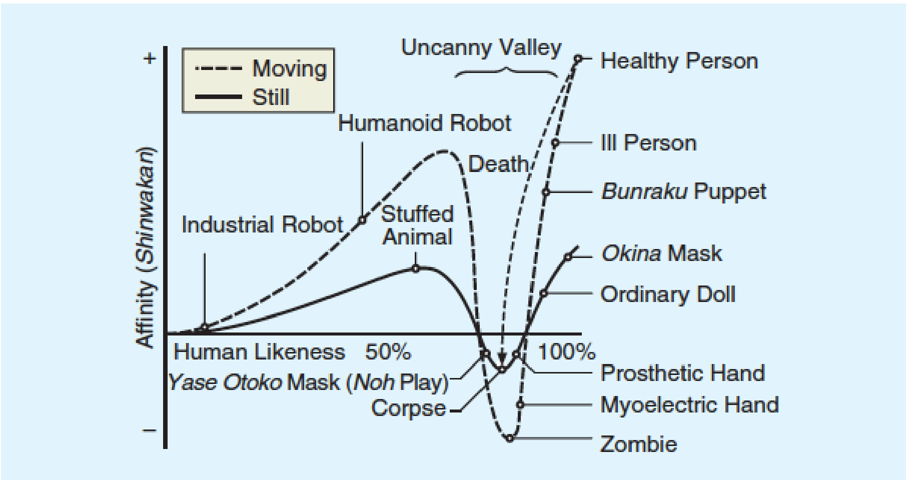


Figure 1.4: Uncanny valley: The presence of movement steepens the slopes of the uncanny valley. The arrow's path represents the sudden death of a healthy person [42]

1.2.5 The Uncanny Valley

The way a social robot and avatar looks, behaves and moves is crucial for them to be accepted by the users. In an attempt to improve human-robot interaction, roboticists have attempted to construct humanoid robots whose physical appearance is identical to real humans [43, 44, 45]. However, Mori (1970) warned that objects should not be made too identical to actual humans as those objects can fall into the ”uncanny valley”. The uncanny valley theory proposed by [42] suggests that when human appearance or behaviour is given to an artificial figure or object, there comes the point after which the affinity or acceptance of that object plunges, which gives rise to an eerie or unsettling feeling. This eerie feeling is because that figure or object is not quite human (see Figure 1.4). It is suggested to create a safe level of affinity by deliberately pursuing a non-human design.

Researchers have proposed several explanations for the uncanny valley phenomenon [46, 47]. These hypotheses can be mainly divided into two categories (refer to Figure 1.5). The first one explains from the perspective of evolutionary psychology that the uncanny/eerie feeling comes from the facial features, including the Threat Avoidance hypothesis and the Evolutionary Aesthetics hypothesis. The other category explains cognitive conflicts, including the Mind Perception Hypothesis, the Violation of Expectation Hypothesis and the Categorical Uncertainty Hypothesis. As the cognitive response is easy to quantify and manipulate, most empirical studies focus on explanation based on cognitive conflicts [47].

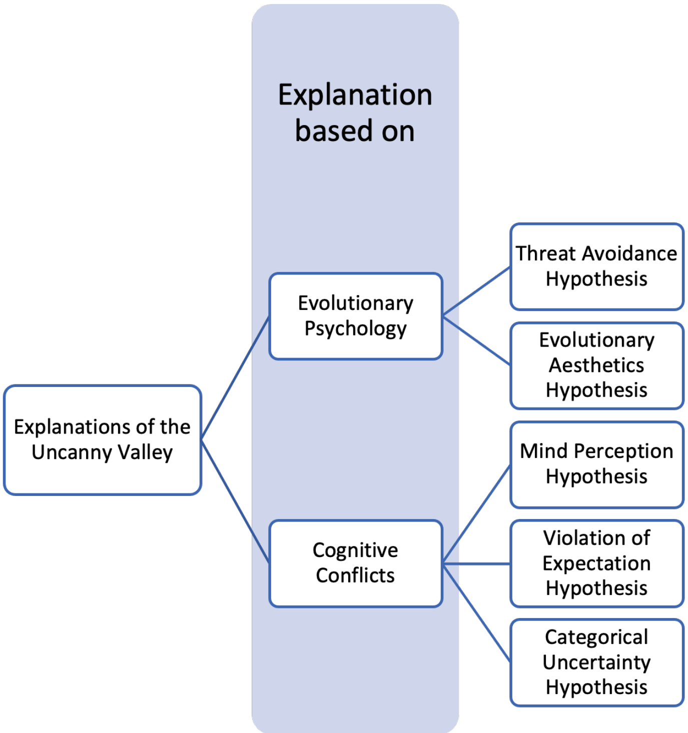


Figure 1.5: Explanations of the Uncanny Valley based on Evolutionary Psychological Perspective: Threat Avoidance(for e.g. associating the defects with diseases), Evolutionary Aesthetics Hypothesis(for e.g. judgement based on attractive traits associated with health, fertility and other aspects that close to reproduction) and based on Cognitive Conflicts: Mind Perception Hypothesis(for e.g. unexpectedness of unique human characteristic on robots), Violation of Expectation Hypothesis(for e.g. mismatch between expectations and reality which gives negative feelings like eerieness or coldness), Categorical Uncertainty Hypothesis(for e.g. conflict between deduction and stereotype, between expectations and reality, or between different categories [47].

1.2.6 Facial Tracking

Face tracking technology detects and tracks the human face in a digital video frame with the help of cameras infrared illumination sensors. Cameras help capture facial motion from all angles, and IR illumination sensors help maintain reliable and accurate tracking in low light conditions. This technology helps read facial expressions in real-time. This technology is currently incorporated by the smartphones like Apple iPhone X(and further) and virtual reality technologies like

HTC VIVE Facial Tracker.

Facial tracking can be used with avatars to make them lively and expressive. This expressive characteristic enhances the communication experience to stay connected and social in practical and emotive ways. It gives a personalised experience to the user as well the recipient. If avatars are displayed on robotic heads, which represent the remote user, they can offer three benefits for robotic heads. Firstly, avatars being a stylised/abstract version of users will help keep the balance between humanness and machine-like. Thus, avoiding the uncanny valley phenomenon(an eerie or creepy feeling that some people experience in response to non-quite-human looking objects). Secondly, it could make humanoid robots alive. [48] argued that people feel uneasy because robot seems party-dead because of a lack of human-like expressivity. Thirdly, allowing express emotions. The inclusion of emotion display can decrease the sense of eeriness successfully [49, 50]. These emotional displays can bridge the gap between the design's expectations of human nature and people's perceptions of it, resulting in harmonious interaction.

2 PREVIOUS RELATED WORK

A significant part of the overarching iBotics projects is having an expressive face on the remote robotic system, representing the remote user controlling the robot. The goal is to have a facial representation of the robot's operator, which enables a higher social presence. This research is trying to achieve that by tracking the face and mapping it to a personalised avatar and abstract face with low and high levels of expressiveness. Very realistic avatars of users can be made, but these may induce a negative effect or reactions from the viewers. Even though they have realistic properties, they are not as perfect as human beings in terms of behaviour and appearance. This imperfection leads to a feeling of revulsion. This is a phenomenon known as the uncanny valley [42]. Interestingly, the animated face-tracked stylised faces have the potential to improve self-identification, communication, empathy, and express behaviours in virtual reality [51]. (Refer to Table 1. for a summary of the literature review of Avatars and Social Presence.)

2.1 Social Robots and the Uncanny Valley

In the last two decades, social robots have advanced rapidly. They are already being utilised to interact with humans in a variety of settings, including homes, hospitals, and shopping malls [52]. Engineers have created robots that closely resemble humans in order to have better human-robot interaction [46]. However, there is a sharp drop in comfort and a sense of eeriness when robots appear almost but not totally human, which is known as the ”uncanny valley” [42]. Researchers have presented several theories to explain the phenomenon of the uncanny valley [46]. From an evolutionary psychology perspective, the uncanny feeling comes from facial features themselves, including the Threat Avoidance hypothesis and Evolutionary Aesthetics hypothesis [46, 42, 53, 54] (see Section 1.2.5). These previous studies indicate that the face plays an important role in human-robot interaction in terms of acceptance.

Efforts have been made to make the face of humanoid robots expressive and acceptable [28]. The humanoid robot head should be considered a medium of communication to improve HRI quality. [28] suggests a need to research towards generating extensive and refined variation of facial expressions and head motions. [55] shows that robotic characters are not able to express emotions better than screen characters(e.g. Microsoft paper clip assistant). It is because of their anthropomorphic shape, which does not help to express emotions. So, it would be possible to let the robots express themselves better by focusing on expressive robots with projection displays and avatars (with the qualities of screen-like characters).

A large and growing body of literature has investigated the effects of avatars appearance on people's perception. An interesting finding by [56] demonstrates that the uncanny valley was confirmed only when the avatars had abnormal features such as bizarre eyes. These findings imply that a nearly perfect human appearance is necessary but not sufficient for experiencing the uncanny valley. Although some studies demonstrate the positive effects of using realistic avatars [57, 31, 58], the creation of avatars needs to be contextual. It should be consistent with the form and behavioural realism as well as with the shape, and material [21, 59]. The idea of partially stylising for creating appealing characters could be a way to project the avatar's faces on robots' faces [60].

2.2 Why use Avatars?

Virtual avatars that represent humans are becoming more and more prevalent in our daily lives. Avatars' form and behaviour are important as they elicit an experience of being with another person [22]. This feeling of being with another person is referred to as social presence(co-presence)—a sense of shared connection at the same point in time [36]. In 2001, [57] published a paper has indicated that the most realistic looking avatar generated higher levels of co-presence. It was also discovered that avatars with gestures and facial expressions exhibited much higher co-presence levels than static avatars. Another research states that how an avatar looks like a user affects how users view themselves. They found that "people have positive emotions such as affection, connection, and passion toward avatars and that as the degree of identification with an avatar increases, the more they want to interact with" [61]. Apple could have used this psychological effect with their Memoji avatars (Figure 1.3), which gave users more control to create an avatar that better reflects them. Moreover, partially stylised avatars are perceived as more appealing compared to original looking and fully stylised avatars [60]. Collectively, these studies outline a critical role for using an avatar to enhance the online communication experience.

Previous research has indicated that people disclose more verbal information in text and computer-administered interface than in more realistic conditions like face-to-face [62, 63]. Also, verbal and non-verbal self-disclosure was lowest in videoconferencing compared to voice-only and face-tracked artifact which changes color according to facial expressions (called Emotibox) [22]. Therefore, user representations with high behavioural realism and low form similarity is a worthy goal. Hence, animated avatars are believed to be such representation with a good balance of high behavioral and low form realism.

2.3 Social Presence

Several studies have revealed that social presence is associated with a range of positive communication results, such as trust, attraction and persuasion, and avatars have a big influence overachieving them. [64, 65, 61]. Face-to-Face(F2F) is considered to be the gold standard for social presence [36]. Past research compares F2F communication with CMC to determine how successful a given system builds social presence. Most of the research has found that users experience lower levels of social presence during CMC(e.g. video conferencing) than F2F conversations. [66] found that CMC users felt less social presence than F2F users while discussing news article issues for 20 minutes. Similar results were found in the contexts of online learning, and decision-making scenarios [39, 36, 67]. However, there were no differences in felt social presence between students who finished a two months online seminar series and those who attended the same session in person [68]. This example aligns with the argument that provided sufficient time, users interacting with CMC could achieve desirable communication outcomes as their F2F counterparts [40]. Nonetheless, communication possibilities are limited, such as a short timeframe or a certain task type. Technological features like avatars' appearance and their behaviour may influence a person's level of social presence.

In order to assess the degree of the perceived social presence by the dyads, Network Minds Social Presence inventory is appropriate in the settings where users are interacting with imbalanced media connections; in this project, users in VR interact with the user in physical space

[69]. The user in physical space can see the VR user's avatar on a screen that acts as the face of the robot. This inventory is also appropriate for settings in which users' levels of familiarity vary prior to the mediated interaction; users who experience avatars that can express emotions via teleconferencing technologies. In this study, the users would be unknown to each other prior to the experiment. Previous research used Network Minds Social Presence Inventory to measure social presence of the communication tasks such as guessing word by asking question to the partner [23, 70], desert survival task where participants collaborate to find a survival solution [71, 72], crossword puzzle and collaborative furniture placement [73], and other collaborative tasks such as puzzle game, negotiation [74]. The Network Minds Social Presence Inventory consists of three orders of social presence:

- **First order social presence: Co-presence** The degree to which the users feel like they are together in the same space.
- **Second order social presence: Psycho-behavioural interaction** This measure the user perception of attention, emotional contagion, and mutual understanding with their partner or participant.
- **Third order social presence: Subjective and Intersubjective symmetry** It is derived from the scales used for the first order and second order social presence.
  - Subjective symmetry: Subjective symmetry measures how much the user believes their level of social presence is symmetrical (correlated) with that of their partner. It is calculated as a correlation between ratings of one's social presence (”Perception of self”) and that of another (”Perception of my partner”). This can be calculated for each scale individually or the entire inventory.
  - Intersubjective symmetry: Intersubjective symmetry is a measure of how symmetrical (correlated) the user's rating of their social presence is with their partner's rating of the user's level of social presence. It is calculated as a correlation between the self's ratings of social presence (”Perception of self”) and the other person's rating of the user (i.e., the partner's ”Perception of my partner”). For each self-partner pairing, the intersubjective symmetry can be calculated. This can be calculated for each scale individually or the entire inventory.

2.4 Anthropomorphism, Realism and Truthfulness of Avatars

The attractiveness of avatars is considered to have a substantial impact in both single-user and multi-user applications. It has the potential to influence how participants rate their avatars and how comfortable they are with them. Positive impact on the truthfulness on the evaluation of attractiveness and a correlation between self-esteem and avatar selection [75]. When people are exposed to social circumstances in immersive virtual environments, it can also alter how they behave, interact and feel about themselves. More attractive avatars leads to more intimate behaviour and taller avatars behaved more confidently [76] . Virtual character's attractiveness can be influenced by a number of factors. Previous research has shown, for example, that realism of avatar is not a good predictor of attraction. The work of [59] demonstrates the relevance of consistency in the amount of stylisation of the characters' shapes and materials, with discrepancies reducing their attractiveness. [60] also highlights the importance of forms and proportions. In comparison to the original and extremely realistic scanned 3D models, beauty evaluations are more favorable for avatars with an intermediate level of stylisation. On the other hand, [77] found that both extremely realistic and highly abstract characters might be assessed as more appealing, which could be explained by the uncanny valley effect for intermediate conditions

[78]. As a result, avatar visual fidelity must be considered while creating virtual characters because it influences how users interact with their avatars [75] as well as how others view that avatar [77]. According to [79], visual fidelity of virtual characters can be classified into three categories:

- **Anthropomorphism** (non-human-like <—> human-like)
- **Realism** (few detailed <—> more detailed)
- **Truthfulness** (does not look like the user <—> looks like the user)

2.4.1 Anthropomorphism

Anthropomorphism refers to the virtual character's morphological traits. Anthropomorphism is vital for establishing social connection when human connection is lacking, and anthropomorphising technological agents/avatars appears to help effectively connect with them. Humans tend to ascribe human-like attributes to non-human agents to make sense of certainty and establish social connections. This sense of certainty and social connection can be gained by making artefacts appear more familiar, explainable, or predictable. It can be predicted that anthropomorphic tendency will increase when people feel lonely and decrease when people feel a strong sense of social connection [6].

In robotics, the goal of anthropomorphism should not be to create a synthetic human. The question could be how much human-likeliness is optimal in non-human objects. What will people think of a robot that looks like a human?. In 1970, Mashiro Mori answered this with the uncanny valley theory. It explains people's reactions to technologies that look too much like humans yet are not. Mori hypothesised that a person's reaction to a humanoid robot would move from empathy to aversion when it falls short of a fully human-like appearance [78].

A product's appearance and function influence how people perceive it, interact with it and form long-term relationships with it [80]. The appearance of the robot should correspond to its capabilities as well as the expectations of the users [81, 82]. According to studies, humanoid robots elicited more hesitant and negative responses than robots with a pet-like, or more functional shape [83]. This occurrence might be due to the notion that form needs to match behaviour. Although the form could be matching in the case of a human-like robot, the behaviour is not as expected based on social norms, which might have evoked the uncanny valley phenomenon [78].

In human-human communication, the face plays an important role in communication as we can figure out most of the non-verbal cues and emotions through facial expression. Giving the quality necessary to convey non-verbal cues through robots' faces would enhance the human-robot interaction. In a robotic face, particularly the nose, the eyelids, mouth and width of the face increases the perception of humanness [84]. Previous studies have explored the effects of a robot's ability to exhibit facial expressions when interacting with humans. [85] examined the effects of a robot's emotional nonverbal response on evaluations of anthropomorphism. When a cat-like robot (iCat) provided emotional feedback, people perceived it as more likeable, felt closer to it, and rated interaction as more pleasant than when the same robot responded naturally. The evaluation of participants shows that emotionally expressive robots that displayed two emotional states (happiness and fear) are perceived as more human-like and anthropomorphised. Similarly, [86] showed a similar effect by measuring people's empathy towards the robot head EDDIE when: (1) it was neutral, (2) displayed the subject's facial expressions, (3) when it displayed facial expressions according to the internal model, i.e. indirectly mirroring the subject's expressions based on the "social motivation model". Participant's ratings on empathy, subject to performance, trust, and likeability differed significantly between the three conditions, with the most positive ratings going to the robot using the social motivation model. Human social behaviour, such as facial expressions, influences how we interact with one another and how a robot is evaluated. [84] suggests that when designing robots, a balance must be struck that takes three factors into account: *"the need to retain an amount of robot-ness so that the user does not develop false expectations of the robots emotional abilities but realises its machine capabilities; the need to project an amount of humanness so that the user will feel comfortably engaging the robot; and the need to convey an amount of product-ness so that the user will feel comfortable using the robot."*

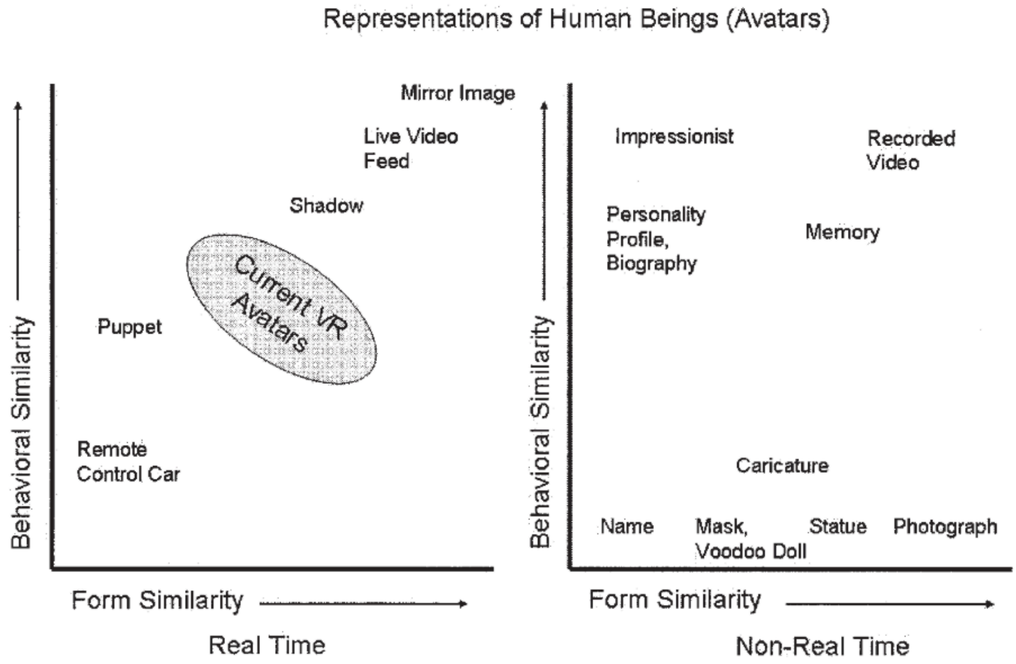


Figure 2.1: A classification system for human representations in physical and digital space [22]

2.4.2 Realism

Realism corresponds to the level of detail of meshes and textures of 3D models. Nowadays, advancements in computing power for real-time 3D rendering make it possible to create realistic and optimised models. [59] states that realism is not a good predictor for appeal or attractiveness and emphasises the importance of shape and material for avatar creation. It was discovered that shape is the most crucial factor in realism and expression intensity, while the material is the most important factor in appeal. Inconsistency in stylisation between material and shape negatively affect the appeal, attractiveness and make the avatar eerier. [60] illustrates that partially stylised body scans are perceived as more appealing compared to the original and fully stylised body scans. It seems that shape is the dominant factor in terms of perceiving realism and appeal rather than improved render quality [77].

Many studies have examined the effects of realism on avatars. In 2001, [57] demonstrated that realistic avatars evoked higher levels of co-presence and avatars having gestures and facial expressions produced a significantly higher co-presence compared to static avatars. Realistic avatars also tend to establish greater confidence and trust [31]. There could be an issue regarding the uncanny valley phenomenon as avatar creation approaches realism but could not achieve perfection [78]. However, despite an indication of the uncanny valley, the realistic avatars elicited greater acceptance than non-realistic (abstract wooden avatar) in terms of virtual body ownership (VBO) [58]. This body of research tells us about the positives of using realistic avatars.

On the other hand, realism alone is a lousy predictor of appeal and attractiveness [59]. [77] demonstrated that realism of avatar had no main effects, i.e. highly abstract or highly realistic avatars are considered equally appealing. A drop in appeal occurs when an avatar is neither abstract nor realistic. In terms of behavioural realism, embodied avatars with only a floating head and hands experienced greater social presence, self-presence and interpersonal attraction compared to full-body avatar [70]. In contrast, [73] realistic whole body avatar was considered the best for remote collaboration based on mixed-reality(MR) technology. It might be because of inconsistency between form and behavioural realism in the case of full-body avatar [22] which yielded unfavourable responses. This evidence supports the result that lower-realism avatars are adversely affected by inferred gaze [79]. Thus, revealing a significant interaction effect between appearance and behaviour. Therefore, there needs to be a consistency between the form and behavioural realism of avatars to achieve acceptance. Figure (2.1) presents an attempt to give a framework for thinking about human representations that is not confined to digital avatars.

2.4.3 Truthfulness

Truthfulness is the degree of closeness between users' appearance and virtual characters. Previous research shows some positive results regarding using an avatar that resembles the user. According to [61], the more an avatar resembles its user, the more likely the user is to have positive feelings like affection, connection, and passion. Observing the doppelganger doing a higher performance in sports tasks has potential benefits on the users' behaviour [87]. The avatars, which has more degree of similarity with users, demonstrated a positive impact on attractiveness and self-esteem [75].

This study focuses on the effects of truthfulness and involves avatars. Previous research has identified several characteristics that influence how 3D objects are perceived, including textures, shading, and forms [59, 77]. It seems like avatars' animations dictate the acceptance and revulsion rather than the quality of render [77]. As a result, consistency between look, animation, and behaviour is one of the most essential factors leading to 3D character acceptability and credibility. [88] pointed out the importance of low end to end latency for facial tracking in order to avoid unwanted effects. A point to note is that very few studies have assessed the implementation of low latency facial-tracked avatars. The use of such technologies in multi-user studies should be investigated to allow for fuller non-verbal and truthful engagement.

2.5 Avatars and its Face Tracking for Facial Expression

The avatars and their facial expressions are being used to express/represent users playfully and appealingly. Avatars have been proven beneficial for the online communication experience (see Section 2.2). It might be because of stylization of characters [59, 60], and the user has the freedom to choose the way he/she can present themselves, which enables them in a more positive light. This phenomenon is called the hyperpersonal model [41].

With the rapid improvement of facial tracking technology in recent years, rendering realistic facial expressions on an avatar has become less difficult technically and monetarily. Virtual environments can now use facial tracking data from webcams or specialized depth cameras to portray the user's authentic expressions on a virtual avatar in real-time, thanks to several innovative technologies (e.g. true depth camera of iPhoneX and later, HTC VIVE Facial Tracker). More significantly, virtual environment interactants can alter and augment these expressions subtly.

Numerous studies investigated the effects of avatars' appearance and how people perceive them. Previous research focused on static images of avatars/characters to assess the perception of the users [89, 56, 90, 59, 60]. Although the results are insightful for designing avatars, the assessment of static avatars does not clearly indicate how that avatar will be perceived when it is in motion and express emotion. A number of studies measured the effect of moving an expressive avatar [57, 77, 91, 21, 92, 93, 88, 94, 23, 58, 31, 72, 74]. Although the results of expressive avatars can help us understand how users perceive communication with avatars, they cannot provide a true picture because the avatar does not represent the user's true real-time expression. Very few studies demonstrated the usage of real-time face tracked avatars, and even if they did, it had some limitations. According to [95], participants interacting with highly expressive avatars felt more social presence and attraction and performed better on tasks than those interacting with partners represented by low-expressive avatars. For example, [88] created a system that reflects users' real-time body and face movements on a virtual mirror in physical space. The problem with this system was the end to end latency of 150-200ms, which is not within the necessary threshold (<=150ms), which could distort the results. [23] measured the effects of enhancing facial expressions, particularly smile. The avatar can express five expressions(neutral, open mouth, smile, pressing lips, puffing out cheeks). These limited expressions cannot express all human expressions (happiness, sadness, fear, anger, surprise, disgust). Therefore, it is necessary to investigate whether and how the avatars' appearance interact with enhanced facial expressions and low latency real-time facial tracking.

2.6 Individual Differences and Facial Expression

Numerous studies in neuroscience and psychology have been conducted to see if and how gender/sex influences emotion detection while analysing human facial expressions. The majority of these studies findings show that females understand emotion through facial expressions better than males [96, 97, 98, 99]. The ability of women to empathise also may play an important role in the ability to recognise other's emotions [100, 101, 102]. These characteristics show that females are more accurate and sensitive in judging facial expressions. Interestingly, for happiness emotional expression, no sex-related difference was observed [103].

For avatars, women tend to rate the expressions of abstract expressive avatars more positive than men [104]. Another study explored avatar facial fidelity and emotional expressions on observer's perceptions, where female participants found the low-fidelity avatars to be more unpleasant than male participants. Furthermore, interacting with a smiling avatar was more unpleasant than watching a sad emotional expression [105]. To the best of our knowledge, no study assesses the effects of dynamic human-like looking avatars and non-human-like (abstract) looking avatars on the perception of males and females.

2.7 Videoconferencing

During the COVID-19 pandemic, the use of videoconferencing rose steeply. It will not be a surprise that people will keep up the high use of videoconferencing even post-pandemic as humanity got used to the hybrid mode of working. While saving the cost and time of travelling, will the use of videoconference improve our lives mentally and physically? Will it improve our productivity?

There are several limitations of videoconferencing, which is well known as ”Zoom Fatigue”. Zoom fatigue refers to tiredness, anxiety or worry resulting from overusing virtual conferencing platforms [10]. These negative effects arise because of the human nature of being wired for face-to-face or in-person conversation and meetings. Videoconferencing causes nonverbal overload, which potentially causes mental and physical fatigue [11]. While preserving the benefits of video conferencing, such as saving cost, time, and potentially nature by reducing the carbon footprint, social virtual reality platforms aim to tackle the limitations of video conferencing. [106] demonstrates that social VR platforms such as AltspaceVR and VRChat tend to feel more engaging, intimate, and emotionally fulfilling. In social VR, users become intimate with their avatars because their physical bodies serve as the immediate and sole interface between them and the avatars. Because of their strong attachment saw avatars in social VR as a more engaging and embodied way to explore their own identity. However, there could be drawbacks of using Social VR related to motion sickness. These drawbacks are because of a mismatch between what the brain thinks and body feels [107].

2.8 Telerobotics

If we want to deploy manual skills remotely, we cannot provide them with video conferencing systems. In such cases, telerobotics plays an important role. Telerobotics has been shown to be beneficial in the field of healthcare. Telepresence robots, for example, have been used by surgeons for postsurgical ward rounds and have been found to have similar patient satisfaction ratings as in-person visits [108]. Doctors were able to make additional postsurgical visits to gastric bypass patients using the robot, resulting in significantly shorter hospital stays and cost savings [109].

Similarly, the use of telepresence robots in intensive care allowed neurologists to respond to nurse pages more quickly, which was associated with a shorter length of patient stay as well as significant cost savings [110]. Using telepresence robots instead of telephones allowed physicians to access critical visual information (minutes rather than hours), allowing for faster diagnosis and decision-making. Children with chronic illnesses such as cancer who become isolated can use telepresence robots to attend school classes. Case studies show a mix of positive and negative interactions, but overall, the robot can help hospitalized children reduce social, emotional, and academic isolation [111]. Another real-world application in which robots are controlled remotely is minimally invasive robot-assisted surgery. The da Vinci surgical system is a market leader in this field, with over 500 units sold in 2013 across the United States, Japan, Europe, and other markets. Despite promises of fewer complications and less blood loss, a new meta-analysis of 20 randomized controlled studies found no differences in surgical blood loss, complication rates, or length of hospital stay between robot-assisted surgery and laparoscopic surgery [112]. The only difference was that surgery aided by a robot took longer. Robot-assisted surgery took longer than open surgery, but it resulted in less blood loss [112]. There is little study on patients’ attitudes and feelings about these robots [52].

2.9 Lessons Learned from Past Research

This section summarises the key aspects of avatar and facial representation that emerged from previous work that needs to be addressed. The existing, related work, recommendations and critique have the following implications for this study:

1. People disclose more verbal information in text, voice-only communication and computer-administered interface than in more realistic conditions like video conferences and face-to-face. Therefore, user representation with high behavioural realism and low form similarity is a worthy goal. Hence, animated avatars are believed to be such representation with a good balance of high behavioral and low form realism.

2. To make a humanoid robot with an expressive display on its head express acceptably, it is essential to have an avatar that matches the robot's form and behaviour. This is to avoid the mismatch of expectations between visual and behavioural reality to avoid the uncanny valley phenomenon.

3. To achieve higher levels of social presence and appeal, it appears that the avatar creation should focus on (a) having expressions that truly express the operator (higher levels of animation to convey intentions), (b) Stylising the avatars, maintaining consistency between shape and material.

4. Using low latency face tracking system to represent and evaluate the true facial expressions of users on avatar.

5. Investigate the different avatars representing operator: low truthful avatar<—>high truthful avatar with different levels of expressiveness: low expressive<—>high expressive. This would enable us to know which form and behaviour are appropriate to represent users on the face of robots for specific communication tasks.

6. Measure the social presence of the different avatars representing the user in a non-virtually immersive environment. This would give us an idea about robotic faces featuring avatars to connect with people socially.

7. Effect of different dynamic representations of avatar (abstract or human) and expressions (low or high) on male and female.

2.10 Research Questions

This study investigates the social presence of facial avatars representing the remote user. Face to Face(F2F) interaction is considered as the gold standard for social presence [36], many studies compare F2F communication with Computer-Mediated Communication(CMC) to judge how successful a given system is at establishing social presence. Most of the studies found that CMC based communication experienced lower social presence compared to F2F [113, 114, 67]. So, given the relevancy of communication context, the goal is to achieve a comparable social presence as F2F. The visual representation of communication partners plays an important role. The current studies show a higher level of social presence with the mere display of profile picture [115, 116]. Here we are monitoring the interaction with the real-time face tracked avatar representation. The avatars have two levels of anthropomorphism (the attribution of human-like features to non-human entities): low anthropomorphic avatar and high anthropomorphic avatar, and two levels of facial expressively: low expressive and high expressive face (see Figure 3.1).

In addition, behavioural realism affects social presence (e.g., presence and absence of non-verbal behaviour like animations, eye-gaze, blushing) [117, 118]. The avatars having two levels of anthropomorphism may posit certain expectations for expressiveness or vice versa. Therefore, it is necessary to know the effects of truthfulness on expressiveness and vice versa. This knowledge would help understand more about form and behaviour balance in order to meet communication interaction expectations and avoid the uncanny valley phenomenon [42]. Measuring the social presence of the interaction with avatars may tell us about its acceptance level.

Realising the importance of avatars and their behavioural aspects in social VR as well as social humanoid robot [119], it seems necessary to investigate facial representation. Moreover, the user's facial features would be appropriate in terms of anthropomorphism and facial expression modalities for a particular remote communication via a social robot. This idea brings us the following research questions:

RQ1: Does more anthropomorphic appearance lead to an increase in social presence?

RQ1(a): *What is the effect of the increase in anthropomorphism on the social presence of sex differences?*

RQ2: Does a more expressive avatar lead to an increase in social presence?

RQ2(a): *What is the effect of the increase in the expressiveness of avatars on the social presence of sex differences?*

RQ3: What is the three-way effect of sex, anthropomorphism and expressiveness on the social presence and preference?

The research question 1 and 2 will help us understand the effect of the increased anthropomorphism and true to life facial expressions of avatars on social presence. Answers will give insights on individual's responses to which level of visual and behavioural realism is appropriate for representing users via facial avatars [77, 21, 59] (addressing all points of Section 2.9).

Sub-research question 1-(a) will assess the impact of anthropomorphism levels of avatar-looks on social presence of males and females (focusing point 6 from Section 2.9).

Sub-research question 2-(a) will assess the impact of facial expressiveness levels of avatars on the social presence of male and female users (addressing point 6 from Section 2.9).

Research questions 3 will analyse the interaction effect of independent variables: Anthropomorphism, Expression Modality and Sex on dependent variables: Social presence and User Preference. This research question will aim to analyse all the possible interaction effects(3-way and 2-way interaction) on the social presence. For example, interaction effect between Anthropomorphism and Expression Modality ignoring the Sex variable.
Investigating these research questions can help in designing the avatars for particular modes and conditions of communication.

Table 1: Summary of the literature of avatars and its effects on users' perception

References	Purpose	Avatar details	Communication details and modality	Communication task	Social Presence outcome	Social Presence Measurement	Other outcome	Gaps/Limitations
(Casanueva & Blake, 2001)	Effects of avatars on co-presence in a collaborative virtual environment.	Abstarct vs. cartoon-like vs. realistic human-like. Static vs. Dynamic facial expressions	Virtual environment on computer screen. Interaction with stranger partners (3 total).	Reading a story (4 short paragraphs) by each. After that they have to agree on a ranking for the five characters in the story. This had a time limit of 20 minutes.	More realistic avatars generated higher levels of co-presence. Avatars having gestures and facial expressions produced a significantly higher co-presence compared to static avatars.	Immersive Tendency Questionnaire (Witmer & Singers, 1998); Personal presence measurement (Slater et al., 1995); Self co-presence questionnaire	—	Only elicitataion of 6 facial experssions. No realtime face-trackig. GUI to select the gestues/expressions
(Garau et al., 2003)	Investigate the impact of visual and behavioural realism.	Avatars: Low-realism vs. High-realism Gaze: Inferred vs. Random	Paired by gender; shared 3D(CAVE) environment.	Mayor or a baker role-playing negotiation.	----	----	Lower-realism avatar are adversely affected by inferred gaze. Revealing a significant interaction effect between appearance and behaviour.	Impact of other behaviours such as facial expression, gestures and posture
(Nowak & Biocca, 2003)	Effect of the Agency and Anthropomorphism on Users' Sense of Telepresence, Copresence, and Social Presence.	Avatar Face Image: high-anthropomorphic vs. low-anthropomorphic vs. no image.	-Manipulated agency: controlled by human vs. by computer. -19'' computer screen.	-Interaction about getting to know their partner who may work with them and compete as a team for a prize. Talking by turn taking.	Less-anthropomorphic image reported more copresence and social presence	(Short et al., 1976)	----	Static avatar images
(Bailenson et al., 2005)	Effects of embodied-agent appearance and behaviour on self-report, cognitive and behavioural markers of copresence in immersive VE.	Three levels of avatar faces with same body: Photographically realistic human vs. teddy bear vs. blockhead. Four levels of Behavioural realism(head movements): static vs. random vs. mimic vs. recorded.	VR: the virtual room in which participants sat facing embodied agent.	Participants need to interact with VE with gamepad and can examine the embodied agent.	Copresence was the lowest when there was a large mismatch between the appearance and behavioural realism of an embodied agent.	Own	----	Effects of other behaviours such as facial gestures, hand movements, and gait.
(Bailenson et al., 2006)	Effect of behavioural realism and form realism of real-time avatar faces on verbal disclosure, nonverbal disclosure, emotion recognition, and copresence in dyadic interaction	Video conference vs. (high behavioural and high form realism) vs. voice only (low behavioural and low form realism) vs. emotibox(high behavioural and low form realism)	In front of screen with webcam. Marker-less facial tracking in emotibox condition.	Task1: Question and answer session. Task2: convey the a list of seven emotions one at a time for 10 seconds. Task3: Fill out the copresence questionnaire.	Not much difference between copresence of voice only and video conference. Emotibox had lowest copresence.	Four-item copresence scale (Biocca et al., 2002)	Verbal and non-verbal self-disclosure were lowest in the videoconference condition. Self-reported copresence and success of transmission and identification of emotions were lowest in emotibox condition. Both verbally and non-verbally, people disclosed more information to avatars that were in low in realism.	Fallen short of producing high behavioural similarity in emotibox condition.

(Seyama & Nagayama, 2007)	Effect of realism on the impression of artificial human faces	Morphed sequences from CG to human	A stimulus image and five buttons showing from -2(extremely unpleasant) to +2(extremely pleasant)	A sequence of stimulus images with ratings on each image.	----	----	The uncanny valley was confirmed only when morphed faces had abnormal features such as bizarre eyes.	Static images.
(Yee & Bailenson, 2007)	Effect of transformed self-representation on behaviour Independent on how others perceive them.	Avatar faces: high vs. medium vs. low attractive. Avatar height: high vs. medium vs. low.	Participants in VR with same gender male or female confederates.	Negotiation task.	----	Interpersonal distance and self-disclosure	More attractive avatars leads to more intimate behaviour. Taller avatars behaved more confidently.	No facial expressions.
(Gong, 2007)	Linear polynomial trend analyses for avatar anthropomorphism and social responses	Computer agents having 4 levels of anthropomorphism: low vs. medium vs. high vs. real human	Participants randomly assigned each of the 4 levels of avatar. Computer with a 17'' flat screen.	The social influence instrument of five choice dilemma scenarios between participants and computer agent.	----	----	More anthropomorphic agent received more social responses.	Static avatar image.
(Bente et al., 2008)	analyses the influence of avatars on social presence, interpersonal trust, perceived communication quality, nonverbal behaviour, and visual attention in Net-based collaborations using a comparative approach.	Text chat vs. audio vs. audio-video vs. high-res avatar vs. low-res avatar.	Dyadic real-time communication 19'' screen including a special avatar interface integrated into shared collaborative workspace.	Collaborate in a management decision task commonly used in assessment centers: Participants had to select the best candidate from a group of six job applicants.	Nonverbal activity and visual attention were similar between video and avatar modes, both showing higher levels of exposure to the virtual other and visual attention.	58 5-point likert scale items based on (Biocca et al, 2001); (Kumar & Benbasat, 2002) and (Tu, 2002)	----	In the video and in both avatar modes, it was used to display the nonverbal behaviour of the partner in real time (delay ,1/20 s) Animated avatars, not face tracked with facial expression
(McDonnell et al., 2012)	Exp1: Investigating the effect of render style on the perception of animated virtual humans	Block 1: 30 still images- 10 render styles from (abstract to realistic) in 3 different neutral poses. Block 2: Motion applied to avatars with visible eye, eyelid and lip motion.	In Block 2, the participants did not hear auido, to makes sure they judge based on visual information alone.	Block 1: Each stimulus on screen and for each stimulus 6 rating questions. Block 2: showed 3 motion clips of the male actor for 6-10 seconds and presented with 6 ratings for each	—	—	Realism: No main effect of the presence or absence of motion was found. No interaction effect. Appeal: highly abstract or highly realistic are considered equally appealing. A drop in appeal occurs when avatar is neither abstract nor realistic. Re-assuring: same as Appeal results. Familiar: moving are more significantly more familiar than still. Friendly: No main effects of movement, no interaction effect. Trustworthy: neither main effects nor interaction.	No real-time dynamic face tracking for conversing.

(McDonnell et al., 2012)	Exp2: Motion Anomalies: test how unpleasant animation artifacts are perceived to be, and if they more unpleasant on realistically rendered avatars.	45 clips: 5 render styles(from abstract to realistic) x 3 motion alterations (no alteration, half face, static eyes) x 3 motion clips.	the participants did not hear auido, to makes sure they judge based on visual information alone.	On screen showing the same clips(with no alteration, half face, static eyes) as in Block 2 for 6-10 seconds. After that rating on a scale 1-7 on pleasantness.	—	—	Half face alteration is significantly more unpleasant than the other two. No significant difference between static eyes and no-alteration. Large motion anomalies are much more acceptable on toons than on human characters. The artifacts applied to the most realistic avatar were not the most disturbing overall.	No real-time dynamic face tracking for conversing.
(McDonnell et al., 2012)	investigating if the choice of rendering styles is important for the display of subtle cues	audio only vs. video of 5 avatars(abstract to real) vs. only visuals (no audio)	between group in order to avoid same truth and lie sequences on different render styles. Stimuli were displayed on 24" LCD monitor.	the participants were asked to detect if a virtual character was telling truth or lying (7 truth and lie sequences). This was done by clicking left or right mouse button.	—	—	The audio track alone appeared to be the best representation for detecting lies. Appealing render styles does not bias participants in believing that the avatar was telling the truth. Audio and animation contributed to the interpretation of the characters' intention rather than the render style.	No real-time dynamic face tracking for conversing.
(Kokkinara & McDonnell, 2015)	Perceived appeal by avatar realism and animation realism.	Avatar: Realistic vs. cartoon-like Animation realism: complete vs. reduced facial movements	virtual world on flatscreen with face-tracking enabled virtual face.	Questions asked by AI agent in virtual world on flatscreen with face-tracking enabled virtual face.	----	----	Higher levels of animation more appealing. High level of ownership through synchronous mapping of the face-tracking avatar.	Did not measure social presence.
(ZellEduard et al., 2015)	Effect of Shape and Material Stylization on the Perception of Computer-Generated Faces	From most abstract to the most realistic versions Five levels of stylisation.	----	Participants were shown avatars of different level of realism, expressions and stylisation.	----	----	Shape is the dominant factor for realism and expression intensity. While material is the key component for appeal. Strong mismacth between stylisation of material and shape negatively affect the appeal, attractiveness and make characters more eerie.	Static images of avatars. Only one male and one female character. Only analysed clear peak expression

(Fleming et al., 2016)	Perceptual effects of stylisation	Body shape stylisation: Original, Marvel, Disney, Sony, Pixar, Barbie (different percentage of sylisation for men and women: orginal vs. 33% vs. 66% vs. 100%). Colour maps: Original albedo vs. cleaned up and gray body suit added vs. stylised result.	—	Within subject; rate the appeal of the stylised avatars	—	—	Our results demonstrate that some stylization (approximately 48% for female and 44% for male) is perceived as most appealing on average across all styles and actors. High stylisation or no stylisation were rated to have least appeal. Color information or render quality had no significant effect on appeal. Shape is the dominant factor	Static avatar image. Only one male and one female character.
(Chaturvedi et al., 2016)	Effects of Virtual Human Appearance Fidelity on Emotion Contagion in Affective Inter-Personal Simulations Matias	Realistic vs. cartoon-shaded vs. charcoal-sketch like	Mixed reality simulation via 21" LCD monitor	Between-subject; participants interacted with one of the three appearances of virtual patient. Emtional states were analysed across four distinct time stamps during an emotionally stressful situation	Realistic condition perceived the character as a real-person, immersive and interactive, and like a real patient. Also, with a complex and diverse personality than sketch. In cartoon condition, lacking facila expressions, some perceived him as rude, while others as friendly.	Interpersonal social distance in immersive virtal environments (Blascovich et al., 2003)	skin Electrodermal Activity(EDA) showed in all 3 conditions male participants exhibit higher arousal as compared to females. Negative affect levels were significantly lower in realistic condition. Shyness, presencem perceived personality, and enjoyment-joy were different in the realistic condition compared to the other two.	In non-realistic conditions, the virtual environment was not rendered corresponding the avatars.
(Latoshchik et al., 2016)	A Fake Mirror System for Avatar Embodiment Studies. Investigated the impact of 3 main factors: low-level physical immersion, avatar realism and user resemblance and motion and face tracking latency fidelity	Mannequin vs. robot vs. individual	A mirror-like screen where users can see their real-time body and face-tracked representations	within subject design consisting of five conditions of one minute each. The user task ensures participants to constantly interact with their real and their virtual body. Prerecorded oral instructions were played-back asking participants to perform three randomized types of actions.	—	—	No significant difference between the effects of avatars	end to end latency of appoxiamately 150-200ms which is hardly within the necessary threshold (<=150ms)

(Roth et al., 2016)	Investigate the effects of reduced social information and behavioural channels in immersive virtual environments with full-body avatar embodiment.	Real world vs. VR (Full body faceless wooden mannequin)	Immersed in a two-person VR environment simulating a simple room.	A physical task- a ball game. A verbal task- a negotiation roleplay.	Significant differences in social presence and physical performance. No difference in effectiveness of verbal task.	(Biocca & Gregg, 2001); (Nowak & Biocca, 2003)	Participants appear to make up for missing social and behavioural cues by shifting their attention to other behavioural channels.	Disturbed visuomotor synchronisation caused by latency.
(Oh et al., 2016)	Effects of Enhancing Facial Expressions in Virtual Environments	Stylised avatar: normal smile vs. enhanced smile vs. mouth open-close. 5 expressions: neutral, open mouth, smile, pressing lips together, puffing out cheeks)	Dyadic interaction with same avatar to both via the avatar interaction platform.	A 20 Question game with their partner. The aim is to guess the partners' word by asking 20 or fewer questions. Words were "rabbit" or "ocean".	Enhanced smile condition felt more positive affect and experience stronger social presence.	Networked Minds Social Presence Inventory(Harms (Nowak & Biocca, 2003)	----	Same male and female avatar. 5 expressions.
Choi &Kwak, 2017)	Identity and presence in robot-mediated communication	Telepresence robot: high identity vs. low identity	Flat screen	Participants engaged in videocall with a remote sender with either a robot with high or with low identity in random order. Conversation using a script. Robot showed status of the videocall with visual notification on screen.	Participants felt more remote senders' presence when interacting with the telepresence robot with low-identity. When with the robot has high-identity, participant felt more presence toward the robot.	Co presence: (Nowak & Biocca, 2003); Social presence: (Short et al., 1976), (Nowak & Biocca, 2003); Telepresence: (Lombard & Ditton, 1999), (Nowak & Biocca, 2003)	—	—
(Latoschik et al., 2017)	Effect of Avatar Realism in Immersive Social Virtual Realities	Full body: wooden vs. photorealistic human	In VR; Phase1: self-avatar embodiment. Phase2: other avatar interaction	Phase1: Participants enter the virtual word and step in front of the virtual mirror. Phase 2: A virtual interaction counterpart	No significant difference	(Nowak & Biocca, 2003)	The realistic avatars were significantly more human-like and evoked a stronger acceptance in terms of VBO although there was some indication of potential uncanny valley	totally in virtual environment, no real-time facial expressions.

(Greenwald et al., 2017)	Investigating social presence and communication with embodied avatars in room-Scale virtual realit.y	F2F vs. VR(with avatar)	Within subject dyadic. VR vs. Face to Face(F2F). 2D vs. 3D drawing.	Charades and Pictionary 2D, each in F2F and VR, plus Pictionary 3D in VR.	The participants communicated effectively in VR and reported strong sense of social presence.	----	----	The avatars were low anthropomorphic. Similar kind of avatars to all participants. Bias due to within subject design.
(Heidicker et al., 2017)	Influence of avatar appearance on presence in VR	Idle vs. Mapped vs. Only heads&hands	Dyadic, Within subject. In VR, both participants experienced the same avatar	Collaborative task(Desert Survival Task)	Motion-controlled as well as avatars with only hands&hands produced an increased feeling of co-presence and behavioural interdependence.	Networked Minds Social Presence Inventory(Harms & Biocca, 2004); (Slater, Usoh & Steed, 1994)	----	No facial expression.
(Jo et al., 2017)	Effects of avatar and background types on users' co-presence and trust for mixed reality-based teleconference systems.	Realistically constructed vs. character-like	Between subject(2x2) In VR with HMD with MR. Environment background: realistic vs. 3D VR	Role of interviewer: Job interview with virtual avatar.	Higher sense of co-presence with realistic video..	One question.	Greater confidence/trust with realistic constructed avatar.	Basic facial expression and no real-time face tracking.
(Waltemate et al., 2018)	Impact of avatar personalization and immersion on virtual body ownership, presence, and emotional response.	Full body: Generic hand-modelled vs. generic scanned vs. individualised scanned version.	Within subject. L shaped part of CAVE vs. HMD	Movement-related audio instructions.	Personised avatars significantly increase body ownership, presence, and dominance	Subjective presence (Bouchard et al.,2008)	The degree of immersion significantly increases the body ownership, agency and feeling of presence.	No face tacking(no facial expression) Maybe latency 62ms and 67ms.
(Gorisse et al., 2018)	Immerse the user in front of three virtual characters with several levels of truthfulness while keeping a constant level of anthropomorphism and realism	Full body: robot vs. suit vs. virtual doppelganger	Within subject in VR	Participants immersed in the application for a period of time that is left to their discretion(between 3 to 10 minutes) to observe three avatars freely	----	----	Positive impact on the truthfulness on the evaluation of attractiveness and a correlation between self-esteem and avatar selection. Participants with higher self-esteem prefer choosing their own representation, and those with lower self-esteem prefer either of the remaining avatars.	No face tracking and demonstration of facial expressions

(Yoon et al., 2019)	Effect of avatar appearance on social presence in an augmented reality remote collaboration	Head&hands vs. upper body vs. whole body Realistic vs. cartoon-like	Within subject AR remote collaboration.	Two tasks: crossword puzzle and furniture placement.	Realistic whole body avatar was the best for remote collaboration. But upper body or cartoon style could be considered as a substitute depending upon the collaboration context.	Networked Minds Social Presence Inventory(Harms & Biocca, 2004);	----	Realistic and Cartoon avatars were not in the same gender, which could have affected the user perception. No facial expression
(Herrera et al., 2020)	Effect of behavioral realism on social interactions inside collaborative virtual environments	Full body avatar(mapped vs. inferred hands) vs. Mapped floating head and hands vs. static full-body.	Between-Dyadic. Inside a CVE using a HMD	20 question game to guess the partners' word.	Embodied avatar with only a floating head and hands experienced greater social presence, self-presence and interpersonal attraction	Networked Minds Social Presence Inventory(Harms & Biocca, 2004);	side-to-side head movements were negatively correlated with interpersonal attraction.	No facial expression.
(Cho et al., 2020)	Effects of volumetric capture avatars on social presence in immersive virtual environments	Photorealistic user's avatar: 2D-video vs. volume-capture vs. 3D(pre-scanned).	Within-subject in VR(for user) Actor(with avatars) is the same for all conditions.	Exp1- Dynamic task: user walks through a virtual space and is able to see the actor from various directions. Task is to solve a cube puzzle. Actor knows the solution and conveys it to the user. Exp2- static task: desert survival task.	Highest sense of social presence with the volumetric capture avatar when performing dynamic tasks. Higher sense of social presence with the volumetric avatar and 2D video than the pre-scanned avatar when performing static tasks.	Networked Minds Social Presence Inventory(Harms & Biocca, 2004); Temple Presence Inventory (Lombard et al., 2009)	----	Eye tracking function is not fully utilised. Pre-scanned avatar had animated lip sync based on users' microphone input. Unlike volumetric and 2D-video avatar that produces the users' motion as is.
(Gonzalez-Franco et al., 2020)	Using Facial Animation to Increase the Enfacement Illusion and Avatar Self-Identification.	Animated avatars' facial expressions: Static vs. lip-sync motion vs. lip-sync+additional facial animation with blinks.	Within subject in VR	Self-pep talk in front of mirror(40cm away) by repeating the given phrases chanted by experimenter.	-----	----	Self-identification on avatars can be increased through pre-bakes animations even when these are not photorealistic nor look like the participant.	No precise eye and face tracking. Need more pre-defined facial animation such as more abstract or affective motions on the face.

(Dubosc et al., 2021)	Impact of avatar facial anthropomorphism on body ownership, attractiveness and social presence in collaborative tasks in immersive virtual environments	Screen-based(virtual eyes and mouth) vs. physical eyes and virtual mouth vs. physical eyes and mouth.	Between subject, in VR. Same avatar for each pair.	Asymmetric collaborative task	High but no significant differences in social presence in both tasks(in terms of avatars).	Networked Minds Social Presence Inventory(Harms & Biocca, 2004)	The sense of social presence appears to be task sensitive.	A potential ceiling effect could be there for the co-presence.
				Task1: two puzzle games; first one independently, second one with collaboration following the instructions of their partner who had the corresponding plan on his/her side.	Statistical difference between two task types. The scores of co-presence, perceived message understanding were higher in task2.		Significant differences in attractiveness and completion time of the task1. Correlation: the more attractive the avatar, the shorter the completion time.	No real-time face tracking with more anthropomorphic avatars.
				Task2: Negotiation: survival on the moon exercise; sort objects from 1 to 15.				Measured the effects of avatars in virtual environments. There is a need to measure those effects in physical space to gain insights for humanoid robots' facial properties
(Jung et al., 2021)	Evaluation of task performance, presence, and attraction using a fully expressive avatar in collaborative VR	Realistic looking avatar: highly-expressive vs. low-expressive.	Within subject in VR	charades game playing scenario.	Participants interacting with highly expressive avatars felt more social presence and attraction and exhibited better task performance than those interacting with partners represented using low-expressive avatars	(Nowak & Biocca, 2003)	—	No real-time face tracking.

3 METHODS

The primary aim of this study is to determine which avatar representation would yield more positive social presence. More specifically, we are interested in whether increasing the anthropomorphism of robotic heads' faces by displaying truthful avatars of users would lead participants to feel a greater social presence towards their partner. Social presence refers to "the sense of being with another" [34]. It is also used to assess communicator's awareness of the presence of another person and access to other people's affective and cognitive states [120]. In general, greater social presence is associated with greater satisfaction with the communication medium.

We are interested in knowing the type of avatar representing the remote user that would be suitable for humanoid robot's faces. In order to investigate the impact of avatar visual characteristics, we need to determine the social presence associated with avatars. There have been numerous studies that investigated the users' social presence toward truthfulness of avatar face (look or does not look like remote user) in a virtual environment using VR headsets [21, 94, 58, 71, 31, 70, 72] as well as mixed-reality environments [57, 89, 22, 121, 23, 122, 73, 74]. Some studies favour truthful looking avatar [57, 31] and some showed that avatars that looked partially truthful reported more co-presence compared to their truthful counterpart [89, 70]. The lower presence score in the case of truthful avatars could be because they set up higher expectations, i.e. a mismatch between appearance and behavioural realism [79]. In addition, as per our knowledge, no studies use a real-time low latency facial tracking system (HTC VIVE Facial Tracker) to reflect users' expressions on avatars on robotic heads. Using such a system would give new insights into how participants perceive avatars. Therefore, it is needed to investigate social presence with low latency real-time facial tracking system.

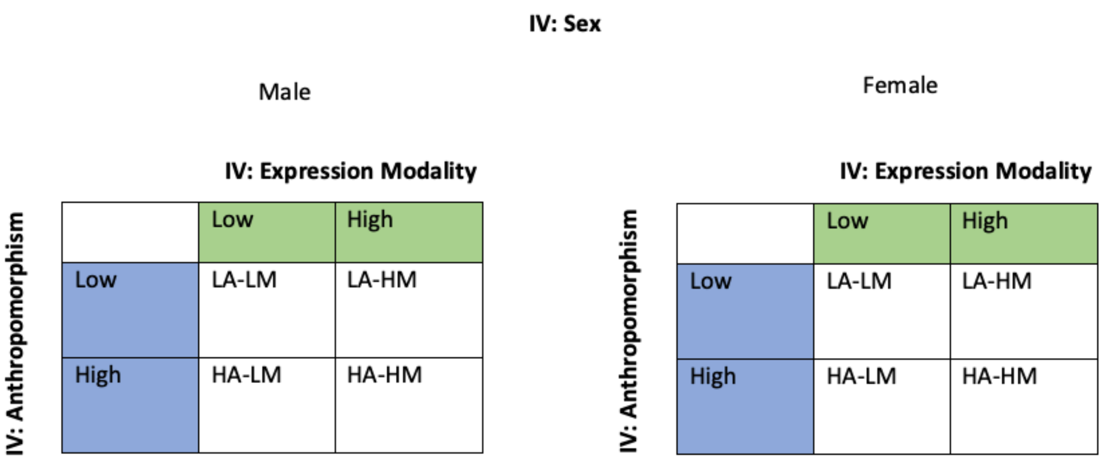


Figure 3.1: Study design for the avatars having two levels of Anthropomorphism, Expression Modality and sex

3.1 Study Design

The experiment is a 2x2x2 between-subject design using two factors (see Figure 3.1): (1) Truthfulness with two levels-(i)EVE- low anthropomorphic avatar (robotic face) or (ii) RPM high anthropomorphic avatar (stylised human face). (2) Expressiveness-(i)LM- low expressive (only eyes and mouth up-down) or (ii)HM- high expressive (with eye-gaze and mouth tracking. (3) Sex- (i) Male (ii) Female. The high truthful avatar will be a personalised one representing the participant.

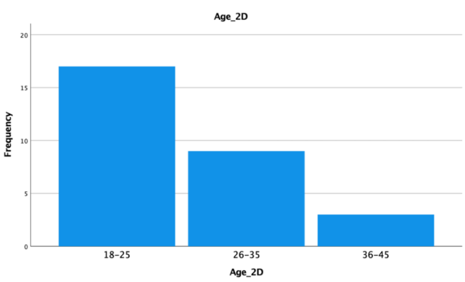
NOTE:

- Independent Variables:
  - EVE: The robotic avatar which represents low anthropomorphism
  - RPM: Human-like stylised avatar which represents high anthropomorphism
  - LM: Low Expression Modality
  - HM: High Expression Modality
- Dependent Variables:
  - COP: Perceived Copresence
  - PAE: Perceived attentional engagement
  - PEC: Perceived emotional contagion
  - PC: Perceived comprehension
  - PBI: Perceived behavioral interdependence
  - PREF: Preference

3.2 Participants

We measured the social presence of the participants who were interacting with avatars of their counterparts. All participants were assigned to same-sex dyads to account for potential sex effects. We recruited 34 dyads which are 68 participants in total, from the University of Twente campus. 41 Male and 27 Female. Out of 34 users interacting with avatars, 21 Males and 13 Females. Age ranging from 18 to 45. Two of the participants were excluded from the analysis as they reported knowing each other. In addition, one researcher who was familiar with the purpose of the experiment repeated the experiment to make up for the unavailability of recruited participants twice, and one greeted their partner in person before answering the questionnaire. This accounts for the exclusion of five participants from the analysis.We included a female participant despite being familiar with her counterpart to account for a better estimation of the mean in RPM-LM condition. Total 29 participants were taken into consideration. 18 Males and 11 Females. See the frequency distribution for the age in the Figure 3.2. Ethics approval was obtained before we began recruiting participants. The study was advertised through general emails send to university-wide mailing lists, social media posts, and flyers across University of Twente campus (see Appendix H). Participants were self-selected and compensated €5 Bol.com online shopping gift card for 45 minutes long study.

The pair of participants did not know each other prior to the experiment to avoid the possibility of any familiarity influencing the avatar's role during the conversation. All participants were assigned to a same-sex dyad to account for potential sex affects. One would be wearing the VR headset and seeing their partner on the immersive virtual screen. Another one would be



Age_2D

	N	%
18-25	17	25.4%
26-35	9	13.4%
36-45	3	4.5%

miro

Figure 3.2: Age frequency distribution

in physical space and see the avatar representation of their partner on a screen as a robotic head. The interaction between them will be asynchronous. Considering the limited scope of this project, we recruited seven dyads per condition, i.e. total of 56 participants. Although this number will not give statistically reliable results, it will hint at the desired outcomes.

3.3 Material

3.3.1 Task

Figure 3.4 shows the view of the participants interacting in VR and telepresence robot conditions.

In order to evaluate the effect of avatars' facial expression, we chose a task of solving a factual trivia quiz. Prior to entering the laboratory, the participants were told to play a fact-based quiz collaboratively. Participants were told that their partner is a real person in another physical location and would interact via this communication system. Only the user in VR condition can see the question on the bottom left corner of the immersive virtual screen (see 3.5 (c)). The instruction regarding the quiz: (1) The user in VR needs to convey the questions verbally to their partner. (2)To answer each question, both need to agree. (3) After an agreement, the participant in VR only can lock the answer commanding the voice assistant named "Quizzy" by calling "Quizzy", and the answer is selected. For example, "Quizzy, answer is ABC." It is necessary to say two keywords Quizzy and the chosen answer to lock the answer. If participants wish to change the answer, they can repeat the keywords accordingly. (4) To proceed to the next question, the users in VR need to say "next". (5) The time limit for the quiz sessions is 15 minutes. In this way, the quiz can be carried away. The participants were not informed about the true purpose of this task and will be told that the high score will matter. (see Appendix J for quiz questions and answers)

The overview of the setup can be seen in the Figure 3.5. The face of the participant in VR was getting tracked and reflected on the avatar. Other participant (partner) was conversing with the avatar representation. Only the user in VR can see the quiz questions and answer options (see Figure 3.6 for quiz and partner view setup) and can give a voice command to 'Quizzy' to select the agreed upon answer. Wizard of Oz technique was used for voice commands. The operator was controlling the quiz play on a tablet connected to the PC via AnyDesk [1] remote desktop application from the other side of the room while listening the conversation of participants.

[1] https://anydesk.com/en

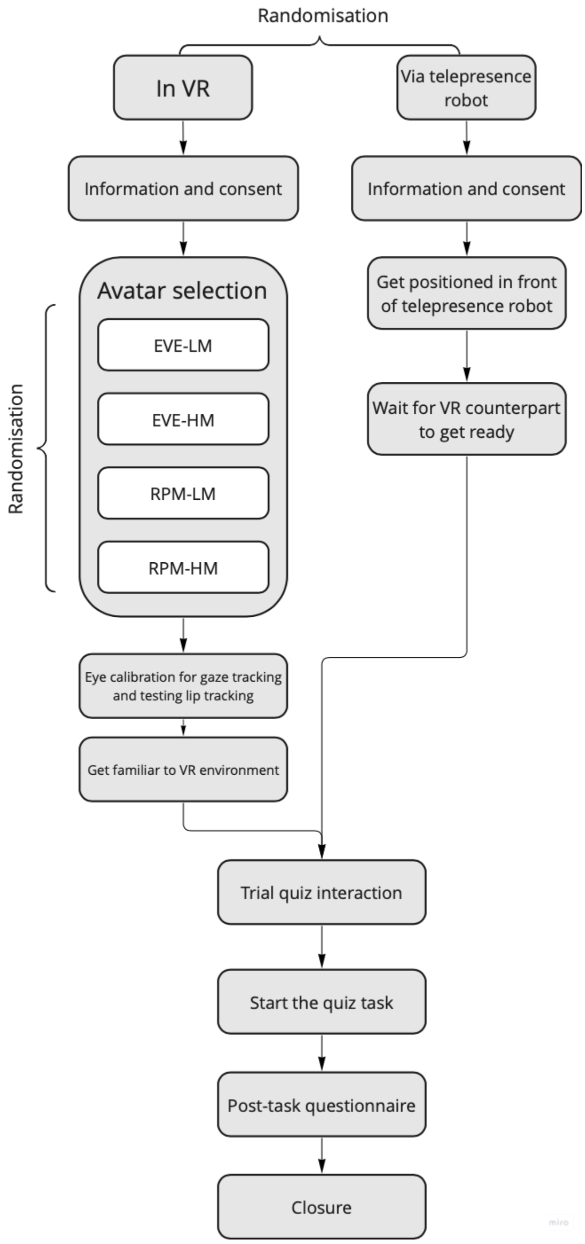


Figure 3.3: Illustration of the experimental procedure. There are two main levels of avatars: EVE- Low Anthropomorphic Robotic avatar and RPM- High Anthropomorphic Human avatar. Each of the avatars has two levels of expression, namely LM- Low Expressive Modality and HM- High Expressive Modality. This makes four types of avatars. The participant in VR will be randomly allotted any one of the four avatars. After the interaction task, the both the participants (in VR and their counterparts) filled out the Network Minds Social Presence questionnaire [36]

3.3.2 Hardware

We have used HTC VIVE Facial Tracker [2] to capture facial expressions and mouth movement with precision. It can track up to 38 facial movements with near-zero latency (sub-10 millisecond response time) accompanying voice audio. This facial tracker was combined with HTC VIVE

[2] https://www.vive.com/eu/accessory/facial-tracker/

Figure 3.4: The view of the participants interacting in: (a)telepresence robot condition and (b)VR condition

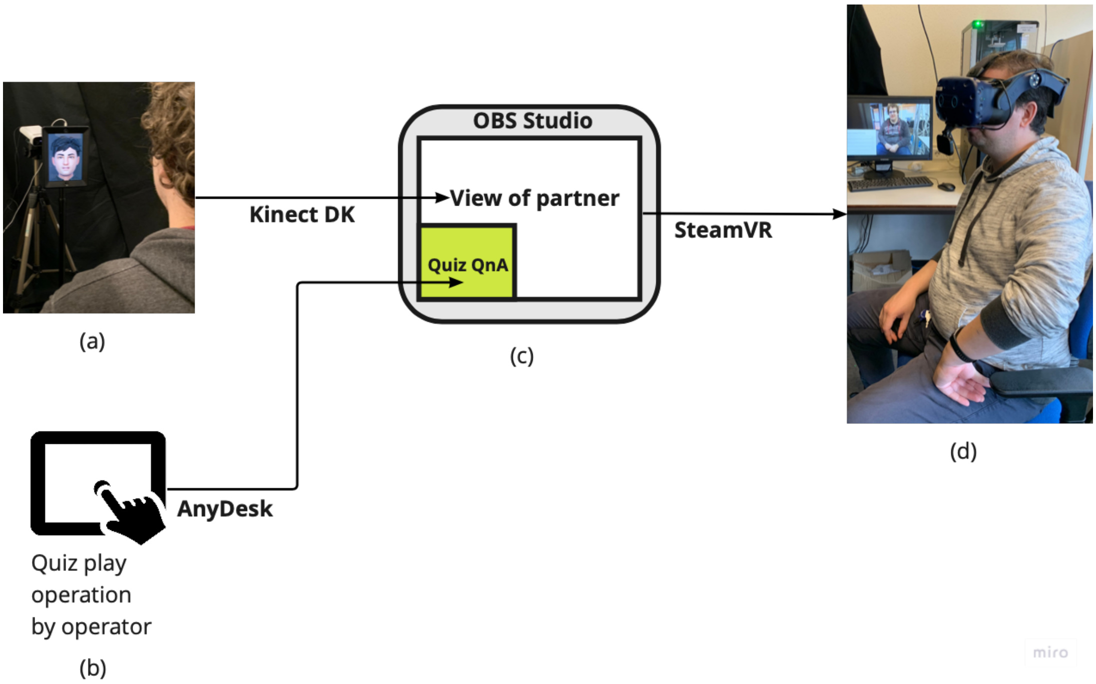


Figure 3.5: Collaborative Quiz Interaction Setup: (a) Participant interacting with avatar representation of partner via telepresence robot; Kinect DK (behind the screen) capturing the live video of the participant. (b) Quiz play controlled by the operator in the Wizard of Oz way as per the response from the participant in VR. (c) The video of capture of participant in (c) with the quiz game-play from tablet is merged with the help of OBS studio software. The view created in OBS studio is the same view seen by the participant in VR via SteamVR desktop view. (d) Participant in VR interacting and conveying the quiz questions and answers to his partner in physical space.

Pro Eye [3] which has precision eye-tracking to reflect eye-blinks and eye-gaze on avatars with gaze data output frequency of 120Hz [4]. This hardware requires a computer with the following

[3] https://www.vive.com/eu/product/vive-pro-eye/overview/
[4] https://developer.vive.com/resources/hardware-guides/vive-pro-eye-specs-user-guide/

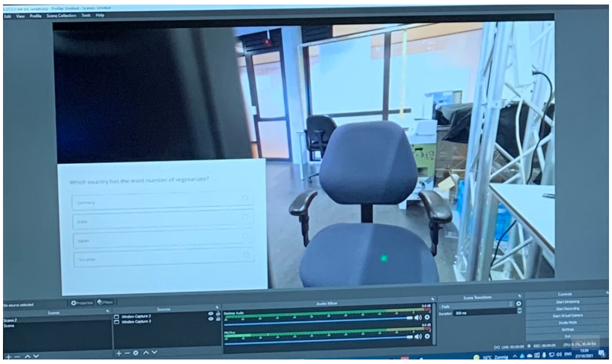


Figure 3.6: The setup of Quiz(on bottom left) and Partner view in OBS Studio

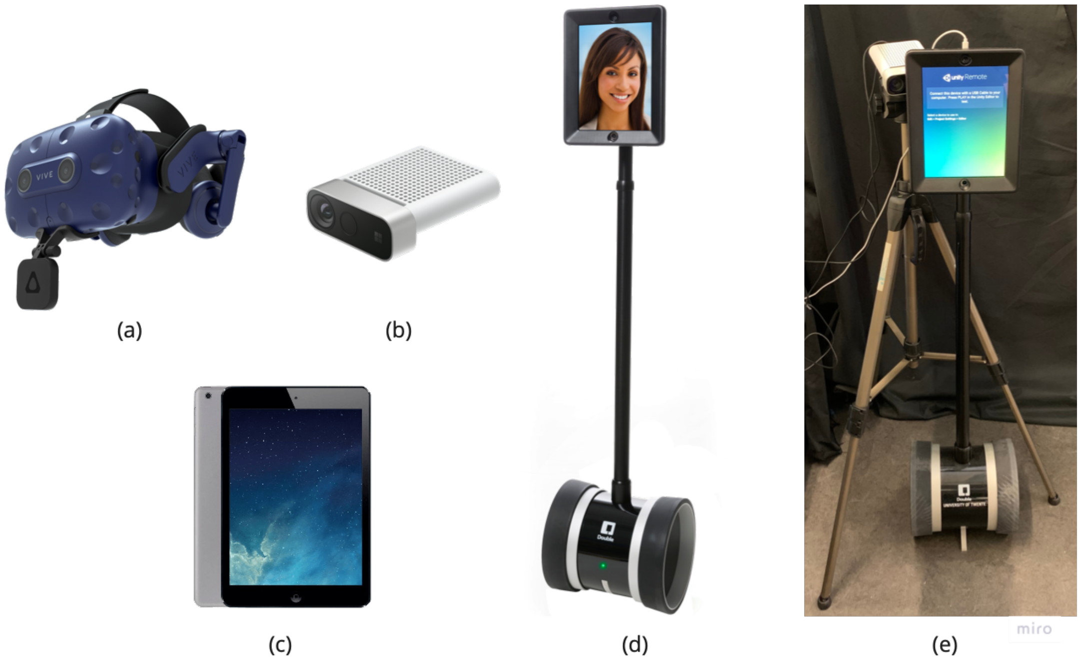


Figure 3.7: Hardware used: (a) HTC VIVE Pro Eye with Facial Tracker attached. (b) Microsoft Azure Kinect DK for live video capture. (c) iPad Air 1st Generation to display avatars as an Unity Remote output. (d) Double 2 telepresence robot with iPad mounted. (e) Our setup to display avatar of the user wearing VR HMD along with Kinect camera for video capture of the interactant.

specifications :

- **Processor:** Intel® Core™ i5-4590 or AMD FX™ 8350, equivalent or better.
- **Graphics:** NVIDIA® GeForce® GTX 970 or AMD Radeon™ R9 290 equivalent or better.
- **Memory:** 4 GB RAM or more.
- **Video out:** DisplayPort 1.2 or newer.
- **USB ports:** 1x USB 3.0 or newer port.
- **Operating system:** Windows® 7, Windows® 8.1 or later, Windows® 10. Upgrade to Windows® 10 for the best results with the dual front facing cameras.
- **SDK engine compatibility:** Unity, Unreal Engine

- **Eye and Facial Tracking SDK:** SRanipal [5]

Microsoft Azure Kinect DK [6]

3.4 Software

- Detailed description of the software used. - Unity with Unity Remote on iPad. - All the required packages. for e.g. OpenXR, XR plugin Management settings and stuffs. - SteamVR - SRanipal - RPM plugin

3.4.1 Avatar Facial Appearance and Expression

Avatars' form and behavioural are significant because they elicit the experience of being with another person. To determine which level of visual and behavioural fidelity representing the remote user evokes more social presence, we need contrasting conditions. In terms of appearance, the changing levels of anthropomorphism and behaviour (changing levels of facial expression should be evaluated). Figure 3.8 shows two anthropomorphism levels of avatars.

(a) EVE: Low Anthropomorphic avatar

(b) RPM (Ready Player Me):High Anthropomorphic avatar

Figure 3.8: Low and high level of anthropomorphic avatars

Facial expressions are necessary to convey our emotions effectively. It was discovered that when facial animation from one half of the face was removed from a realistic model, participants found this extremely noticeable. Furthermore, removing all eye motion was not regarded as a disturbing artefact [123]. Therefore, to investigate facial expressions' effects, it is necessary to test a range of expressiveness on avatars. This investigation will enable us to judge the appropriateness of a certain level of expressiveness given to avatars. To look into the effects of the level of expressions on the level of truthfulness, we will have two levels of facial expression modality:

- **low expressive avatar:** only mouth and eyes open-close (in real-time sync with users' facial expressions)
- **high expressive avatar:** tracking the real-time lip and cheek movements along with eye gaze movements

[5] https://developer.vive.com/resources/vive-sense/eye-and-facial-tracking-sdk/
[6] https://azure.microsoft.com/en-us/services/kinect-dk/overview

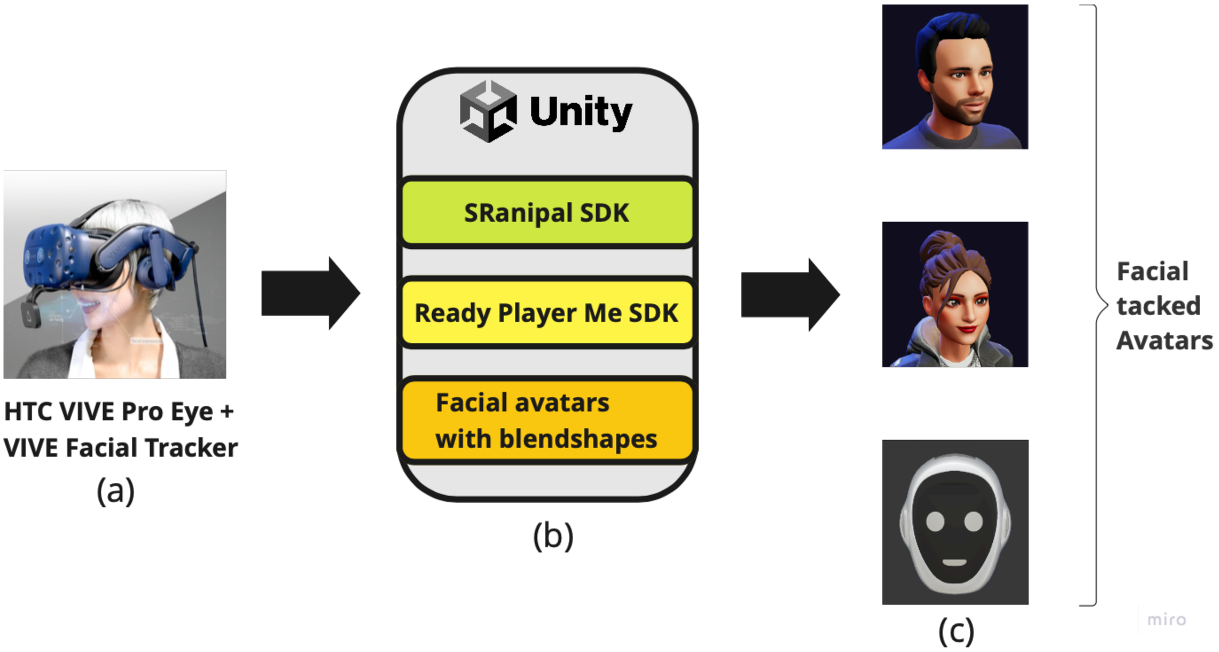


Figure 3.9: Overall architecture of the face tracking system: (a) Users facial expressions tracked by HTC VIVE Pro Eye (eye tracking) and HTC VIVE Facial Tracker (mouth tracking) (b) Integration with Unity: Software Development Kits (SDK) with facial avatars having blendshapes which enables movements of facial parts. (c) Generated real-time facial tracking enabled avatars.

3.5 Avatar Creation

3.8 illustrates two types of avatars used for this study. In this section we will discuss how these avatars are generated so that they are able to be used for real-time facial tracking system mention in the Figure 3.9.

3.5.1 Creation of EVE avatar

The following are the steps to create EVE avatar depicted in Figure 3.8: (1) The 3D model of EVE's head named 'head.obj' is retrieved from Halodis' GitHub repository [7]. (2) The eye blinking and mouth movement motion capabilities are created with the help of blenshapes/shape keys in Blender [8]. Shape keys are used to animate objects by deforming them into new shapes. The process is defined in the online manual of Blender [9] as well as the YouTube video demonstrating Blender character animation [10]. (3) Total 30 blendshapes were created: 5 for eyes, 25 for mouth (see Figure 3.10)

3.5.2 Creation of RPM avatar

The steps to create RPM avatar depicted in Figure 3.8 are mentioned on the Ready Player Me website [11]. The creation process allows to customise several features of avatar (for instance skin color, see Figure 3.11). See Figure 3.12 for some examples of personalised avatars created by the participants.

[7] https://github.com/Halodi/halodi-robot-models/find/main
[8] https://www.blender.org
[9] https://docs.blender.org/manual/en/latest/animation/shape$_{k}eys/introduction.html$
[10] https://www.youtube.com/watch?v=YDu6y$_{2}jFg0$
[11] https://support.readyplayer.me/hc/en-us/articles/360020887418-How-to-create-a-3D-avatar-with-Ready-Player-Me-

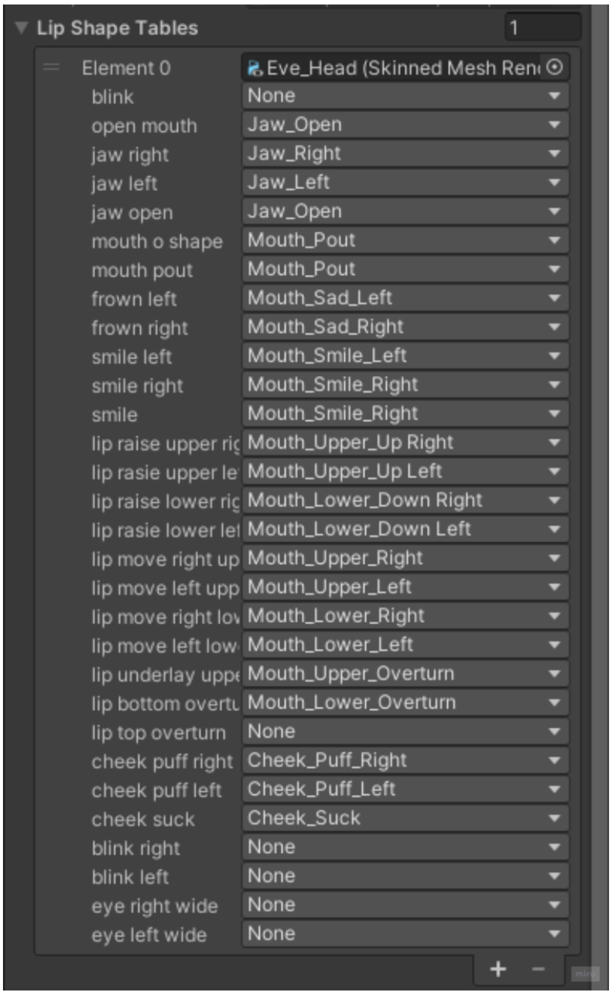


Figure 3.10: 30 blenshapes for EVE avatar

Figure 3.11: A screenshot of customising skin color of RPM avatar

- Steps the generate the avatars(with screenshots)

3.6 Software integration and Tracking of Facial Expressions

This section will explain the process of generating expressive avatars. The system includes Unity®along with two SDKs SRanipal and Ready Player Me. SRanipal helps to create a eye-

Figure 3.12: Examples of personlised RPM avatars

aware and lip-aware application with actual facial expressions on make-believe 3D avatars. ”anipal” stands for ”animation pal.” Ready Player Me Unity SDK is used to integrate avatar system in Unity®application. The overall architecture is depicted in the Figure 3.9. Along with SDKs we need avatars with blend shapes visemes to enable facial expression (see section 3.5).

3.6.1 Adding the required Scripts

Following are the steps to integrate avatars with blend shapes in Unity®:

1. Download Unity ®
2. Download SRanipal: Eye and Facial Tracking SDK from the VIVE Developers website [12]
3. Follow the steps to install and integrate with Unity mentioned in Appendix G.
4. Install XR plugin-in Management from Edit > Project Settings > XR Plug-in Management and then install OpenXR (see Figure 3.13)

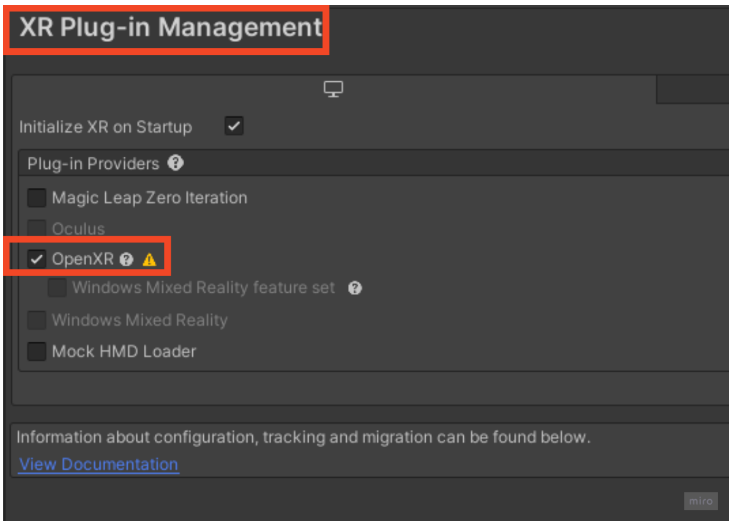


Figure 3.13: XR Plug-in Management in Unity®

[12]https://developer.vive.com/resources/vive-sense/eye-and-facial-tracking-sdk/

5. Run the scene called Lip Sample or Eye Sample from the SRanipal SDK.

6. In the scene edit the Main Camera and Mirror Camera Sample for displaying the face of the default avatar in an optimal way. We have used the value for Main Camera and Mirror Camera Sample mentioned in the Figure 3.14. The Mirror Camera Sample is the display which is visible after playing the scene.

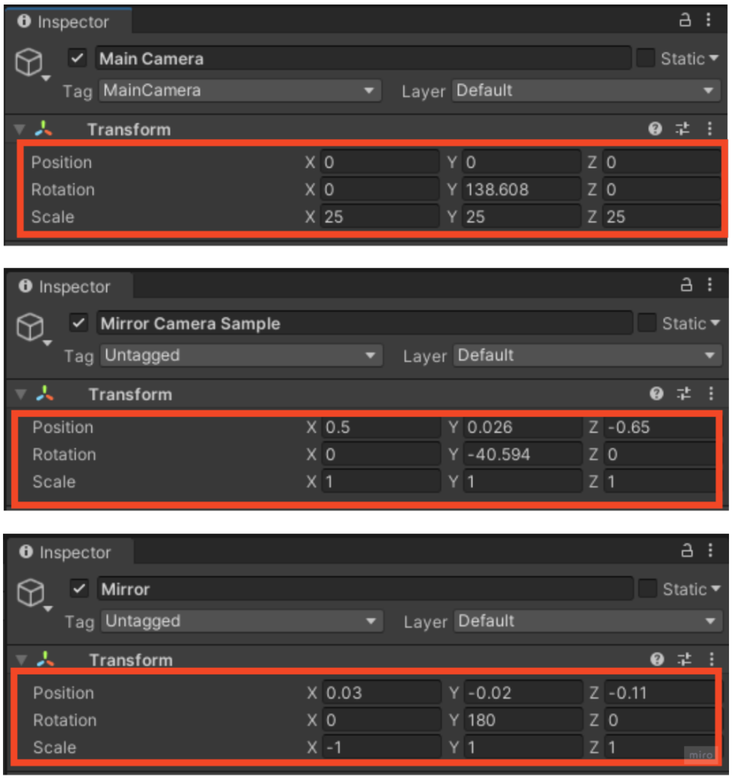


Figure 3.14: Position values of Main Camera and Mirror Camera Sample in the Scene of Unity®

7. After adjusting the value for Main Camera and Mirror Camera Sample the view was looking like the one in the bottom-left corner screen depicted in the Figure 3.15

8. Add component of 'SRanipal Eye Framework (Script)' if you have selected Lip Sample from the Scenes folder (vice versa if selected Eye Sample form the Scenes). Refer the screenshot Figure 3.16

9. After selecting the default avatar 'Avatar Shieh' (or any other avatar if available) add component 'S Ranipal Avatar Eye Sample (Script)'. Refer the screenshot Figure 3.17.

10. Select the 'Eyes Models' and 'Eye Shape Table' of the 'Avatar Shieh' to enable eye-tracking (blink and gaze)

11. 'Avatar Shieh' is ready. Click Play button. The avatar should tracking your eyes and mouth movement via HTC VIVE Pro Eye®HMD and VIVE Facial Tracker®and reflect them on 'Avatar Shieh'.

3.6.2 To import Ready Player Me avatars in Unity

After adding the required scripts of SRanipal SDK from the section 3.6.1 following are the steps to import Ready Player Me avatars:

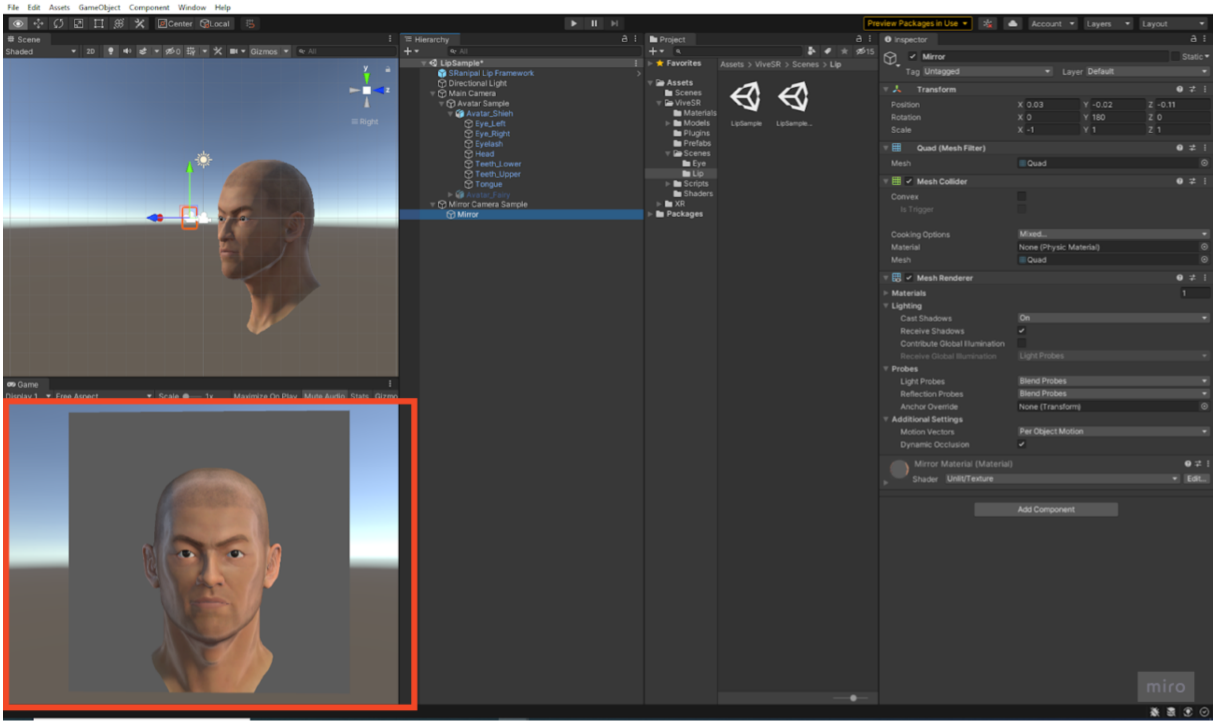


Figure 3.15: A screenshot of the game-view after adjusting the Mirror Camera Sample position values in the Scene of Unity®

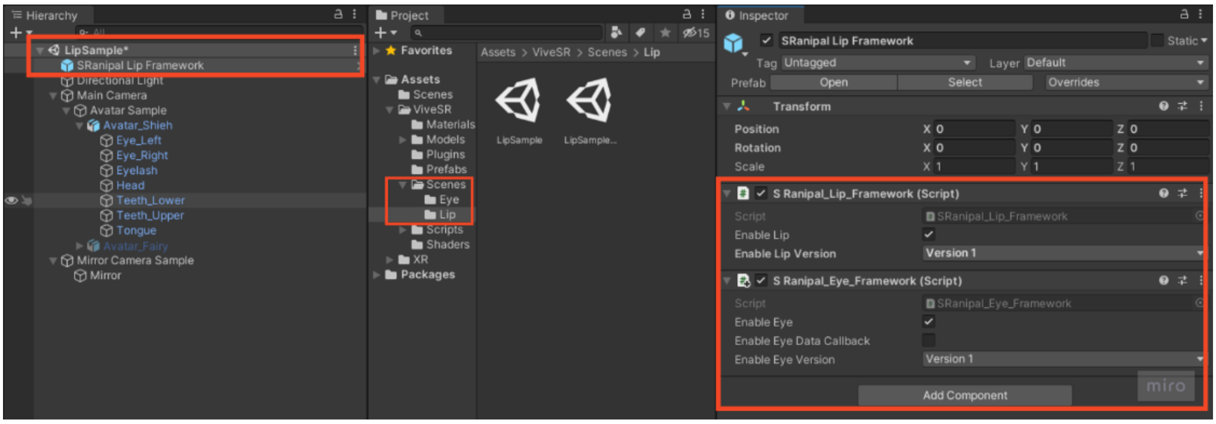


Figure 3.16: A screenshot depicting the selection of folder and scene from SRanipal SDK in Unity®

1. Download Ready Player Me SDK form the developer website[13]

2. Import the package from the top toolbar via Assets > Import Package > Custom Package. From the file browser select the SDK file and import. Hit 'OK' to start importing.

3. After creating the avatar by following steps in section 3.5.2, to import avatar get the link by clicking 'Copy .glb URL' (see Figure 3.18). Open the Ready Player Me SDK via Ready Player Me > Avatar Loader and paste the copied URL in the field mentioned in the Figure 3.19 and click 'Load Avatar'.

4. You will see the avatar in the bottom of the folder hierarchy of the Unity scene. Drag it into projects section to enable prefab editing and move it inside the folder 'Avatar Sample'

[13] https://docs.readyplayer.me/integration-guides/unity

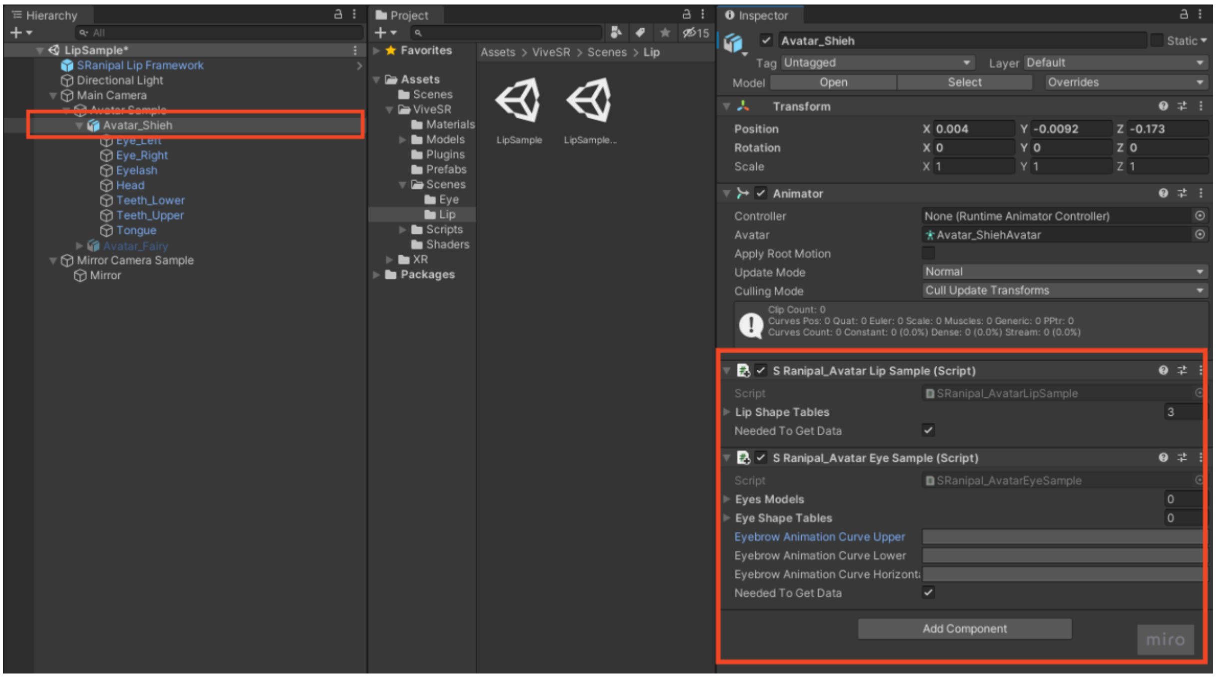


Figure 3.17: A screenshot showing scripts needs to be present for eye and lip tracking in the Scene of Unity®

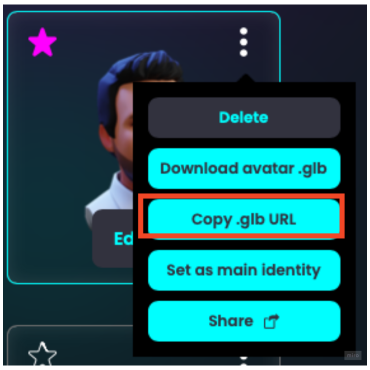


Figure 3.18: A screenshot of where to get .glb file link of the Ready Player Me avatar

shown in the Figure 3.20.

3.6.3 To set up facial expressions for the Ready Player Me avatars

In this section we will explain the steps to setup face tracking to the imported avatar in Unity.

Lip Tracking

After integrating the required scripts (from section 3.6.1) and importing the avatar by following the steps in section 3.6.2, following are the steps to set up lip tracking:

1. After adding the 'SRanipal Avatar Lip Sample (Script)' to the imported Avatar via the inspector, add two elements in the Lip Shape Table. Element 0 for lip movements and Element 1 for jaw movements (see Figure 3.22).
2. Select the avatars' head 3D model in those Elements and match the blend shapes of the avatars' face to the parameters of the SRanipal lip tracking (see Figure 3.22). For jaws,

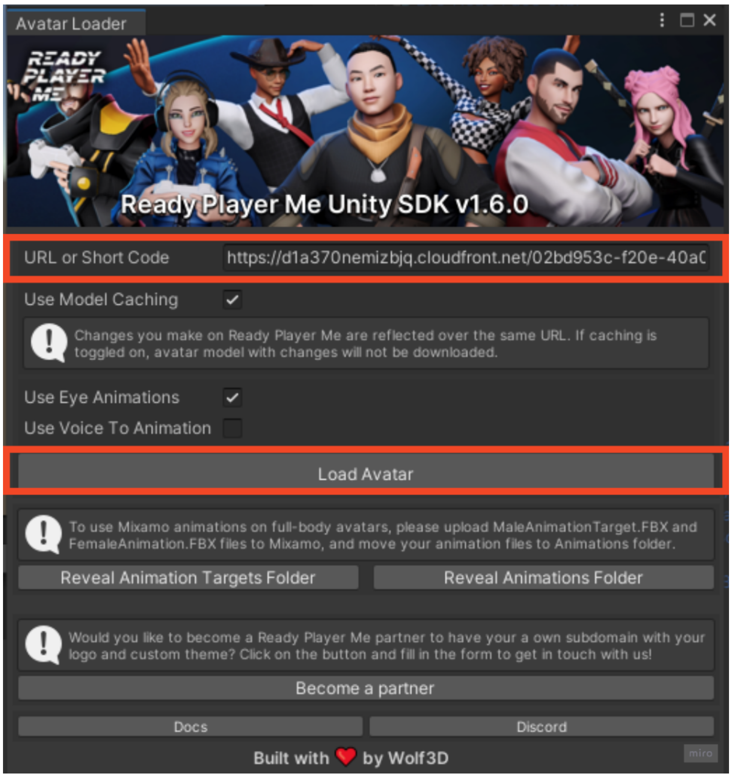


Figure 3.19: Screenshot of Ready Player Me Unity SDK version 1.6.0 window

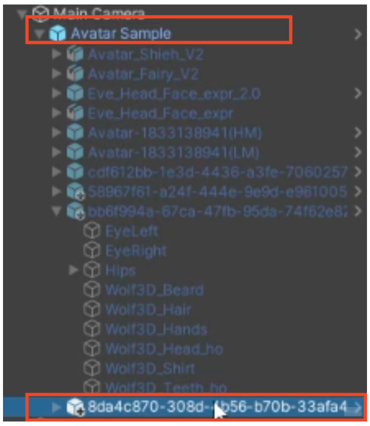


Figure 3.20: Placing of the imported avatars in the folder Avatar Sample

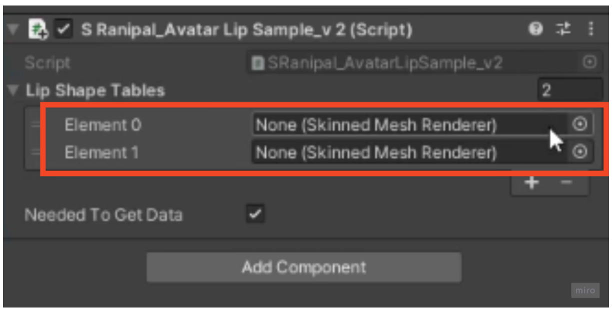


Figure 3.21: Two elements added to Lip Shape Table of SRanipal Lip Script

only select 'Jaw Open' parameter for mouthOpen and jawOpen blend shape (see Figure 3.23)

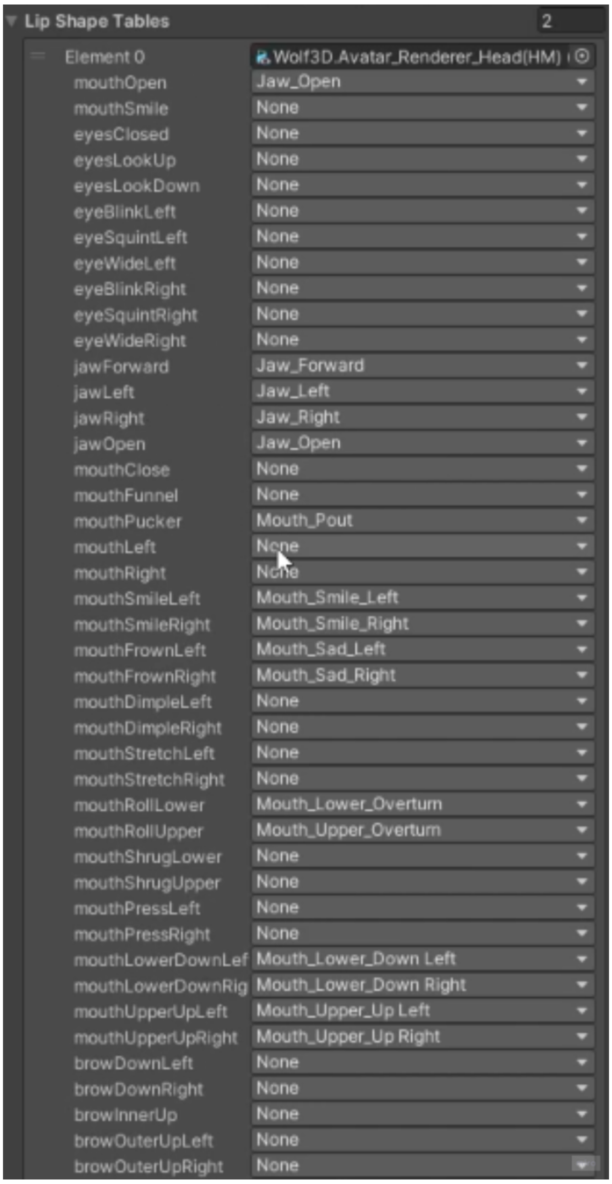


Figure 3.22: Blend Shapes table of the avatars'(on left side) face matched with the SRanipal lip tracking parameter(on right side)

3. Mouth tracking is ready for the avatar.

Eye Gaze and Blink Tracking

The SRanipal script assumes that the eye bones are pointing straight forward in the local z direction in the hierarchy. Since the ReadyPlayerMe .obj file had eye bones that were not pointing straight forward, two extra empty objects were added (Left Eye Pivot Right Eye Pivot) which contain the eye bones. These game objects should be rotated using data from the eye tracker.

After integrating the required scripts (from section 3.6.1) and importing the avatar by following the steps in section 3.6.2, following are the steps to set up eye tracking:

Eye blink tracking

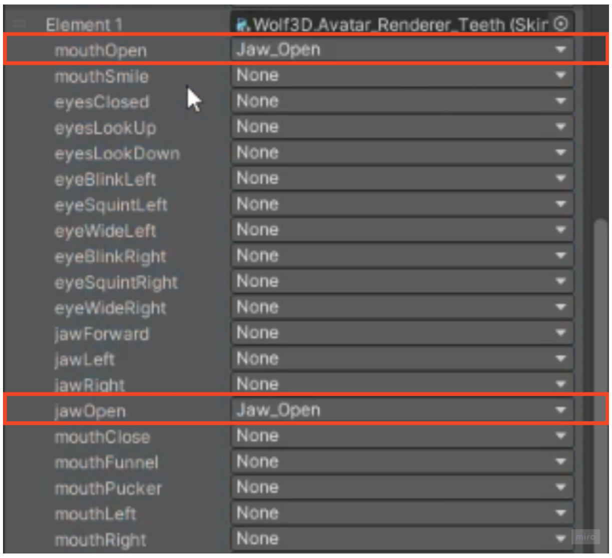


Figure 3.23: Blend Shapes table of the avatars'(on left side) face matched with the SRanipal lip tracking parameter(on right side)

1. After adding the 'SRanipal Avatar Eye Sample (Script)' to the imported Avatar via the inspector, add an elements in the Eye Shape Table (see top Figure 3.24).

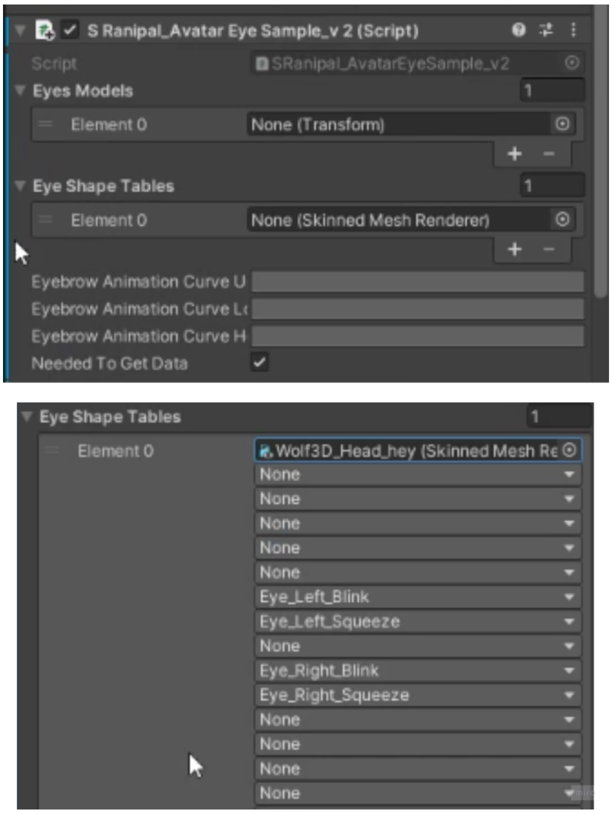


Figure 3.24: A screenshot of SRanipal Eye Tracking Script with eye tracking parameters

2. Select the avatars' head 3D model in those Elements and match the blend shapes of the avatars' face to the parameters of the SRanipal eye tracking. (see bottom Figure 3.24)

Eye Gaze Tracking

1. After importing the avatar in the Unity Scene (refer section **??** for importing Ready Player Me avatars), drag it into projects section to enable prefab editing and move it inside the folder 'Avatar Sample' shown in the Figure 3.20.

2. Select the avatar model > Right click and and select Prefab > Select Open Asset in Context (see Figure 3.25)

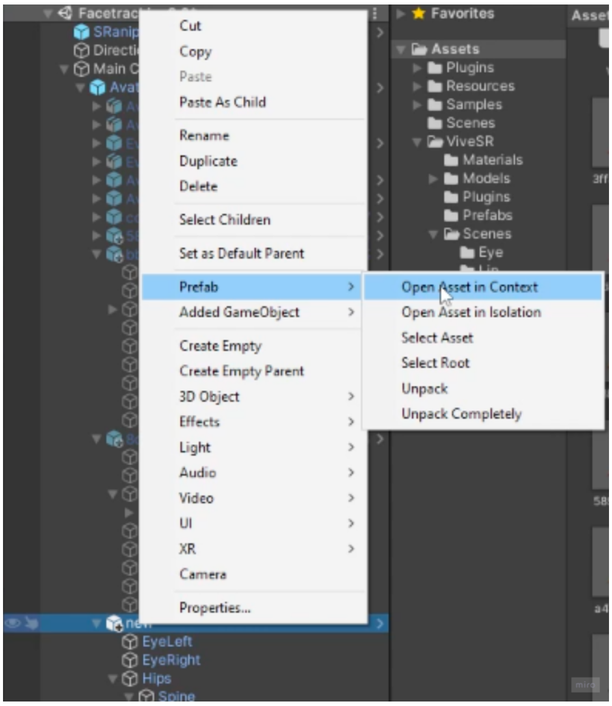


Figure 3.25: A screenshot of selecting Ready Player Me avatars' prefabrication and asset to edit

3. Create two empty object in 'Head' asset of the avatar: Right click on Head > Create Empty (see Figure 3.26) and rename them 'Left Eye Pivot' and 'Right Eye Pivot'.

4. Copy the positions of the 'LeftEye' and 'RightEye' to the 'Left Eye Pivot' and 'Right Eye Pivot'. Then move the asset 'LeftEye' inside 'Left Eye Pivot' and 'RightEye' inside 'Right Eye Pivot'. The structure should look like the one in Figure 3.27.

5. Now change the Rotation value for X-axis of 'Left Eye' and 'Right Eye' from -88.751 to -120. In the game view initially the avatar will look like the eyes rolled up (see Figure 3.28)

6. Add the 'Left Eye Pivot' and 'Right Eye Pivot' in the Eye Models of SRanipal Script as indicated in the figure 3.29.

7. Press the play button in Unity and now the avatar is ready to reflect your eye gaze. Figure 3.30 shows the users' eye gaze reflected upon avatar where user is looking at the left side and avatar is looking at right side.

3.6.4 Creating Low and High Expressive avatars

High Anthropomorphic and High Expressive avatar (RPM-HM) The procedure mentioned in section 3.6.3.

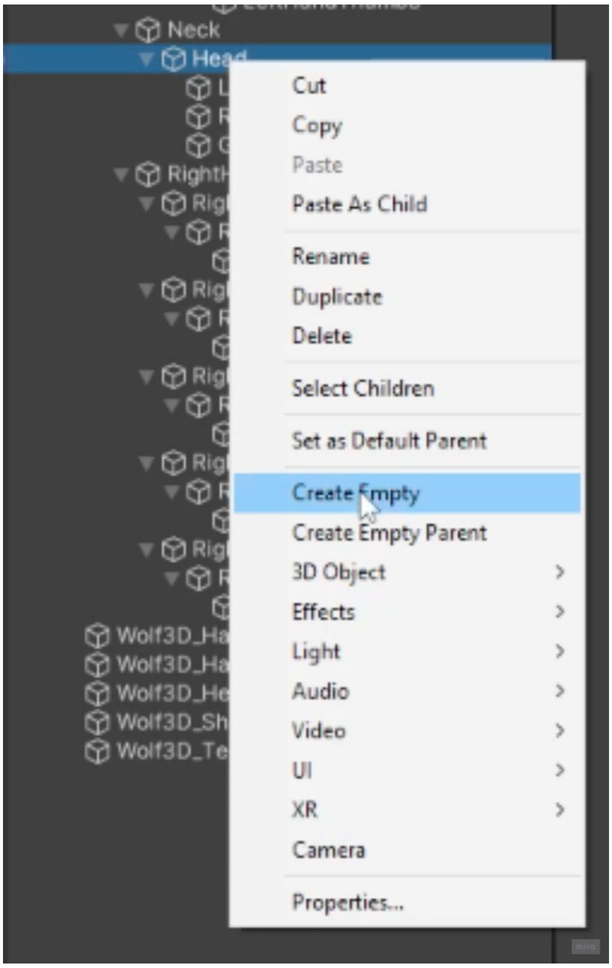


Figure 3.26: A screenshot of creating Empty Object in an asset of avatar

Figure 3.27: Asset folder structure of eyes to enable gaze tracking

High Anthropomorphic and Low Expressive avatar (RPM-LM) The steps are the same as mentioned in the section 3.6.3 except that only 'Jaw Open' parameter is set in 'mouthOpen' and 'jawOpen' blend shapes (see Figure 3.22 for blend shapes). For eyes, the steps are same as section 3.6.3. No eye gaze was enabled in this case.

High Anthropomorphic and Low Expressive avatar (EVE-HM) After creating the avatar by following the steps in section 3.5.1, import it in the Assets section of the Unity by drag and drop. Make sure the avatar is in the folder named 'Avatar Sample' as shown in the figure 3.20. The steps for lip tracking is same as section 3.6.3 except there is no need to add another element for jaw movement. The steps for eye blink tracking is also same as section 3.6.3. There is no

Figure 3.28: A screenshot of Unity Inspector and initial Game view showing the changed X-axis Rotation for the eyes of avatar.

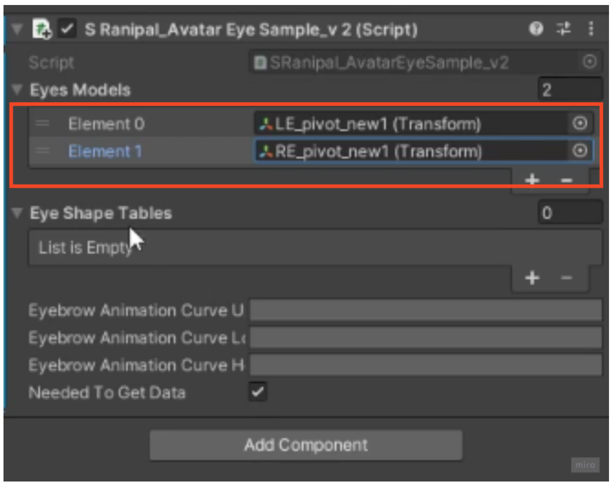


Figure 3.29: A screenshot of SRanipal Avatar Eye Script where the eyes model are added.

need to set up eye gaze in this case.

High Anthropomorphic and Low Expressive avatar (EVE-LM) The procedure is same as for creating EVE-HM except that only 'Jaw Open' parameter is set in 'open mouth' and 'jaw open' blend shapes (see figure 3.10 for EVEs' blend shapes).

3.6.5 Telepresence Robot Face

To show the face-tracked-expressive avatar on screen as a robots' face, telepresence robot Double 2 [14] was used. Double 2 has is only compatible with iPad, which acts as the face of the robot representing remote person. For our purpose, we can connect iPad to the Unity engine

[14] https://www.doublerobotics.com/double2.html

Figure 3.30: A screenshot of the game play view where the eye-gaze is tracked and avatar is looking at right side.

where the face-tracking avatar system is running to display the avatar on it. Unity Remote App needs to be installed to run Unity project in Play Mode from the Unity Editor. The steps to run has been mentioned in the Unity Remote Documentation [15]

3.7 Procedure

An overview of overall experimental procedure is illustrated in figure 3.3

One of the main challenges is tracking human faces and eyes in VR Headset, which occlude a large portion of the face. Efforts have been made to track and classify facial expression using machine learning in order to create an expressive photorealistic avatar [124, 125]. The motive is to read facial intentions and emotions in real-time. Photorealistic avatars have the potential of having the uncanny valley phenomenon [42]. So, it is beneficial to reflect facial expressions on stylised avatars.

Each session began with pairs of participants arriving at the laboratory at around the same time. The participants would be randomly assigned to the VR or telepresence robot conditions (see section 3.6.4 for the details of all 4 conditions). After signing the informed consent form, the participant in Avatar condition will be asked to be seated while setting up the avatar and VR setup for VR condition.

In RPM condition, the participant for VR condition were asked to create their personlised avatar from Ready Player Me platform [16]. The created avatar was enabled for face-tracking to reflect users' facial movements and expressions (see section 3.6.3). After wearing the VR headset, the system initiates eye calibration so that users can see the virtual environment clearly and calibrate their eye gaze to achieve eye-tracking accuracy. Then, the user previewed their facially tracked personalised avatar to make sure everything is working as expected. Later on, the user

[15]https://docs.unity3d.com/Manual/UnityRemote5.html
[16]https://readyplayer.me

can see their partner on the immersive virtual screen. At the same time, their partner can also see the avatar on the screen in front. In LM conditions (for RPM and EVE), the avatar reflects only eye blinks and mouth up-down movements. However, in EVEs' condition, the participants cannot choose their representation and will be fixed as a robotic avatar. For full instructions and details of the four conditions of avatar representation, see section 3.6.4.

The pair asked to solve the quiz collaboratively for 15 minutes. After coming to a common conclusion, only person in VR can give a voice command to answer the question. For more details regarding quiz setup, see section 3.3.1.

After the end of quiz session, both the participants will be asked to fill up the social presence questionnaire on a computer via *Qualtrics* [17] and the preference rating of avatar independently. Compensation in the form of a 5€ gift card will be handed as a token of thanks and goodbye. The study took approximately 35 minutes, 10 minutes for getting familiar with the setup, such as getting comfortable with VR and eye-gaze calibration for the user in VR, 15 minutes were spent on the quiz task, 5 minutes for filling the questionnaire and 5 minutes to debrief participants.

3.8 Data analysis

3.8.1 Testing assumptions for 3-way ANOVA

We are using three-way ANOVA because this study follows a between-subject design. It is used to determine if an interaction effect exists between three independent variables on a continuous dependent variable (i.e., if a three-way interaction exists). When the influence of one independent variable on a dependent variable varies depending on the levels of the other independent variables, this is known as an interaction effect. In other words, the impact of one independent variable on a dependent variable is influenced by the levels of the other independent variables. Furthermore, we would be using three-way ANOVA six times as we have six dependent variables namely *copresence, perceived attentional engagement, perceived emptional contagion, perceived comprehension, perceived behavioral interdependence and aggregated social presence*. Aggregated Social Presence score aggregates all the five sub-scales. In order to run a three-way ANOVA, six assumptions need to be considered. We will see how these assumptions are met:

- Assumption 1: One dependent variable that is measured at the continuous level (i.e., the interval or ratio level). We are considering the means of the subscales: COP, PAE, PEC, PC, PBI, AggSP and preference as continuous levels.
- Assumption 2: Three independent variables where each independent variable consists of two or more categorical, independent groups. We have three independent variables with two categorical independent groups: Anthropomorphism (EVE and RPM), Expression Modality (LM and HM) and sex (Male and Female).
- Assumption 3: Independence of observations means that there is no relationship between the observations in each group of the independent variable or between the groups themselves. This study follows a between-subject design and has no relationship between the observations. Moreover, amongst the dyad, we consider the participants interacting with the avatar representation of their counterpart, which satisfies the condition of independence.

[17] https://www.qualtrics.com/uk/?rid=ipprevsite=ennewsite=ukgeo=NLgeomatch=uk

- Assumption 4: No significant outliers in any design cell. There we no significant outliers in the dataset.
- Assumption 5: Dependent variable should be approximately normally distributed for each design cell. This assumption is necessary for statistical significance testing. However, the three-way ANOVA is considered 'robust' to violation of normality. From the Shapiro-Wilk test of normality, all the dependent variables are normally distributed except for the groups: EVE-LM-Male for PC (perceived comprehension) p = 0.027, EVE-HM-Male for AggSP (Aggregated social presence) p < .001, RPM-LM-Male p = 0.020 and EVE-HM-Female p < .001 for PC (perceived comprehension). For some conditions, the sample size was limited and therefore not sufficient to test normality: EVE-LM-Female, RPM-LM-Female, RPM-HM-Male, where the sample size was 2. See B.1
- Assumption 6: Homogeneity of variances. The variance of the dependent variable should be equal in each cell of the design. If the variances are unequal, this can affect the Type I error rate (i.e., this might lead to falsely rejecting the null hypothesis) by determining if there are equal variances (called homogeneity of variances) in all combinations of groups of the three independent variables (i.e for all 12 cells of the design). In this case, the variances of dependent variables: copresence (COP), perceived attentional engagement (PAE), perceived emotional contagion (PEC), perceived comprehension (PC) and perceived behavioural interdependence (PBI) and aggregated perceived social presence (AggSP), for all groups of anthropomorphism, expression modality, and sex need to be equal.

  Levene's Test of Equality of Error Variances is used to test this assumption of homogeneity of variances. The assumption of homogeneity of variances was violated for COP, PAE, PC, PBI and PREF p = .020, .028, .003, .011, and .034 (See the table of Levene's Test of Equality of Error Variances Appendix C)

3.9 Measures

After the task was completed, the participants answered Harms and Biocca's Social Presence (HSP) questionnaires [36]. The participants answered the questions regarding the sub-scales of (1) Co-presence (2) Perceived attentional engagement (3) Perceived emotional contagion (4) Perceived comprehension (5) Perceived behavioral interdependence. We also asked participants about their preference to interact with the given system.

3.9.1 Copresence

COP which stands for copresence is "The degree to which the observer believes he/she is not alone and secluded, their level of peripherally or focally awareness of the other, and their sense of the degree to which the other is peripherally or focally aware of them." [36]. Participants rated their level of agreement with statements like, "I often felt as if (my partner) and I were in the same (room) together" and "I think (my partner) often felt as if we were in the same room together." on a 7 point Likert scale (1 = Strongly Disagree, 7 = Strongly Disagree). It consisted of eight questions. The scale had a high level of internal consistency, as determined by a Cronbach's alpha of .871. For complete items, refer to Appendix A.1.

3.9.2 Perceived Attentional Engagement

PAE which stands for Perceived attentional engagement ”seek to measure the degree to which the users report attention to the other, and the degree to which they perceive the other’s level of attention to them.” [69]. Participants rated their level of agreement with statements like, ”I paid close attention to (my partner).” and ”(My partner) paid close attention to me” on a 7 point Likert scale (1 = Strongly Disagree, 7 = Strongly Disagree). It consisted of six questions. The scale had a questionable level of internal consistency, as determined by a Cronbach’s alpha of .665. For complete items, refer to Appendix A.1.

3.9.3 Perceived Emotional Contagion

PEC which stands for Perceived emotional contagion self-report item measures ”the transfer of emotional states from the user to the other” [69]. Participants rated their level of agreement with statements like, ”When I was happy, (my partner) tended to be happy” and ”When (my partner) was happy, I tended to be happy.” on a 7 point Likert scale (1 = Strongly Disagree, 7 = Strongly Disagree) It consisted of eight questions. The scale had an acceptable level of internal consistency, as determined by a Cronbach’s alpha of .779. For complete items, refer to Appendix A.1

3.9.4 Perceived Comprehension

PC which stands for Perceived comprehension self-report items measures the level of shared attention about certain communication topic that arises while conversing with the mediated other [69]. Participants rated their level of agreement with statements like, ”I was able to communicate my intentions clearly to my partner” and ”My partner was able to communicate their intentions clearly to me.” on a 7 point Likert scale (1 = Strongly Disagree, 7 = Strongly Disagree) It consisted of six questions. The scale had an acceptable level of internal consistency, as determined by a Cronbach’s alpha of .797. For complete items, refer to Appendix A.1

3.9.5 Perceived Behavioral Interdependence

PBI which stands for Perceived behavioral interdependence self-report items measures the level ”to which the observer believes his/her actions are interdependent, connected to, or responsive to the other and the perceived responsiveness of the other to the observer’s actions.” [36]. Participants rated their level of agreement with statements like, ”My actions were often dependent on my partner’s actions.” and ”My partner’s actions were often dependent on my actions.” on a 7 point Likert scale (1 = Strongly Disagree, 7 = Strongly Disagree) It consisted of six questions. The scale had an acceptable level of internal consistency, as determined by a Cronbach’s alpha of .773. For complete items, refer to Appendix A.1

3.9.6 Aggregated Social Presence

AggSP which stands for Aggregated Social Presence is the average of all HSP sub-scales scores. It consisted of total 34 questions. The scale had a good level of internal consistency, as determined by a Cronbach’s alpha of .882.

3.9.7 User Preference

To know how much the participants would prefer to interact with the given system by asking a question: ”How likely you would choose this mode of interaction compared to the virtual interaction you are used to?” on a 7-point Likert scale (from ’extremely unlikely’ to extremely likely’).

4 RESULTS

4.1 Interpreting Results

The primary goal of running a three-way ANOVA is to determine whether there is a three-way interaction between three independent variables. When one or more simple two-way exchanges are different, it is referred to as a three-way interaction. Here we have a three-way interaction between anthropomorphism, expression modality and sex (anthropomorphism*expressionMod*sex). We are also interested in the simple two-way interaction between the expression modality and sex as well as anthropomorphism and sex at different levels of sex (i.e., ”males” and ”females”). In another way, is the effect of interaction between the anthropomorphism and its expression modality on perceived COP, PAE, PEC, PC, PBI and AggSP affected by whether the participant was a male or female?.

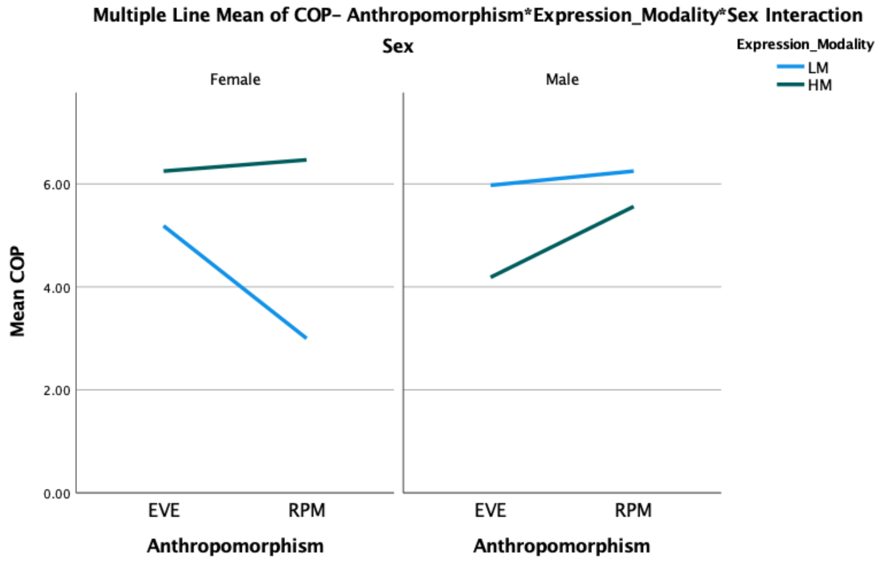
Furthermore, we are also looking for statistically significant two-way interactions. A two-way interaction ’ignores’ the influence of a third factor. There are three two-way interactions possible here: Anthropmorphism*ExpressionModality, Anthropmorphism*sex, ExpressionModality*sex.

If there are statistically significant two-way interactions, we have to know which of the three possible two-way interactions are statistically significant; simple main effects determine the effect of one of the factors at the values of the other factor and vice versa (these two factors being the factors involved in the statistically significant interaction).

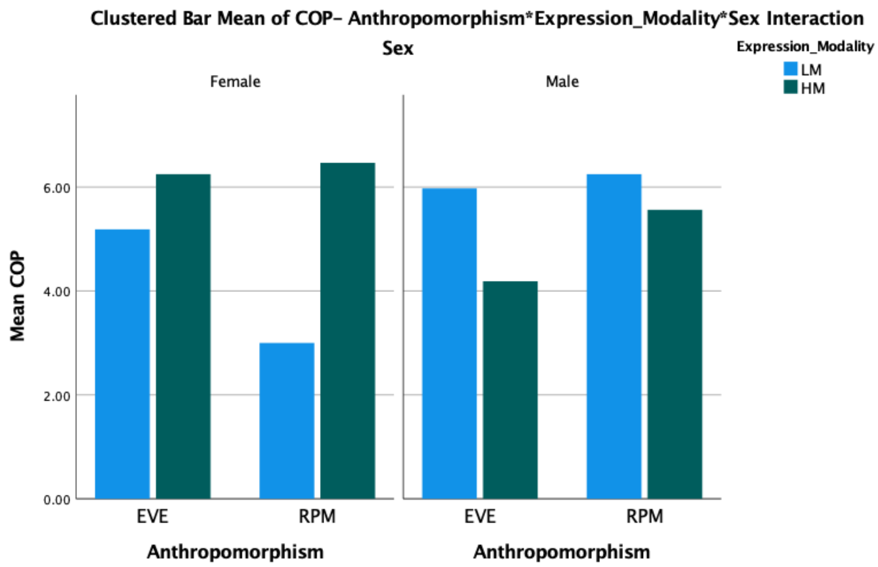
4.1.1 Copresence

A three-way interaction tests whether the simple two-way (Anthropomorphism*ExpressionModality) interactions differ between the levels of sex (i.e., differ for males and females). This is visualised by a profile plot, as shown in the Figure 4.1a.

From Figure 4.1a we can see a simple two-way (Anthropomorphism*ExpressionModality) interaction between males and females. The effect of COP appears to be different depending on whether the avatar is at ’low’ or ’high’ level of expression modality. The two simple two-way interaction between male and female is different for Anthropomorphism and Expression Modality. The Tests of Between-Subject Effects table (4.2) shows that there was a statistically significant Anthropmorphism*ExpressionModality interaction $F(1,21) = 5.147$, $p = .034$, Anthropomorphism*sex interaction $F(1,21) = 5.483$, $p = .029$ and ExpressionModality*sex interaction $F(1,21) = 20.551$, $p = <.001$. However, there was no statistically significant three-way interaction between sex $F(1, 21) = .714$, $p = .408$. The graph and statistics indicates that females perceived HM avatars more co-present than LM. In contrast, males perceived LM avatars more co-present than females. It can also be seen that the copresense rating for LM fell to a noticeable degree from EVE to RPM for females which is opposite in the case of males. For HM, although females rated higher copresence overall, the rating increased from EVE to RPM for both males and females.



(a) Multiple Line Graph



(b) Clustered Bar Graph

Figure 4.1: Profile plots for Copresence showing three-way interaction between three independent variables: Anthropomorphism, Expression Modality and sex

For Anthropomorphism*ExpressionModality interaction, the simple main effect of expression modality on mean COP for RPM was statistically significant ($F(1, 21) = 6.222$, $p = .021$, but not for EVE, $F(1, 21) = .459$, $p = .506$ (see figure 4.3). All pairwise comparisons were Bonferroni adjusted. For RPM, COP was $4.625 \pm .379$ in the LM group and $6.061 \pm .409$ in the HM group, a statistically significance difference of 1.391 (95% CI, .231 to 2.550), $p = .021$. There was no statistically significant difference between EVE and RPM groups for expression modality, for LM, $F(1,21) = 3.052$, $p = .095$, for HM, $F(1,21) = 2.134$, $p = .159$. Figure 4.4 shows the visual representation of the interaction. It can be seen that RPM-LM avatars' copresence were perceived significantly less than RPM-HM avatars.

Tests of Between-Subjects Effects

Dependent Variable: COP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29.790[a]	7	4.256	4.768	.002
Intercept	687.097	1	687.097	769.837	<.001
Anthropomorphism	.038	1	.038	.043	.839
Expression_Modality	1.580	1	1.580	1.770	.198
Sex	.427	1	.427	.478	.497
Anthropomorphism * Expression_Modality	4.594	1	4.594	5.147	.034
Anthropomorphism * Sex	4.893	1	4.893	5.483	.029
Expression_Modality * Sex	18.342	1	18.342	20.551	<.001
Anthropomorphism * Expression_Modality * Sex	.638	1	.638	.714	.408
Error	18.743	21	.893		
Total	959.094	29			
Corrected Total	48.533	28			

a. R Squared = .614 (Adjusted R Squared = .485)

Figure 4.2: The results of 3-way ANOVA showing between-subject effects on Copresence

Pairwise Comparisons

Dependent Variable: COP

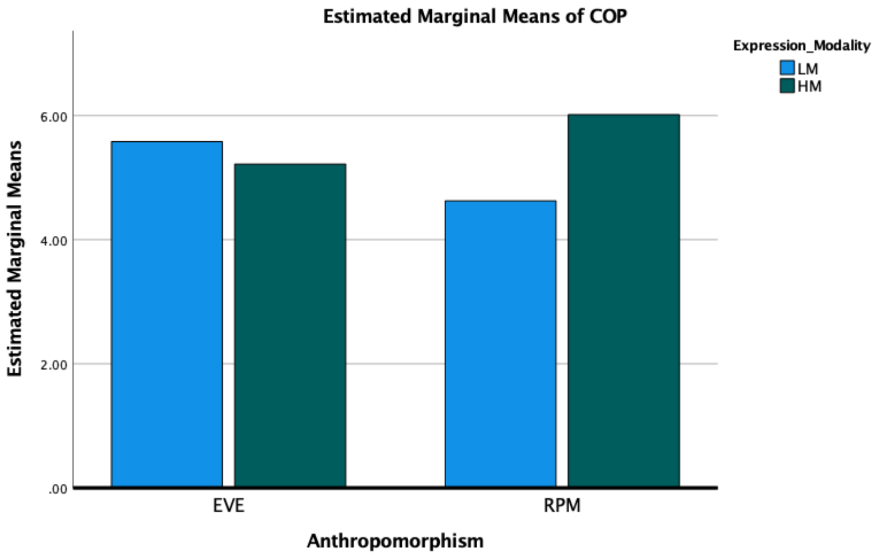
Anthropomorphism	(I) Expression_Modality	(J) Expression_Modality	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
EVE	LM	HM	.363	.535	.506	-.750	1.475
	HM	LM	-.363	.535	.506	-1.475	.750
RPM	LM	HM	-1.391*	.557	.021	-2.550	-.231
	HM	LM	1.391*	.557	.021	.231	2.550

Based on estimated marginal means

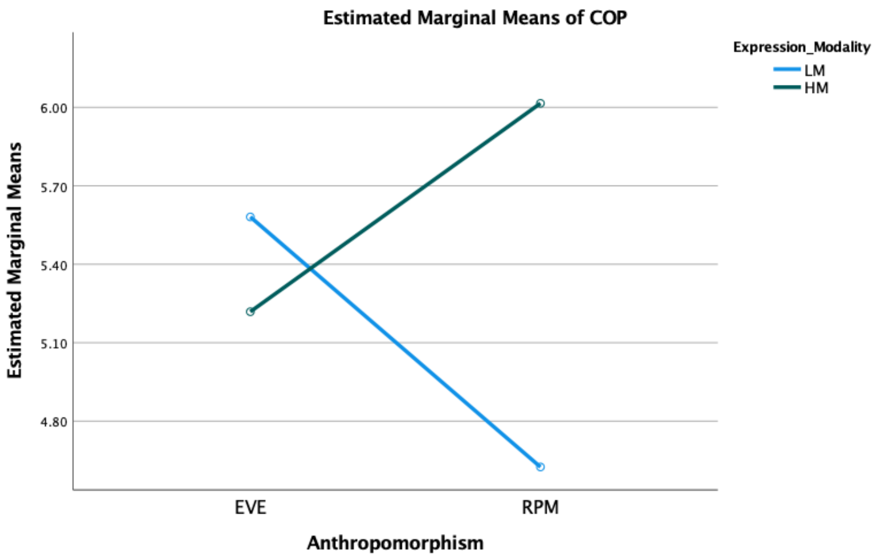
*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Figure 4.3: The results simple main effect of Expression Modality for Anthropomorphism ignoring the influence of sex



(a) Clustered Bar Graph



(b) Multiple Line Graph

Figure 4.4: Interaction between Anthropomorphism and Expression Modality ignoring the influence of sex factor

Pairwise Comparisons

Dependent Variable: COP

Anthropomorphism	(I) Sex	(J) Sex	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
EVE	Female	Male	.637	.535	.247	-.475	1.750
	Male	Female	-.637	.535	.247	-1.750	.475
RPM	Female	Male	-1.172*	.557	.048	-2.331	-.013
	Male	Female	1.172*	.557	.048	.013	2.331

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Figure 4.5: The results simple main effect of sex for Anthropomorphism ignoring the influence of Expression Modality

Pairwise Comparisons

Dependent Variable: COP

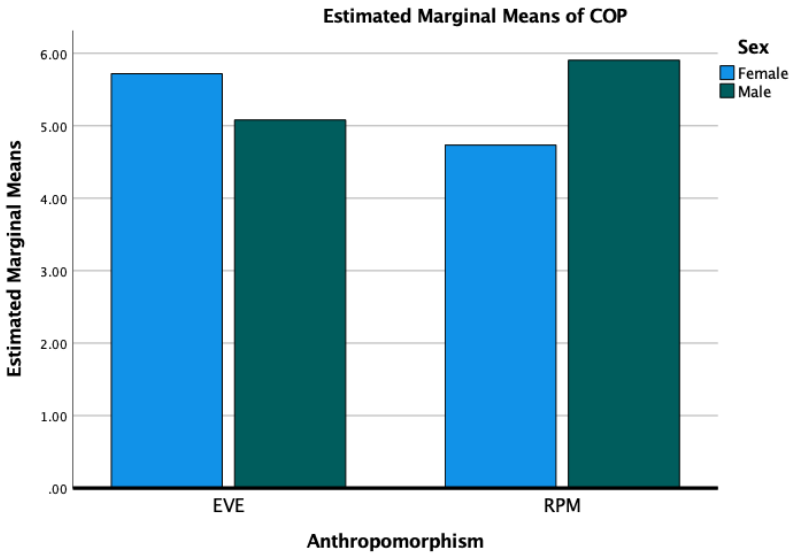
Sex	(I) Anthropomorphism	(J) Anthropomorphism	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
Female	EVE	RPM	.984	.594	.113	-.252	2.220
	RPM	EVE	-.984	.594	.113	-2.220	.252
Male	EVE	RPM	-.825	.494	.110	-1.852	.202
	RPM	EVE	.825	.494	.110	-.202	1.852

Based on estimated marginal means

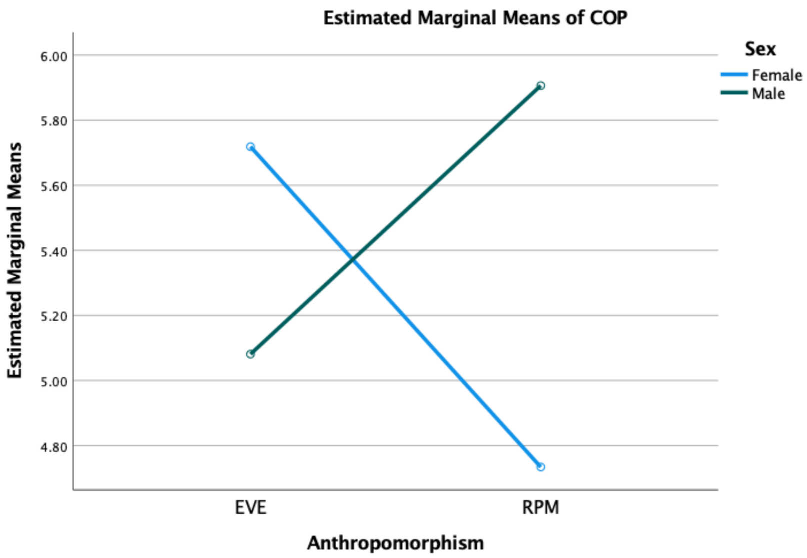
a. Adjustment for multiple comparisons: Bonferroni.

Figure 4.6: The results simple main effect of Anthropomorphism for sex ignoring the influence of Expression Modality

For Anthropomorphism*sex interaction, the simple main effect of sex on mean COP for RPM was statistically significant ($F(1, 21) = 4.419$, $p = .048$), but not for EVE, $F(1, 21) = 1.419$, $p = .247$ (see Figure 4.5). All pairwise comparisons were Bonferroni adjusted. For RPM, COP was $4.734 \pm .409$ in the Female group and $5.906 \pm .379$ in the Male group, a statistically significance difference of 1.172 (95% CI, .013 to 2.331), $p = .048$. There was no statistically significant difference between EVE and RPM groups for sex, for Female, $F(1,21) = 2.743$, $p = .113$, for Male, $F(1,21) = 2.791$, $p = .110$ (see Figure 4.6. From figure 4.7 it can be seen that RPM avatars were perceived significantly lower in copresence by females than males. For EVE, females perceived it more copresent than males.



(a) Clustered Bar Graph



(b) Multiple Line Graph

Figure 4.7: Interaction between Anthropomorphism and sex ignoring the influence of Expression Modality factor

For ExpressionModality*sex interaction, the simple main effect of expression modality on mean COP for Female and Male was statistically significant (F(1, 21) = 14.529, p = .001), and F(1, 21) = 6.280, p = .021 (see Figure 4.8). All pairwise comparisons were Bonferroni adjusted. For female, COP was 4.094 ± .472 in the LM group and 6.359 ± .361 in the HM group, a statistically significance difference of 2.266 (95% CI, 1.030 to 3.502), p = .001. For male, COP was 6.112 ± .277 in the LM group and 4.875 ± .409 in HM group, a statistically significance difference of 1.283 (95% CI, .350 to 2.619), p = .021. Similarly, the simple main effect of sex for expression modality LM and HM is statistically significant (F(1, 21) = 14.529, p = .001), and F(1, 21) = 6.280, p = .013) (see Figure 4.9). For LM, COP was 4.094 ± .472 in Female group and 6.112 ± .277 in Male group, a statistically significance difference of 2.019 (95% CI, .880 to 3.157), p = .001. For HM, COP was 6.359 ± .361 in Female group and 4.875 ± .409 in Male group, a

Pairwise Comparisons

Dependent Variable: COP

Sex	(I) Expression_Modality	(J) Expression_Modality	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Female	LM	HM	-2.266*	.594	.001	-3.502	-1.030
	HM	LM	2.266*	.594	.001	1.030	3.502
Male	LM	HM	1.238*	.494	.021	.211	2.264
	HM	LM	-1.238*	.494	.021	-2.264	-.211

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Figure 4.8: The results simple main effect of Expression Modality for sex ignoring the influence of Anthropomorphism

Pairwise Comparisons

Dependent Variable: COP

Expression_Modality	(I) Sex	(J) Sex	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
LM	Female	Male	-2.019*	.547	.001	-3.157	-.880
	Male	Female	2.019*	.547	.001	.880	3.157
HM	Female	Male	1.484*	.545	.013	.350	2.619
	Male	Female	-1.484*	.545	.013	-2.619	-.350

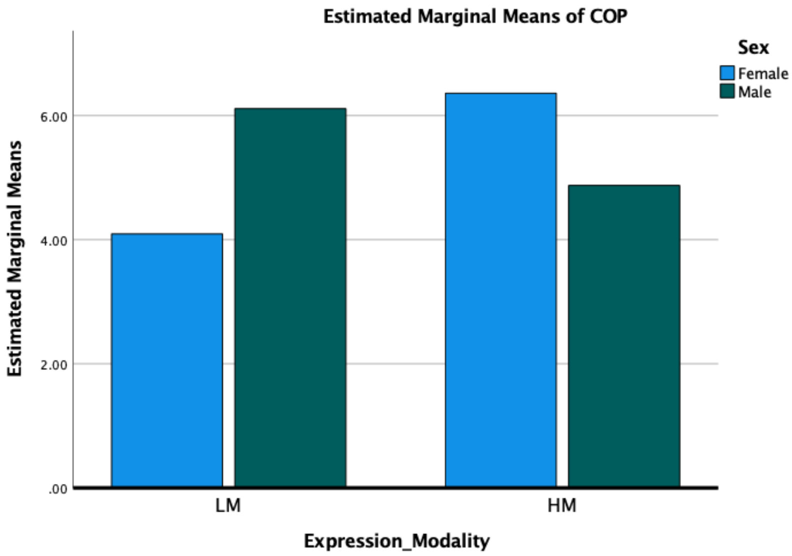
Based on estimated marginal means

*. The mean difference is significant at the .05 level.

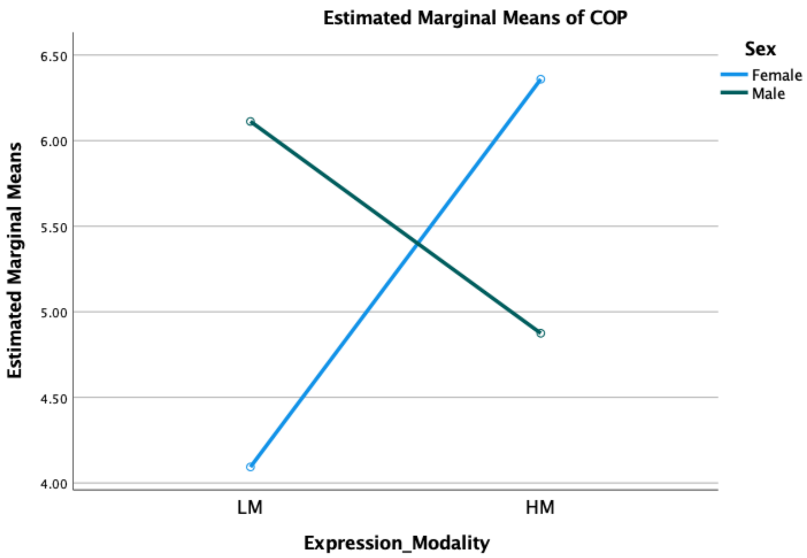
b. Adjustment for multiple comparisons: Bonferroni.

Figure 4.9: The results simple main effect of sex for Expression Modality ignoring the influence of Anthropomorphism

statistically significance difference of 2.266 (95% CI, -2.264.880 to -.211), p = .013. Figure 4.10 shows the visual representation of the interaction. It can be seen that females perceived HM avatars significantly higher than LM avatars which is opposite in the case of males.



(a) Clustered Bar Graph



(b) Multiple Line Graph

Figure 4.10: Interaction between Expression Modality and sex ignoring the influence of Anthropomorphism factor

4.1.2 Perceived Emotional Contagion

There was a statistically significant ExpressionModality*sex interaction, $F(1,21) = 4.714$, $p = .042$ but not for Anthropomorphism*ExpressionModality and Anthropomorphism*sex interactions, $F(1,21) = 2.443$, $p = .133$ and $F(1,21) = 2,184$, $p = .154$. The simple main effect of sex on mean PEC for HM was statistically significant ($F(1,21) = 6.370$, $p = .020$) but not for LM, $F(1,21) = .303$, $p = .588$ (see Figure 4.11. All pairwise comparisons were Bonferroni corrected. PEC was $4.990 \pm .317$ in Female group and $3.781 \pm .359$ in Male group, a statistically significance difference of 1.208 (95% CI, .213 to 2.204), $p = .020$. There was no statistically significant difference between LM and HM groups for sex, for Female, $F(1,21) = 1.684$, $p = .208$, for Male, $F(1,21) = 2.316$, $p = .081$ (see figure 4.12). Figure 4.13 shows the visual representation of the interaction. It can be seen that females perceived HM avatars significantly higher for perceiving emotional contagion than males and and higher (not significantly) than LM. Whereas, male tended to perceived more emotional contagion via LM avatars than females and HM.

Pairwise Comparisons

Dependent Variable: PEC

Expression_Modality	(I) Sex	(J) Sex	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
LM	Female	Male	-.264	.480	.588	-1.263	.735
	Male	Female	.264	.480	.588	-.735	1.263
HM	Female	Male	1.208*	.479	.020	.213	2.204
	Male	Female	-1.208*	.479	.020	-2.204	-.213

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Figure 4.11: The results simple main effect of sex for Expression Modality ignoring the influence of Anthropomorphism

Pairwise Comparisons

Dependent Variable: PEC

Sex	(I) Expression_Modality	(J) Expression_Modality	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
Female	LM	HM	-.677	.522	.208	-1.762	.408
	HM	LM	.677	.522	.208	-.408	1.762
Male	LM	HM	.796	.433	.081	-.106	1.697
	HM	LM	-.796	.433	.081	-1.697	.106

Based on estimated marginal means

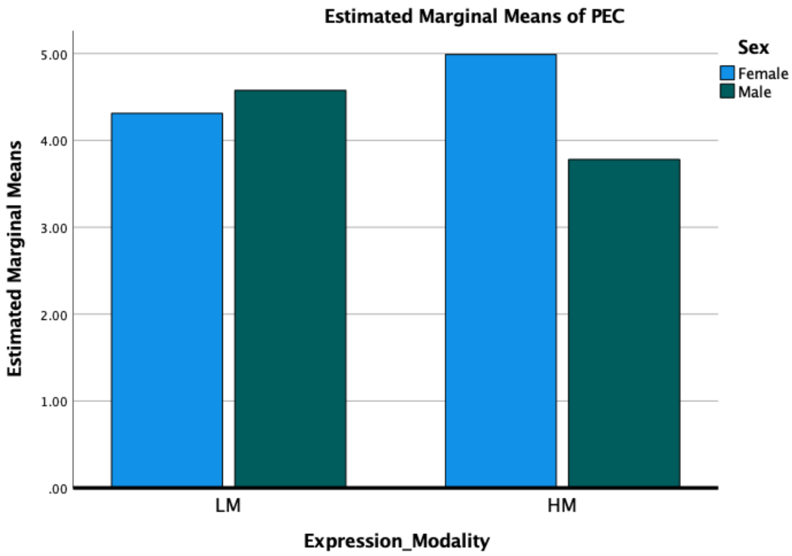
a. Adjustment for multiple comparisons: Bonferroni.

Figure 4.12: The results simple main effect of Expression Modality for Sex ignoring the influence of Anthropomorphism

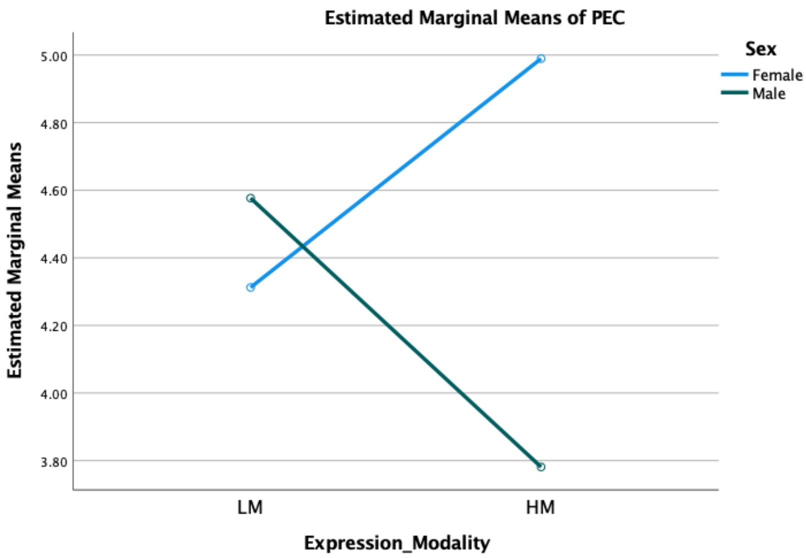
4.1.3 Aggregated Social Presence

There was a statistically significant ExpressionModality*sex interaction, $F(1,21) = 5.037$, $p = .036$ but not for Anthropomorphism*ExpressionModality and Anthropomorphism*sex interactions, $F(1,21) = .263$, $p = .614$ and $F(1,21) = 1.254$, $p = .275$. The simple main effect of sex on mean AggSP for HM was statistically significant ($F(1,21) = 4.538$, $p = .045$) but not for LM, $F(1,21) = 1.093$, $p = .308$ (see Figure 4.14). All pairwise comparisons were Bonferroni corrected. AggSP was $5.877 \pm .246$ in Female group and $5.085 \pm .279$ in Male group, a statistically significance difference of .729 (95% CI, .019 to 1.566), $p = .045$. There was no statistically significant difference between LM and HM groups for sex factor, for Female, $F(1,21) = 1.684$, $p = .208$, for Male, $F(1,21) = 2.316$, $p = .081$ (see figure 4.15). Figure 4.16 shows the visual representation of the interaction. It can be seen that females perceived HM avatars significantly higher for aggregated social presence than males and higher (not significantly) than LM. Whereas, male tended to perceived more aggregated social presence via LM avatars than females and HM.

The was no statistical significant Anthropmorphism*ExpressionModality, Anthropomorphism*sex and ExpressionModality*sex interactions for PAE, PC and PBI.



(a) Clustered Bar Graph



(b) Multiple Line Graph

Figure 4.13: Interaction between sex and Expression Modality ignoring the influence of Expression Modality factor for Perceived Emotional Contagion

Refer Appendix D E F for Descriptive Statistics, Estimate Tables, Tests of Between-Subject Effects Tables (3-Way ANOVA).

4.1.4 Preference

There was no statistically significant three-way interaction between Anthropomorphism, ExpressionModality and Sex, $F(1, 21) = .243$, $p = .627$. Moreover, there was not a statistically significant difference between Anthropomorphism*ExpressionModality, Anthropomorphism*Sex and ExpressionModalit*Sex interaction, $F(1, 21) = 1.613$, $p = .218$; $F(1, 21) = .779$, $p = .388$ and $F(1, 21) = .003$, $p = .955$ (refer the Tests of Between-Subjects Table on Page 76)

Pairwise Comparisons

Dependent Variable: AggSP

Expression_Modality	(I) Sex	(J) Sex	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
LM	Female	Male	-.390	.373	.308	-1.167	.386
	Male	Female	.390	.373	.308	-.386	1.167
HM	Female	Male	.792*	.372	.045	.019	1.566
	Male	Female	-.792*	.372	.045	-1.566	-.019

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Figure 4.14: The results simple main effect of Sex for Expression Modality ignoring the influence of Anthropomorphism

Pairwise Comparisons

Dependent Variable: AggSP

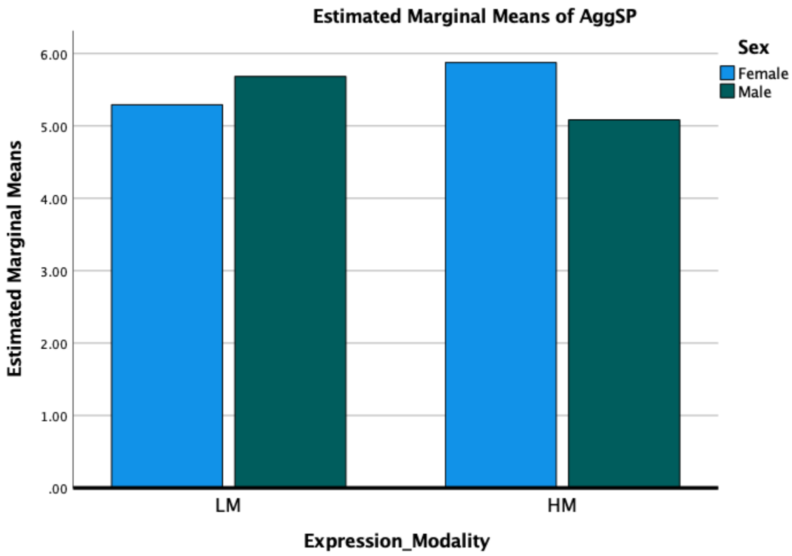
Sex	(I) Expression_Modality	(J) Expression_Modality	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
Female	LM	HM	-.583	.405	.165	-1.426	.260
	HM	LM	.583	.405	.165	-.260	1.426
Male	LM	HM	.600	.337	.089	-.100	1.300
	HM	LM	-.600	.337	.089	-1.300	.100

Based on estimated marginal means

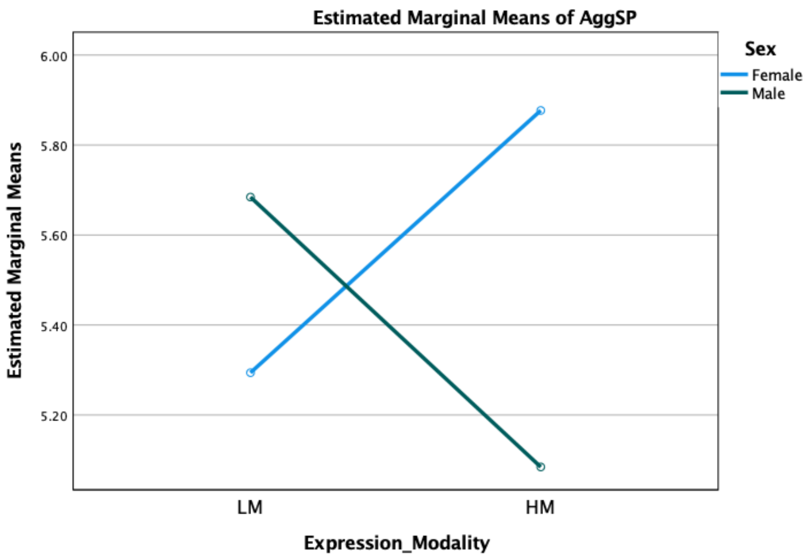
a. Adjustment for multiple comparisons: Bonferroni.

Figure 4.15: The results simple main effect of Expression Modality for Sex ignoring the influence of Anthropomorphism

It can be seen from the graphs 4.17 that females tended to prefer HM avatars. Males tended to have higher preference rating to LM avatars than females. Amongst all, men rated RPM-HM the highest.



(a) Clustered Bar Graph



(b) Multiple Line Graph

Figure 4.16: Interaction between sex and Expression Modality ignoring the influence of Anthropomorphism factor

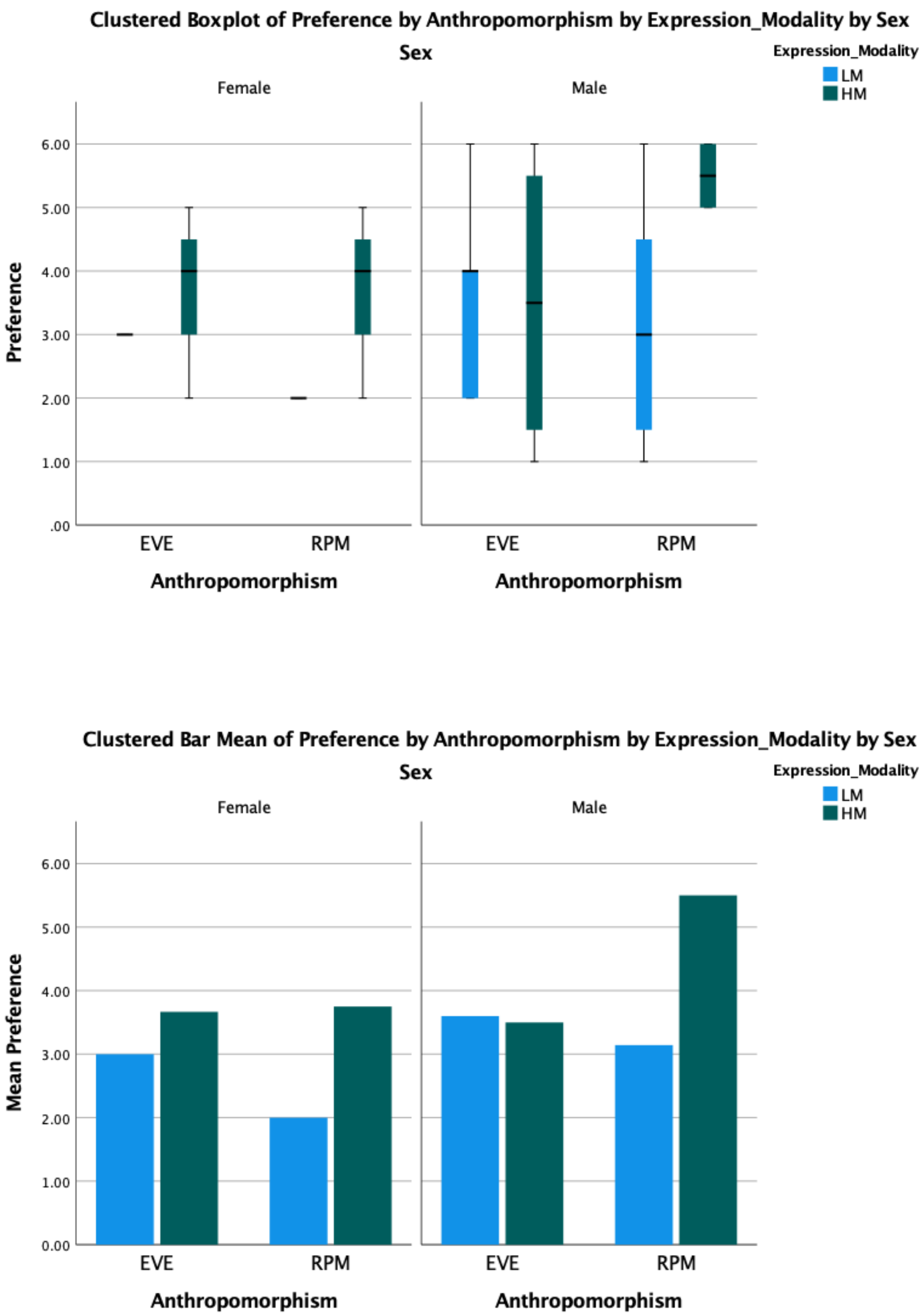


Figure 4.17: User preference visualisation in the form of box plot and bar graph

5 DISCUSSION

This study explores the effects of facial avatars' anthropomorphism and expressions on perceived social presence. A user study experiment was conducted to compare the effects of two levels of anthropomorphic avatars (low [EVE] and high [RPM]) with two levels of facial expression modality (low [LM] and high [HM]). To measure the social presence of the given facial avatar, the 24-item Network Minds Social Presence Questionnaire [69] was presented to the participants post-experiment. To the best of our knowledge, this is the first study that examines the changes in the level of anthropomorphism and expressiveness via real-time near to zero latency rendering on an avatar that can influence one's evaluation of their partner and social presence.

The current study found no statistically significant difference for improved truthfulness of facial avatars, i.e., representation with more anthropomorphism and realistic expression modality for all sub-scales of social presence. Similarly, no statistically significant difference was observed between the responses of males and females for perceived overall social presence. However, for COP, a statistically significant difference was found between anthropomorphism sex and Expression Modality Sex. This difference showed that males reported more COP with RPM than females. In terms of expression modality, females reported more COP, PEC and AggSP for HM avatars than males.

5.1 Interpretation

5.1.1 Anthropomorphism and Expression Modality Interaction

This section addresses the exploration of Research questions one and two: "Does more anthropomorphic appearance lead to an increase in social presence?" and "Does more expressive avatar lead to an increase in social presence?". There was no significant difference found in the social presence sub-scales between RPM and EVE as well as between LM and HM amongst all the participants. However, the results revealed a statistically significant interaction between Anthropomorphism Expression Modality for COP. The main effect was observed for RPM between LM and HM. RPM-HM elicited higher copresence than RPM-LM, RPM-HM being the highest among all conditions. It can also be observed that EVE-LM elicited higher copresence than EVE-HM. This finding aligns with the previous studies, which emphasised the importance of the consistency between visual and behavioural realism [21, 22]. A possible explanation for the low copresence observed on RPM-LM might be that users did not expect such low modality expressions on high anthropomorphic avatars, leading to the eeriness. Therefore, RPM-HM was up to the expectations concerning visual and behavioural realism, where more anthropomorphic representation sets up higher expectations that lead to reduced presence when these expectations are not met [89]. These findings tend to show that avatars with low anthropomorphism with low expression modality and high anthropomorphism with high expression modality elicited high copresence. The highest copresence for RPM-HM is also consistent with the previous research, which demonstrated that higher social presence with realistic-looking, highly expressive avatars compared to abstract, cartoon-like looking low expressive avatars [126, 57]. Developing avatars that have consistent behavioural and visual similarity is a worthy target.

5.1.2 Impact of Anthropomorphism and Expression Modality on Sex Differences

Exploring the first sub-research question 1-(a) (refer Section 2.10) and second sub-research question 2-(a) (refer Section 2.10), ”What is the effect of the increase in anthropomorphism and expressiveness on the social presence of sex differences?” showed that females perceived higher COP for HM avatars than LM avatars. In contrast, males perceived higher COP for LM avatars than HM avatars. In addition, there is an increase in COP from EVE to RPM for all the conditions except for the females in the case where there is a steep decrease in COP from EVE-LM to RPM-LM (see Figure 4.1. One possible explanation for this might be that females are more sensitive and critical toward shortcomings of avatars [117, 127]. Another reason could lie in the eeriness elicited by RPM-LM avatar because of a strong mismatch of behavioural and visual realism [22] and females are more sensitive to creepy and eerie sensations [128] which led to a decrease in COP from EVE-LM to RPM-LM. The graph 4.1 shows a marginal tendency of females to be the highest copresent with RPM-HM than other conditions in this study.

Anthropomorphism and Sex interaction showed statistical significance difference for COP. The simple main effect revealed a significant difference between males and females for RPM, where males reported higher scores than females. The overall lower score for RPM by females than males is mainly due to the lowest scores reported for RPM-LM condition (see Figure 4.1). A possible explanation for this result could be that females are sensitive and more critical to eeriess as well as shortcomings of the avatar [127, 117]. The low expression in RPM avatar could be unexpected and inconsistent according to visual fidelity, which might have led to the lessening of COP for females than males.

Expression Modality and Sex interaction also were statistically significant for COP, PEC and AggSP. For COP, it was observed that females had higher ratings for HM avatars, and males had higher ratings for LM avatars. For PEC and AggSP, the main effect was observed for HM between males and females, which shows that females have higher ratings for HM avatars than males. This indicates that females are more receptive to higher expressiveness than males. This result is in alignment with a past study that shows that females viewed low-fidelity avatars as more unpleasant than males [105]. Another possible explanation for this is that females are more accurate and perform better in terms of recognising facial expressions and emotions [99, 129] which shows females’ ability to notice and be concerned for facial expressiveness.

5.1.3 Preference

This section sheds light on the third research question, ”What is the three-way effect of sex, anthropomorphism and expressiveness on the social presence and preference?” (see Figure 4.17) tends to align with the COP ratings for 3-way interaction of Anthropomorphism*ExpressionModality*Sex (see Figure 4.1) except for the RPM in the case of males. Surprisingly, males preferred RPM-HM higher than every condition in the study. This shows that female preference is consistent concerning the ratings of the COP but not for males. The highest overall preference for RPM-HM by males and females, along with the consistency between COP and preference by females for HM avatars, tend to suggest using high anthropomorphic high expressive facial avatars for remote interaction.

5.2 Implications

Previous work addressed the issues related to the facial avatar representations, stylisation, and their impact on human behaviour, such as social presence, appeal, attractiveness [23, 72, 126, 89, 22, 74, 123, 59, 93]. The findings of this study have practical implications for designers of avatars; introducing changes in anthropomorphism and expressiveness of avatars may lead to changes in the way males and females perceive the avatars. These findings are consistent with the literature in terms of sex difference in perception of facial expression [129, 99, 130, 105] which shows that facially expressive avatars have the potential to allow people to produce communication outcomes that can be more positive according to the targeted sex—for instance, developing an avatar based on whether or not the interaction is with a male or female. A highly expressive avatar, a high anthropomorphic avatar for females, is essential to induce more COP and preference.

5.3 Limitations and Future Directions

The results provide insights into individual's responses to avatars' level of anthropomorphism and facial expressiveness for remote collaborative conversation using VR devices and telepresence robot. Nevertheless, it should be noted that the analysis is based on a relatively small sample of 29 participants (18 males and 11 females). Further studies with more sample size must be conducted to investigate the effects of avatars' facial features on perceived social presence. In addition, pilot testing might be used to assess the avatars' perceived anthropomorphism and expressiveness levels, allowing the experimental conditions to be validated.

Designing EVEs' facial expressions via blend shapes could potentially affect the interaction with the participants and their responses. Several morphological factors such as gestures and animations were not designed professionally. Similarly, there were some glitches in the reflection of facial expressions on avatars for RPM. For example, sometimes, participants touched the VR headset, moved or rotated in the seat, which could have resulted in the need to recalibrate the system and giving some inaccurate or unexpected facial expressions to avatars. Therefore, a more stable facial tracking system is needed, robust to changing positions and touching a VR headset.

We focused specifically on zero-acquaintance dyads. While we did this to target the effects of avatars' facial features, changing nonverbal behaviours will likely have different consequences depending on the relationship dynamics between communicators. Future studies could thus explore the effects of avatars depending on the characteristics of the interactants' relationship. Furthermore, we had only one data point for the RPM-LM Female case. So to have more reliability, we included a female participant in the condition RPM-LM who happened to be familiar with her counterpart. However, two data points are not a good representation of the case 'for RPM-LM-Female'. Therefore, further study with more participants is needed for a more reliable representation.

This study has been unable to clearly demonstrate the uncanny valley phenomenon [42]. It was seen in the case of females for RPM-LM avatars as there could be a mismatch of expectations between high anthropomorphic avatars and low expressions. However, that was not observed for males. The reason could lie in the more sensitivity of females to eeriness and creepiness than males [131]. Another possible explanation of this is that females are more critical towards noticing emotions and facial expressions than males [129, 132, 99]. This suggests that the uncanny valley phenomenon is classified for specific avatars and sex. Therefore, the uncanny valley could be explicitly measured with a tool mentioned in [131], for instance.

Higher copresence may not represent the overall desired goal of communication. Increased social presence may not always be good, especially for people who feel discomfort during social situations (introverts) [133]. Therefore, to take advantage of the unique possibility of shifting levels of social presence in CMCs, it is vital to examine the communicator's traits and context. In addition, with measuring social presence with questionnaires, the objective measures such as behavioural, cognitive, or psycho-physiological measures. Therefore, combining self-reports with objective measures and other types of collaborative tasks would ensure the reliability and validity of users' responses.

In the user study experiment setup, dyads were in the same room with a black screen partition. So, for the voice interaction, no microphones and speakers were used. This could induce inaccuracies in the social presence measurement as every participant could have been aware that their counterpart was in the same room. Nonetheless, the results are valid and insightful as the setup was consistent for each dyad, reflecting avatar interaction's influence. Future studies should ensure that the participants are in a different room to simulate the realistic scenario.

This study has only two levels of anthropomorphism with two levels of expression modality. This would limit us from drawing accurate tendencies of participants towards specific features of avatars. Therefore, for better precision of responses towards specific desired features, more levels of anthropomorphism along with more levels of expression modalities are needed to be explored [56, 77, 59].

One of this research aims to know the fit of the remote users' facial avatar on EVE robot's head. The generalisability of the results is limited by the notion that the visual and behavioural realism needs to be consistent [21, 71, 73, 70]. In this study, we considered the head of the telepresence robot Double 2. However, the results might vary as per the given morphology of the robot. For instance, having an abstract screen-based face on the humanoid robot *Sophia* might be considered unusual and unexpected. Therefore, future work is required to establish the viability of screen-based avatars according to the form of the robot and its movement.

In order to avoid potential sex effects, all participants were assigned to same-sex dyads. However, it is unlikely to interact remotely with a same-sex counterpart in a real-world scenario. In addition, more factors like race, age, and demographics should be considered. Therefore for better reliability and validity, a further study is needed with more diversity and no dyad restrictions.

6 CONCLUSION

This research aimed to investigate the effects of avatars' facial features on social presence. We conducted a user study and analysed Social Presence scores, overall perception, and preference to investigate the research questions. The results showed that females were more Copresent (COP) with high expressive modality avatars (HM), and males were more Copresent (COP) with low expressive modality avatars (LM). Females also reported higher Perceived Emotional Contagion (PEC) and Aggregated Social Presence (AggSP) scores for high expressive modality avatars (HM). Moreover, a high anthropomorphic avatar with high expressive modality (RPM-HM) showed the highest reported Copresence (COP) overall, and males seem to have higher Copresence (COP) for high anthropomorphic avatars (RPM) than females. However, the results showed no significant difference within Anthropomorphism, Expression Modality and Sex individually and overall three-way interaction (Anthropomorphism*Expression Modality*Sex).

The generalisability of these results are subject to certain limitations—for instance, the sample size and diversity and lack of accurate expression of EVE's face. Despite its limitations, the study adds to our understanding of the differences in perception of males and females concerning avatars' facial features. Therefore, designers can consider developing an avatar based on whether or not the interaction is with a male or female. Whereas, if considering overall, avatars with high anthropomorphism and high expression modality (RPM-HM) seem to suit in terms of Copresence(COP) and Preference for both males and females. For future work, we would like to conduct user studies with humanoid robots such as *Halodi's EVE* to know if the results match that of the current study. Also, we would extend our study by including several different levels of anthropomorphism with expressive modality, enabling an accurate understanding of the perceived facial features.

To the best of our knowledge, this is the first study that examines the changes in the level of anthropomorphism with expressiveness via real-time near to zero latency rendering on an avatar that can influence one's evaluation of their partner and social presence. This research addressed the problem of remote collaborative interaction, where achieving an appropriate balance between the level of social presence and self-disclosure is vital. As females are more able to notice and perform better in terms of recognising facial expressions and emotions than males, they felt more Copresence (COP), Emotional Contagion (PEC) and overall Social Presence (AggSP) for high expressive avatars (HM) than low expressive avatars (LM). Moreover, this study emphasises the importance of concurrency between the level of visual realism (Anthropomorphism) and level of behavioural realism (Expression Modalities) for avatar representation, where overall, the avatar with high anthropomorphism and high expressive modality (RPM-HM) seems to be accepted and preferred overall. More research is needed to know about the sex differences in the perception of avatars and its preference to ensure if females perceive more copresence (COP) with high expressive avatars (HM) than low expressive avatars (LM).

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A FIRST APPENDIX

A.1 Social Presence Measurement

A.1.1 First order social presence: Co-presence

The following items measure the degree to which the users feel as if they are together in the same space:

Perception of self	Perception of the other
I often felt as if (my partner) and I were in the same (room) together.	I think (my partner) often felt as if we were in the same room together.
I was often aware of (my partner) in the (room).	(My partner) was often aware of me in the (room).
I hardly noticed (my partner) in the (room)	(My partner) didn't notice me in the (room).
I often felt as if we were in different places rather than together in same (room)	I think (my partner) often felt as if we were in different places rather than together in the same (room).

A.1.2 Second order social presence: Psycho-behavioural interaction

The following items measure the user perception of attention, emotional contagion, and mutual understanding with their partner or participant.

Perceived psychological engagement

Perception of self	Perception of the other
Perceived attentional engagement	
I paid close attention to (my partner).	(My partner) paid close attention to me
I was easily distracted from (my partner) when other things were going on.	(My partner) was easily distracted from me when other things were going on.
I tended to ignore (my partner).	(My partner) tended to ignore me.
Perceived emotional contagion	
I was sometimes influenced by (my partner's) moods.	(My partner) was sometimes influenced by my moods.
When I was happy, (my partner) tended to be happy.	When (my partner) was happy, I tended to be happy.
When I was feeling sad (my partner) also seemed to be down.	When (my partner) was feeling sad, (my partner) I tended to be sad.
When I was feeling nervous, (my partner) also seemed to be nervous.	When (my partner) was nervous, (my partner) I tended to be nervous.
Perceived comprehension	
I was able to communicate my intentions clearly to (my partner.)	(My partner) was able to communicate their intentions clearly to me.
My thoughts were clear to (my partner).	(My partner's) thoughts were clear to me.
I was able to understand what (my partner) meant.	(My partner) was able to understand what I meant.

Perceived behavioral interdependence

Perception of self	Perception of my partner
My actions were often dependent on (my partner's) actions.	(My partner's) actions were often dependent on my actions.
My behavior was often in direct response to (my partner's) behavior.	The behavior of (my partner) was often in direct response to my behavior.
What I did often affected what (my partner) did.	What (my partner) did often affected what I did.

B TEST OF NORMALITY

Tests of Normality

avatar	Anthropomorphism		Sex	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
EVE-LM	EVE	COP	Female	.260	2	.			
			Male	.199	5	.200*	.938	5	.649
		PAE	Female	.260	2	.			
			Male	.194	5	.200*	.979	5	.927
		PEC	Female	.260	2	.			
			Male	.231	5	.200*	.867	5	.255
		PC	Female	.	2	.			
			Male	.307	5	.139	.745	5	.027
		PBI	Female	.260	2	.			
			Male	.278	5	.200*	.893	5	.375
		AggSP	Female	.260	2	.			
			Male	.211	5	.200*	.860	5	.228
		Preference	Female	.	2	.			
			Male	.231	5	.200*	.881	5	.314
EVE-HM	EVE	COP	Female	.385	3	.	.750	3	.000
			Male	.253	4	.	.852	4	.233
		PAE	Female	.204	3	.	.993	3	.843
			Male	.200	4	.	.968	4	.830
		PEC	Female	.211	3	.	.991	3	.817
			Male	.151	4	.	.993	4	.972
		PC	Female	.314	3	.	.893	3	.363
			Male	.185	4	.	.981	4	.906
		PBI	Female	.356	3	.	.818	3	.157
			Male	.195	4	.	.975	4	.875
		AggSP	Female	.383	3	.	.755	3	.011
			Male	.270	4	.	.894	4	.401
		Preference	Female	.253	3	.	.964	3	.637
			Male	.236	4	.	.911	4	.488
RPM-LM	RPM	COP	Female	.260	2	.			
			Male	.282	7	.098	.823	7	.068
		PAE	Female	.260	2	.			
			Male	.247	7	.200*	.915	7	.434
		PEC	Female	.260	2	.			
			Male	.219	7	.200*	.901	7	.338
		PC	Female	.260	2	.			
			Male	.349	7	.010	.769	7	.020
		PBI	Female	.260	2	.			
			Male	.235	7	.200*	.837	7	.094
		AggSP	Female	.260	2	.			
			Male	.181	7	.200*	.964	7	.848
		Preference	Female	.	2	.			
			Male	.150	7	.200*	.930	7	.549
RPM-HM	RPM	COP	Female	.285	4	.	.935	4	.625
			Male	.260	2	.			
		PAE	Female	.237	4	.	.939	4	.650
			Male	.260	2	.			
		PEC	Female	.162	4	.	.993	4	.971
			Male	.260	2	.			
		PC	Female	.298	4	.	.849	4	.224
			Male	.260	2	.			
		PBI	Female	.195	4	.	.971	4	.850
			Male	.260	2	.			
		AggSP	Female	.410	4	.	.731	4	.025
			Male	.260	2	.			
		Preference	Female	.329	4	.	.895	4	.406
			Male	.260	2	.			

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure B.1: Results of Normality Test

C TEST OF EQUALITY OF VARIANCES

Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
COP	Based on Mean	3.123	7	21	.020
	Based on Median	2.235	7	21	.073
	Based on Median and with adjusted df	2.235	7	6.161	.170
	Based on trimmed mean	3.083	7	21	.021

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: COP

b. Design: Intercept + Anthropomorphism + Expression_Modality + Sex + Anthropomorphism * Expression_Modality + Anthropomorphism * Sex + Expression_Modality * Sex + Anthropomorphism * Expression_Modality * Sex

Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
PAE	Based on Mean	2.899	7	21	.028
	Based on Median	1.527	7	21	.212
	Based on Median and with adjusted df	1.527	7	14.709	.233
	Based on trimmed mean	2.834	7	21	.030

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: PAE

b. Design: Intercept + Anthropomorphism + Expression_Modality + Sex + Anthropomorphism * Expression_Modality + Anthropomorphism * Sex + Expression_Modality * Sex + Anthropomorphism * Expression_Modality * Sex

Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
PEC	Based on Mean	1.125	7	21	.385
	Based on Median	.704	7	21	.669
	Based on Median and with adjusted df	.704	7	11.226	.670
	Based on trimmed mean	1.061	7	21	.421

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: PEC

b. Design: Intercept + Anthropomorphism + Expression_Modality + Sex + Anthropomorphism * Expression_Modality + Anthropomorphism * Sex + Expression_Modality * Sex + Anthropomorphism * Expression_Modality * Sex

Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
PC	Based on Mean	4.706	7	21	.003
	Based on Median	.723	7	21	.654
	Based on Median and with adjusted df	.723	7	10.965	.657
	Based on trimmed mean	4.363	7	21	.004

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: PC

b. Design: Intercept + Anthropomorphism + Expression_Modality + Sex + Anthropomorphism * Expression_Modality + Anthropomorphism * Sex + Expression_Modality * Sex + Anthropomorphism * Expression_Modality * Sex

Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
PBI	Based on Mean	3.546	7	21	.011
	Based on Median	1.739	7	21	.154
	Based on Median and with adjusted df	1.739	7	14.737	.175
	Based on trimmed mean	3.465	7	21	.013

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: PBI

b. Design: Intercept + Anthropomorphism + Expression_Modality + Sex + Anthropomorphism * Expression_Modality + Anthropomorphism * Sex + Expression_Modality * Sex + Anthropomorphism * Expression_Modality * Sex

Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
AggSP	Based on Mean	2.200	7	21	.077
	Based on Median	1.404	7	21	.256
	Based on Median and with adjusted df	1.404	7	15.295	.273
	Based on trimmed mean	2.144	7	21	.083

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: AggSP

b. Design: Intercept + Anthropomorphism + Expression_Modality + Sex + Anthropomorphism * Expression_Modality + Anthropomorphism * Sex + Expression_Modality * Sex + Anthropomorphism * Expression_Modality * Sex

Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
Preference	Based on Mean	2.747	7	21	.034
	Based on Median	2.015	7	21	.101
	Based on Median and with adjusted df	2.015	7	16.475	.115
	Based on trimmed mean	2.709	7	21	.036

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Dependent variable: Preference

b. Design: Intercept + Anthropomorphism + Expression_Modality + Sex + Anthropomorphism * Expression_Modality + Anthropomorphism * Sex + Expression_Modality * Sex + Anthropomorphism * Expression_Modality * Sex

D DESCRIPTIVE STATISTICS

Descriptive Statistics

Dependent Variable: COP

Anthropomorphism	Expression_Modality	Sex	Mean	Std. Deviation	N
EVE	LM	Female	5.1875	.26517	2
		Male	5.9750	.88123	5
		Total	5.7500	.82285	7
	HM	Female	6.2500	.21651	3
		Male	4.1875	1.91621	4
		Total	5.0714	1.75128	7
	Total	Female	5.8250	.61619	5
		Male	5.1806	1.62874	9
		Total	5.4107	1.36088	14
RPM	LM	Female	3.0000	.17678	2
		Male	6.2500	.45069	7
		Total	5.5278	1.48663	9
	HM	Female	6.4688	.35904	4
		Male	5.5625	1.67938	2
		Total	6.1667	.92759	6
	Total	Female	5.3125	1.81444	6
		Male	6.0972	.77252	9
		Total	5.7833	1.29428	15
Total	LM	Female	4.0938	1.27629	4
		Male	6.1354	.64283	12
		Total	5.6250	1.20934	16
	HM	Female	6.3750	.30619	7
		Male	4.6458	1.80869	6
		Total	5.5769	1.48827	13
	Total	Female	5.5455	1.36733	11
		Male	5.6389	1.32349	18
		Total	5.6034	1.31656	29

Descriptive Statistics

Dependent Variable: Preference

Anthropomorphism	Expression_Modality	Sex	Mean	Std. Deviation	N
EVE	LM	Female	3.0000	.00000	2
		Male	3.6000	1.67332	5
		Total	3.4286	1.39728	7
	HM	Female	3.6667	1.52753	3
		Male	3.5000	2.38048	4
		Total	3.5714	1.90238	7
	Total	Female	3.4000	1.14018	5
		Male	3.5556	1.87824	9
		Total	3.5000	1.60528	14
RPM	LM	Female	2.0000	.00000	2
		Male	3.1429	1.95180	7
		Total	2.8889	1.76383	9
	HM	Female	3.7500	1.25831	4
		Male	5.5000	.70711	2
		Total	4.3333	1.36626	6
	Total	Female	3.1667	1.32916	6
		Male	3.6667	2.00000	9
		Total	3.4667	1.72654	15
Total	LM	Female	2.5000	.57735	4
		Male	3.3333	1.77525	12
		Total	3.1250	1.58640	16
	HM	Female	3.7143	1.25357	7
		Male	4.1667	2.13698	6
		Total	3.9231	1.65638	13
	Total	Female	3.2727	1.19087	11
		Male	3.6111	1.88302	18
		Total	3.4828	1.63927	29

E MEAN ESTIMATES

Estimates

Dependent Variable: COP

Anthropomorphism	Expression_Modality	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
EVE	LM	5.581	.395	4.759	6.403
	HM	5.219	.361	4.468	5.969
RPM	LM	4.625	.379	3.837	5.413
	HM	6.016	.409	5.165	6.866

Estimates

Dependent Variable: COP

Anthropomorphism	Sex	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
EVE	Female	5.719	.431	4.822	6.616
	Male	5.081	.317	4.422	5.740
RPM	Female	4.734	.409	3.884	5.585
	Male	5.906	.379	5.119	6.694

Estimates

Dependent Variable: COP

Sex	Expression_Modality	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Female	LM	4.094	.472	3.111	5.076
	HM	6.359	.361	5.609	7.110
Male	LM	6.112	.277	5.537	6.688
	HM	4.875	.409	4.024	5.726

Estimates

Dependent Variable: PEC

Sex	Expression_Modality	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Female	LM	4.313	.415	3.450	5.175
	HM	4.990	.317	4.331	5.648
Male	LM	4.577	.243	4.072	5.082
	HM	3.781	.359	3.035	4.528

Estimates

Dependent Variable: AggSP

Sex	Expression_Modality	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Female	LM	5.294	.322	4.624	5.964
	HM	5.877	.246	5.365	6.389
Male	LM	5.684	.189	5.292	6.077
	HM	5.085	.279	4.504	5.665

F RESULTS OF 3-WAY ANOVA

Tests of Between-Subjects Effects

Dependent Variable: COP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29.790[a]	7	4.256	4.768	.002
Intercept	687.097	1	687.097	769.837	<.001
Anthropomorphism	.038	1	.038	.043	.839
Expression_Modality	1.580	1	1.580	1.770	.198
Gender	.427	1	.427	.478	.497
Anthropomorphism * Expression_Modality	4.594	1	4.594	5.147	.034
Anthropomorphism * Gender	4.893	1	4.893	5.483	.029
Expression_Modality * Gender	18.342	1	18.342	20.551	<.001
Anthropomorphism * Expression_Modality * Gender	.638	1	.638	.714	.408
Error	18.743	21	.893		
Total	959.094	29			
Corrected Total	48.533	28			

a. R Squared = .614 (Adjusted R Squared = .485)

Tests of Between-Subjects Effects

Dependent Variable: PAE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.231[a]	7	.462	.893	.529
Intercept	883.996	1	883.996	1710.668	<.001
Anthropomorphism	.074	1	.074	.143	.709
Expression_Modality	.277	1	.277	.536	.472
Sex	.195	1	.195	.377	.546
Anthropomorphism * Expression_Modality	.140	1	.140	.270	.609
Anthropomorphism * Sex	1.986	1	1.986	3.844	.063
Expression_Modality * Sex	.226	1	.226	.437	.516
Anthropomorphism * Expression_Modality * Sex	.242	1	.242	.469	.501
Error	10.852	21	.517		
Total	1060.083	29			
Corrected Total	14.082	28			

a. R Squared = .229 (Adjusted R Squared = -.027)

Tests of Between-Subjects Effects

Dependent Variable: PEC

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8.012[a]	7	1.145	1.665	.172
Intercept	466.155	1	466.155	677.911	<.001
Anthropomorphism	1.193	1	1.193	1.735	.202
Expression_Modality	.021	1	.021	.030	.863
Sex	1.332	1	1.332	1.937	.179
Anthropomorphism * Expression_Modality	1.680	1	1.680	2.443	.133
Anthropomorphism * Sex	1.502	1	1.502	2.184	.154
Expression_Modality * Sex	3.241	1	3.241	4.714	.042
Anthropomorphism * Expression_Modality * Sex	.442	1	.442	.643	.431
Error	14.440	21	.688		
Total	608.578	29			
Corrected Total	22.453	28			

a. R Squared = .357 (Adjusted R Squared = .142)

Tests of Between-Subjects Effects

Dependent Variable: PC

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.986[a]	7	.284	.679	.688
Intercept	997.709	1	997.709	2389.355	<.001
Anthropomorphism	.010	1	.010	.023	.881
Expression_Modality	.443	1	.443	1.062	.315
Sex	.930	1	.930	2.227	.151
Anthropomorphism * Expression_Modality	.434	1	.434	1.039	.320
Anthropomorphism * Sex	.130	1	.130	.311	.583
Expression_Modality * Sex	.043	1	.043	.103	.751
Anthropomorphism * Expression_Modality * Sex	.011	1	.011	.027	.872
Error	8.769	21	.418		
Total	1208.000	29			
Corrected Total	10.755	28			

a. R Squared = .185 (Adjusted R Squared = -.087)

Tests of Between-Subjects Effects

Dependent Variable: PBI

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.296[a]	7	.328	.353	.919
Intercept	725.218	1	725.218	780.477	<.001
Anthropomorphism	.311	1	.311	.334	.569
Expression_Modality	.177	1	.177	.190	.667
Sex	.490	1	.490	.527	.476
Anthropomorphism * Expression_Modality	.077	1	.077	.083	.776
Anthropomorphism * Sex	.982	1	.982	1.057	.316
Expression_Modality * Sex	.115	1	.115	.124	.728
Anthropomorphism * Expression_Modality * Sex	.129	1	.129	.139	.713
Error	19.513	21	.929		
Total	902.362	29			
Corrected Total	21.809	28			

a. R Squared = .105 (Adjusted R Squared = -.193)

Tests of Between-Subjects Effects

Dependent Variable: AggSP

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.661[a]	7	.523	1.260	.317
Intercept	719.482	1	719.482	1733.172	<.001
Anthropomorphism	.020	1	.020	.048	.829
Expression_Modality	.000	1	.000	.001	.975
Sex	.242	1	.242	.582	.454
Anthropomorphism * Expression_Modality	.109	1	.109	.263	.614
Anthropomorphism * Sex	.520	1	.520	1.254	.275
Expression_Modality * Sex	2.091	1	2.091	5.037	.036
Anthropomorphism * Expression_Modality * Sex	.001	1	.001	.001	.970
Error	8.718	21	.415		
Total	903.319	29			
Corrected Total	12.378	28			

a. R Squared = .296 (Adjusted R Squared = .061)

Tests of Between-Subjects Effects

Dependent Variable: Preference

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	14.268[a]	7	2.038	.702	.670
Intercept	296.301	1	296.301	102.049	<.001
Anthropomorphism	.147	1	.147	.050	.824
Expression_Modality	8.163	1	8.163	2.811	.108
Sex	4.134	1	4.134	1.424	.246
Anthropomorphism * Expression_Modality	4.684	1	4.684	1.613	.218
Anthropomorphism * Sex	2.260	1	2.260	.779	.388
Expression_Modality * Sex	.010	1	.010	.003	.955
Anthropomorphism * Expression_Modality * Sex	.705	1	.705	.243	.627
Error	60.974	21	2.904		
Total	427.000	29			
Corrected Total	75.241	28			

a. R Squared = .190 (Adjusted R Squared = -.081)

G HTC VIVE SRANIPAL SDK GUIDE

5. How to Use SR_Runtime

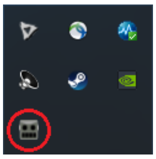
5.1 Installing SR_Runtime

To enable eye tracking capability, you must download the SR_Runtime installer from this link. Follow the instructions to install SR_Runtime.

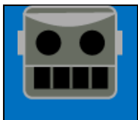
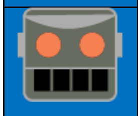
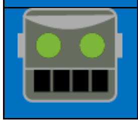
5.2 SR_Runtime Usage

After installing SR_Runtime, follow the steps below to start.

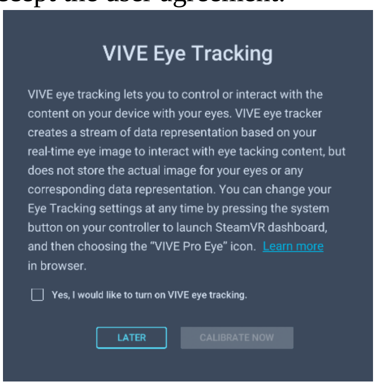
1. Ensure that your Vive Pro Eye HMD is connected to your PC.
2. Launch SR_Runtime and wait until the SRanipal status icon appears in the notification tray — see the image below.

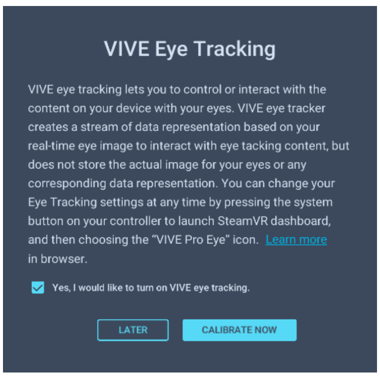


The status icon reflects the status of your tracking devices:

	SR runtime is launched but HMD does not support eye tracking or eye tracking has been disabled by the user.
	The eye tracking device is in idle mode.
	Eye tracking is active; i.e., a program is retrieving data from it.

3. Start **SteamVR** (If not running already)
4. Put on your HMD.
5. Read and accept the user agreement.





6. Start eye calibration (See more details in the next section)

7. You are done! You are ready to develop or use eye-aware applications
8. If you want to quit SR_Runtime.exe, right-click on the status icon and click **Quit** to stop SR_Runtime.

5.3 Build C Sample Code

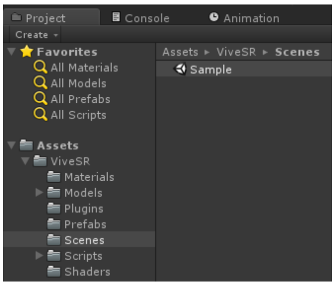
1. Open the solution file of the sample code at *$(SRANIPAL)\01_C\SRanipal\SRanipal_Sample.sln* with Visual Studio 2015.
2. For details about this API, refer to *$(SRANIPAL)\01_\C\Documnet_C.lnk*.

5.4 Build the Unity Plugin

1. Open unity and create a new **3D** project.
2. Go to **Asset** > **Import Package** > **Custom Package**.
3. Select the Vive-SRanipal-Unity-Plugin.unitypackage
4. In the **Importing Package** dialog, ensure that all package options are selected and click on **Import**.
5. Accept any API upgrades if prompted.

- Opening a sample scene

1. In the Unity Project window, find the scene file Sample.unity in **Asset** > **ViveSR** > **Scenes**.

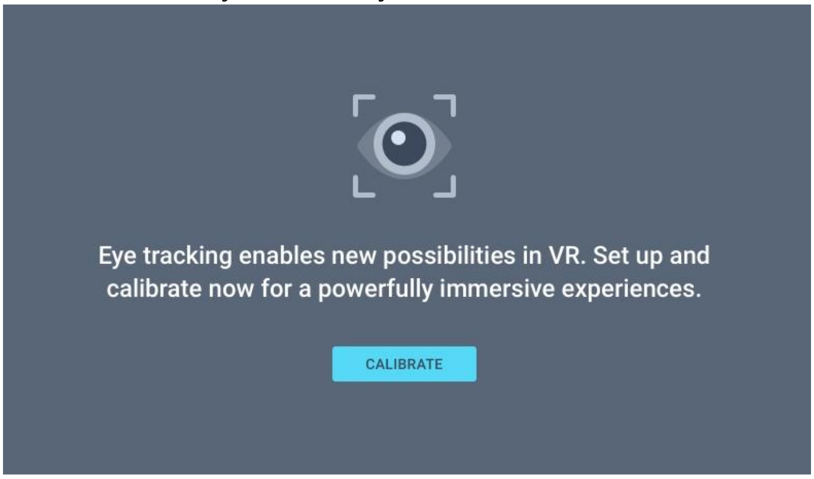


2. Ensure that all Requirements are met and then click **Play**.
3. For details about this sample, please refer to *$(SRANIPAL)\02_Unity\Plugin\Getting Started with SRanipal in Unity.pdf*.
4. For details about this API, please refer to *$(SRANIPAL)\02_Unity\Document_Unity.lnk*.

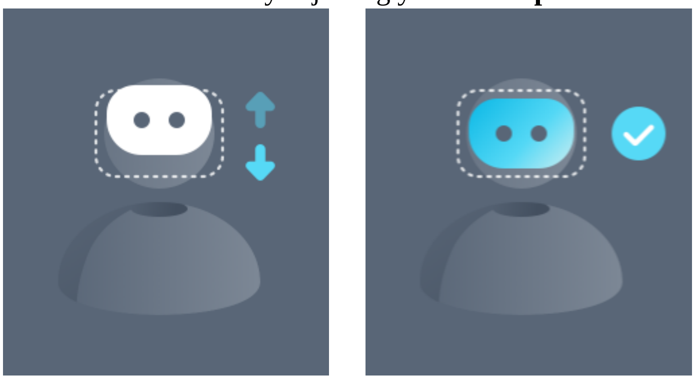
6. Eye Calibration

To calibrate for the eye-tracking feature of SRanipal, please follow the process below. Note that for the highest level of precision, it is recommended to recalibrate for different users, as the eye positions and the pupillary distances are different for each individual.

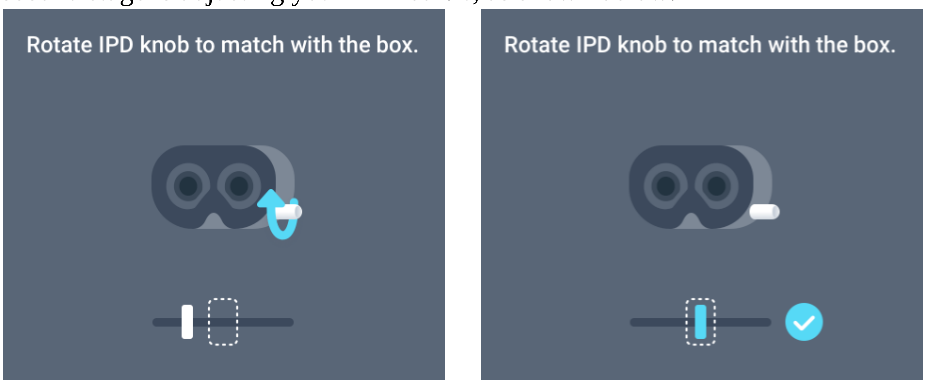
1. To start eye calibration, press your VIVE controller's **system button** and the calibration program will show an overlay window on your HMD.



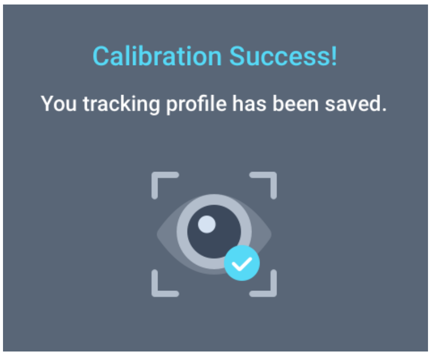
2. If you canno't find it in your overlay window, launch SR_Runtime to open it.
3. Press **Calibrate** to start. It will start by adjusting your **HMD position**

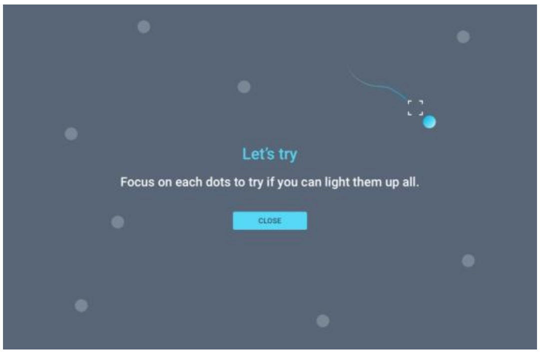


4. The second stage is adjusting your **IPD value**, as shown below.



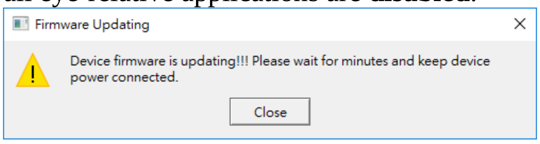
5. After that, you will be guided to do gaze calibration. **Please look at the blue-dot** sequentially shown at the center, right, left, upper and lower of panel until the calibration has been successful.
6. The program will close automatically.
7. You are done! You are ready to develop eye-aware applications.
8. Now you can have a try at this or press your VIVE controller's **system button** to quit eye calibration.



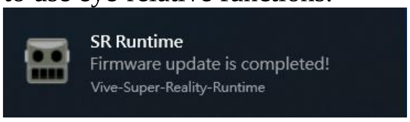


7. Known Issues

- If your HMD requires a firmware update, the window below will pop up. During the process, all eye-relative applications are **disabled**.



After the firmware update, the notification below will show up. Reboot the SR_Runtime.exe to use eye-relative functions.



8. Frequently Asked Questions

8.1 Calibration Issues

- ***How to do eye calibration?***
  - Please check **Section 6: Eye Calibration** and follow the instructions.

- ***Can calibration be done while the framework and an application that needs eye related data are running?***
  - Yes, calibration can be done when SR_Runtime is up and running.

8.2 Update Issues

- ***How to update device firmware?***
  - SR_Runtime automatically checks/updates device firmware.
- ***How to update SR_Runtime?***
  - SR_Runtime automatically checks/updates new versions from the HTC server.

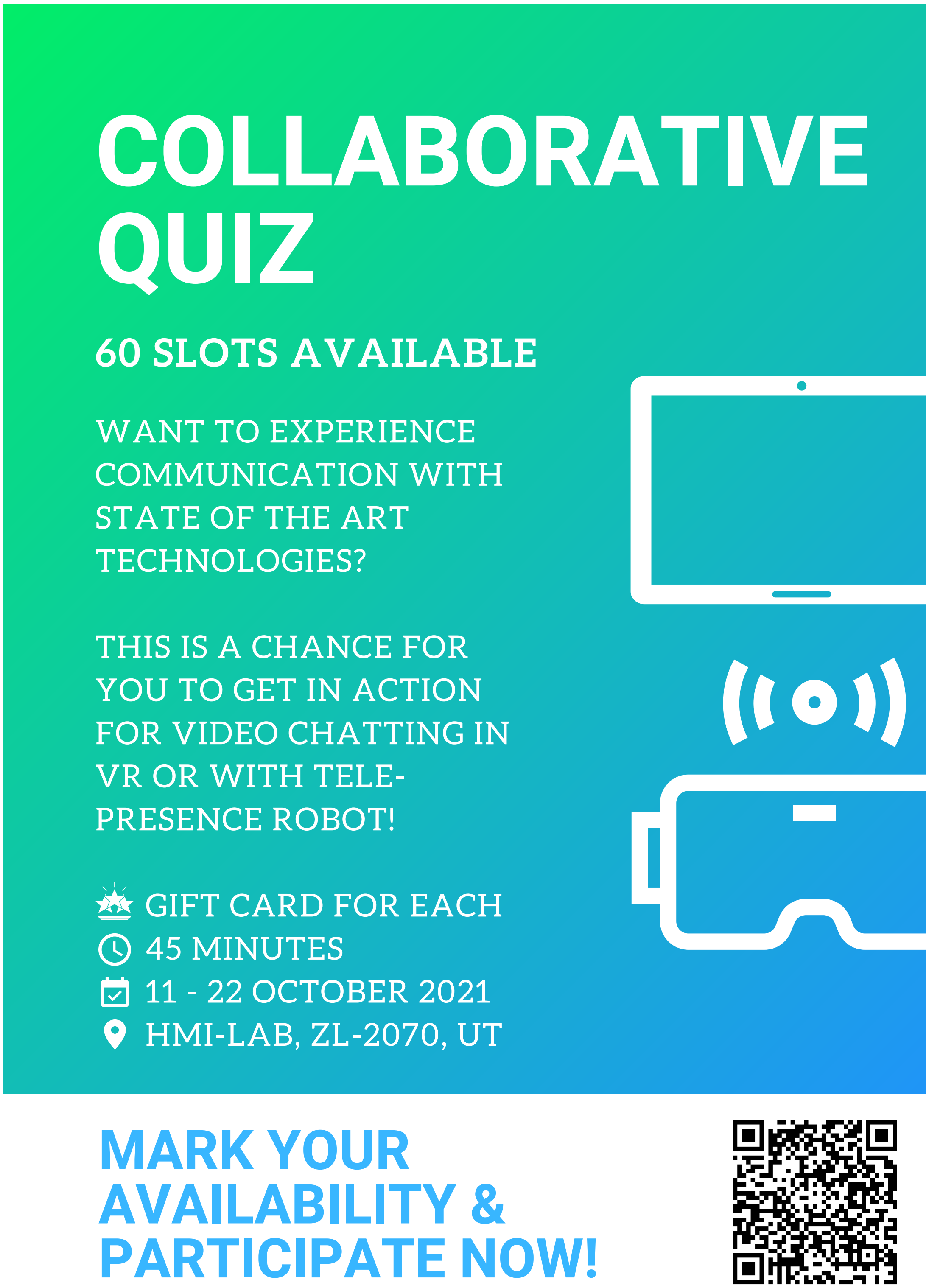
8.3 Other Common Issues

- ***Why is my eye tracking is not working?***
  - Check if the installation steps listed in **Section 5** have all successfully finished.
  - Check if SR_Runtime is running.
  - Check if the HMD is turned on and connected to the PC.
  - Make sure you accepted the user agreement and that the eye tracking feature has not been disabled.

- ***Why I can't see my eye camera version?***
  - If the device firmware upgrade process is interrupted (etc. if you plug out HMD or turn off HMD during firmware upgrade), the information might be missing. You may need to reboot your HMD and follow the instructions in Section 7. (Known Issues)

- ***Do I need to calibrate for different users?***
  - Since every individual has a different IPD setting, it is recommended to do eye calibration for each user to get the highest level of eye tracking precision.

H USER STUDY ADVERTISEMENT FLYER


COLLABORATIVE QUIZ
60 SLOTS AVAILABLE
WANT TO EXPERIENCE COMMUNICATION WITH STATE OF THE ART TECHNOLOGIES?
THIS IS A CHANCE FOR YOU TO GET IN ACTION FOR VIDEO CHATTING IN VR OR WITH TELE-PRESENCE ROBOT!
GIFT CARD FOR EACH
45 MINUTES
11 - 22 OCTOBER 2021
HMI-LAB, ZL-2070, UT
MARK YOUR AVAILABILITY & PARTICIPATE NOW!

I OPENING STATEMENT, CONSENT FORM AND DEBRIEFING FORM

Collaborative Fact-based Quiz.

Main researchers: **Devesh Gulhane, dr.ing. G. Englebienne (Gwenn), ir. Camille Sallaberry** from the Interaction Technology- Faculty of Electrical Engineering, Mathematics and Computer Science(EEMCS) at the University of Twente.

Information for the participants:

You are being invited to participate in a research study where **you will solve a fact-based quiz with your(stranger) partner in VR or non-VR(via screen). In VR condition, you will see your partner in an actual place. In screen condition, you will see your partner's avatar representation on screen. Knowing this premise, you will be asked to solve an objective quiz with four options. The quiz access will be via tablet and will be with the participant with screen condition. Make sure you both agree upon the answer before moving to next quiz question. You will be given 15 minutes to solve the quiz together.**

It is required to be more than 18 years old and without any visual & hearing impairment. This session will take you approximately **50** minutes to complete. You will be asked to fill a questionnaire at the end of the conversation.

Your participation in this study is entirely voluntary and you can withdraw at any point of time during/after session without giving a reason. After the research, if you decide that you don't want your data to be used, you can notify the researcher and your data will be deleted. Your personal data will only be present in consent form(s). This will treated and stored confidentially. The presented quiz and post-quiz questionnaire data, open question responses will be anonymous. In a way, that could not be traced back to you.

We believe there are no known risks associated with this research study; however, if you are in VR condition, you may feel dizzy, motion sick or have headaches. If get any of these symptoms bothers you, you can take off the headset at any time, or ask the researcher to help you. To the best of our ability, your answers in this study will remain confidential. We may use this data for further research after this study. We will minimize any risks by **safely storing data within internal research group systems for 10 years and will be anonymised in a way that cannot be traced back to you if published.**

Feel free to reach out regarding any concerns or questions.

Study contact details for further information:
Name: DEVESH GULHANE
Email: d.gulhane@student.utwente.nl
Phone: +31644496355

Contact details of main supervisor:
Name: DR.ING. GWENN ENGLEBIENNE
Email: g.englebienne@utwente.nl
Phone: +31534894034

If required, contact the ethics committee: ethicscommittee-cis@utwente.nl for independent advice or complaints.

Consent Form:
Collaborative Fact-based Quiz.

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves **completing survey questionnaires and my answers will be collected and analysed anonymously for research purposes in this study and further studies if required.**	○	○
Risks associated with participating in the study		
I understand that taking part in the study involves the following risks: 1) You may have a bit of motion sick, dizzy or have headache if you are in VR condition. However, you can immediately remove the VR Headset if you feel discomfort.	○	○
Use of the information in the study		
I understand that information I provide will be used for **reports, publications and websites.**	○	○
I understand that my name collected in consent form(s) can identify me which will not be shared beyond the study team and will be treated confidentially.	○	○
Future use and reuse of the information by others		
I permit the **questionnaire responses** that I provide to be archived in the **survey database in an anonymised way** so they can be used for future research and learning. We will minimize any risks by **safely storing data within internal research group systems for 10 years. After 10 years the data will be deleted by the admin of the XPrize project. The data will be anonymised in a way that cannot be traced back to you if published.**	○	○
I agree that my information may be shared with other researchers for future research studies that may be similar to this study or maybe completely different. The information shared with other researchers will not include any information that can directly identify me. Researchers will not contact me for additional permission to use this information.	○	○

Signatures

______________________ ______________________ ________

Name of participant Signature Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_________________________ ___________________ ________

Researcher name: Devesh Gulhane Signature Date

Study contact details for further information: Devesh Gulhane- d.gulhane@student.utwente.nl; Gwenn Englebienne- g.englebienne@utwente.nl; Camille Sallaberry- c.sallaberry@utwente.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-cis@utwente.nl

DEBRIEFING FORM
(Disclosing the full purpose of study)

Thank you for your participation in this research study. For this study, it was important that we withhold some information from you about some aspects of the interaction with your partner. Now that your participation is completed, I will describe the withheld to you, why it was important, answer any of your questions, and provide you with the opportunity to make a decision on whether you would like to have your data included in this study.

What you should know about this study:

1) As you might have noticed that you filled out a questionnaire involving presence. The questionnaire was to know your social presence with respect to the quiz and conversation task you had.

2) We couldn't tell you about this beforehand because it could have made you more conscious about yourself as well as conversation. Also, your responses to questionnaire could have been biased. Our goal was to let you have a conversation as freely and naturally as possible. We believe that it is achieved only after not making you aware of the actual purpose of the task/study.

3) To sum it up, we had your social presence measured and other open questions you may have answered. As a reminder, the data you provided will be anonymous, in a way that will not be traced back to you.

Right to withdraw data

You may choose to withdraw the data you provided prior to debriefing, without penalty or loss of benefits to which you are otherwise entitled. Please initial below if you do, or do not, give permission to have your data included in the study:

_______I give permission for the data collected from or about me to be included in the study.

_______I DO NOT give permission for the data collected from or about me to be included in the study.

If you have questions

The main researcher conducting this study is Devesh Gulhane, ir. Camille Sallaberry**,** dr.ing. Gwenn Englebienne, at the University of Twente's HMI-EEMCS. Please ask any questions you have now. If you have questions later, you may contact Devesh Gulhane at d.gulhane@student.utwente.nl or at +31644496355. If you have any questions or concerns regarding your rights as a research participant in this study, you may contact the Secretary of the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-cis@utwente.nl

Whether you agree or do not agree to have your data used for this study, you will still receive 5€ gift card for your participation.

Please do not disclose research procedures and/or purpose to anyone who might participate in this study in the future as this could affect the results of the study.

Your signature below indicates that you have been debriefed, and have had all of your questions answered.

___________________________	_________________________	__________
Devesh Gulhane(Student Researcher)	Signature	Date
___________________________	_________________________	___________
Name of Participant	Signature	Date

If you wish to receive a copy of this, please ask researcher.

J QUIZ QUESTIONS AND ANSWERS

	Quiz Questions						
						Correct answers	**Source**
Q1	How long is an Olympic swimming pool? (in meters)						
Options	a. 25 meters	b. 50 meters	c. 75 meters	d. 100 meters		b.	
Q2	What geometric shape is generally used for stop signs?						
Options	a. Pentagon	b. Hexagon	c. Octagon	d. Decagon		c.	
Q3	What is cynophobia?						
Options	a. Fear of cats	b. Fear of dogs	c. Fear of sea lions	d. Fear of snake		b.	
Q4	What is the rarest M&M collar?						
Options	a. Blue	b. Yellow	c. Green	d. Brown		d.	
Q5	Which country consumes most chocolate per capita?						
Options	a. USA	b. Belgium	c. Switzerland	d. Ghana		c.	
Q6	What was the first soft drink in space?						
Options	a. Pepsi	b. Coca Cola	c. Fanta	d. Mountain Dew		b.	
Q7	Which country invented ice cream						
Options	a. China	b. USA	c. Brazil	d. Australia		a.	
Q8	Which sport is dubbed as "king of sports"?						
Options	a. Basket Ball	b. Soccer	c. Cricket	d. Golf		b.	

	Quiz Questions						
						Correct answers	**Source**
Q9	Which country borders 14 nations and crosses 8 time zones?						
Options	a. USA	b. Australia	c. Russia	d. China		c.	
Q10	What country has the most natural lakes?						
Options	a. Canada	b. Netherlands	c. India	d. Russia		a.	
Q11	How many hearts does an octopus have?						
Options	a. 1	b. 2	c. 3	d. 4		c.	
Q12	The unicorn is the national animal of which country?						
Options	a. Japan	b. Antarctica	c. Finland	d. Scotland		d.	
						for Q1 to Q12	https://www.quizbreaker.com/trivia-questions
Q13	What is the most common colour of toilet paper in France?						
Options	a. White	b. Pink	c. Orange	d. Brown		b.	https://www.edinburghnews.scotsman.com/whats-on/arts-and-entertainment/25-funny-pub-quiz-questions-2021-quirky-and-hilarious-trivia-to-ask-in-your-online-quiz-plus-answers-2540427

	Quiz Questions						
						Correct answers	Source
Q14	From which country do French fries originate?						
Options	a. France	b. Belgium	c. Netherlands	d. USA		b.	https://www.anadventurousworld.com/funny-quiz-questions/
Q15	Which finger is responsible for 50% of the strength in your hand?						
Options	a. Forefinger	b. Middlefinger	c. Thumb	d. Pinky		d.	https://bestlifeonline.com/genius-trivia-questions/
Q16	What country has the most islands in the world?						
Options	a. Indonesia	b. Japan	c. Sweden	d. India		c.	https://www.ef.com/wwen/blog/language/questions-virtual-pub-quiz/
Q17	Which planet has the most gravity?						
Options	a. Jupiter	b. Saturn	c. Earth	d. Mars		a.	https://www.scarymommy.com/best-trivia-questions-answers/

	Quiz Questions						
						Correct answers	Source
Q18	What is the name of the biggest technology company in South Korea?						
Options	a. Samsung	b. LG	c. Apple	d. Panasonic		a.	
Q19	What is the chemical symbol for silver?						
Options	a. Hg	b. Ag	c. Au	d. Si		b.	
Q20	What is the lifespan of a dragonfly?						
Options	a. 24 hours	b. 48 hours	c. 72 hours	d. 12 hours		a.	
						For Q18 to Q20	https://ahaslides.com/blog/170-general-knowledge-quiz-questions-and-answers-for-your-next-virtual-pub-quiz/
Q21	Which country invented tea?						
Options	a. China	b. Japan	c. India	d. Indonesia		a.	https://www.scarymommy.com/best-trivia-questions-answers/

	Quiz Questions						
						Correct answers	Source
Q22	How many bones do sharks have in their bodies?						
Options	a. 0	b. 219	c. 119	d. 1199		a.	https://www.scarymommy.com/best-trivia-questions-answers/
Q23	Which company owns Bugatti, Lamborghini, Audi, Porsche, and Ducati?						
Options	a. Daimler AG	b. Tata	c. Volkswagen	d. BMW		c.	https://www.scarymommy.com/best-trivia-questions-answers/
Q24	What is the hottest continent on Earth?						
Options	a. Asia	b. Africa	c. Australia	d. Europe		b.	https://www.express.co.uk/life-style/life/1278265/100-general-knowledge-quiz-questions-and-answers
Q25	How many ribs are in a human body?						
Options	a. 16	b. 24	c. 10	d. 12		b.	https://thoughtcatalog.com/samantha-newman/2020/03/250-best-trivia-questions/

	Quiz Questions						
						Correct answers	Source
Q26	Which country is known as the Land of White Elephant?						
Options	a. Thailand	b. South Africa	c. India	d. Australia		a.	https://thoughtcatalog.com/samantha-newman/2020/03/250-best-trivia-questions/
Q27	How many eyes does a bee have?						
Options	a. 2	b. 4	c. 5	d. 6		c.	https://thoughtcatalog.com/samantha-newman/2020/03/250-best-trivia-questions/
Q28	What country has the world's most ancient forest?						
Options	a. Australia	b. Brazil	c. South Africa	d. Kenya		a.	https://thoughtcatalog.com/samantha-newman/2020/03/250-best-trivia-questions/
Q29	The Eiffel Tower was originally intended for what city?						
Options	a. Madrid	b. Barcelona	c. Amsterdam	d. Rome		b.	https://thoughtcatalog.com/samantha-newman/2020/03/250-best-trivia-questions/
Q30	What is the driest continent?						
Options	a. Africa	b. Antarctica	c. South America	d. Asia		b.	https://thoughtcatalog.com/samantha-newman/2020/03/250-best-trivia-questions/