UNIVERSITY OF THE AEGEAN

Department of Cultural Technology and Communication
MSc Cultural Informatics and Communication

Body Ownership Illusion in Virtual Reality

THE IMPACT OF SOCIAL CONTEXT

Post-graduate thesis
Elena Dzardanova

Supervisor
George Caridakis

Mytilene, February 2017

UNIVERSITY OF THE AEGEAN

Department of Cultural Technology and Communication
MSc Cultural Informatics and Communication

Body Ownership Illusion in Virtual Reality

THE IMPACT OF SOCIAL CONTEXT

Post-graduate thesis

Elena Dzardanova

Approved by the Examining Committee on the 22 of February 2017

George Caridakis
Assistant Professor
University of the Aegean

Damianos Gavalas
Associate Professor
University of the Aegean

Despina Catapoti
Assistant Professor
University of the Aegean

Mytilene, February 2017

Elena Dzardanova

MSc Cultural Informatics and Communication
Department of Cultural Technology and Communication

University of the Aegean

ΠΕΡΙΛΗΨΗ

Η πρόσφατη εμπορική διάθεση οικονομικά προσιτών φορετών μασκών απεικόνισης (head mounted displays) πυροδότησε μία φάση ραγδαίας ανάπτυξης εφαρμογών εικονικής πραγματικότητας (ΕιΠ). Ωστόσο, από την επιστημονική βιβλιογραφία απουσιάζουν μελέτες που να διερευνούν τις επιπτώσεις κοινωνικής αλληλεπίδρασης μεταξύ χρηστών εμβυθισμένων σε περιβάλλοντα ΕιΠ. Η παρούσα διπλωματική εργασία βασίστηκε στη διεξαγωγή πειράματος, όπου 54 συμμετέχοντες (31 γυναίκες), εμβυθισμένοι σε ένα εικονικό κατάστημα ρούχων, είδαν το εικονικό σώμα που τους ανατέθηκε να απογυμνώνεται, χωρίς προειδοποίηση, ενώπιον ενός εικονικού καθρέφτη. Διερευνήθηκε η συναισθηματική τους ανταπόκριση εν συναρτήσει με το αν είχαν επιλέξει τον εικονικό καθρέφτη που βρισκόταν στον κεντρικό, ανοιχτό χώρο του καταστήματος ή τον καθρέφτη του δοκιμαστηρίου, καθώς και σε σχέση με τρεις διακριτές πειραματικές συνθήκες όπου μία ομάδα συμμετεχόντων δε συνάντησε άλλους εικονικούς χαρακτήρες, ενώ οι άλλες δύο ομάδες βίωσαν την εμπειρία της απογύμνωσης παρουσία ενός εικονικού πωλητή. Τα αποτελέσματα της έρευνας ανέδειξαν ότι η παρουσία και μόνο ενός δεύτερου χαρακτήρα δεν επιδρά στο αίσθημα *παρουσίας* και *ψευδαίσθησης ιδιοκτησίας σώματος* των υποκειμένων. Το κοινωνικό πλαίσιο ωστόσο άσκησε ισχυρές επιδράσεις με αναφορά στο βαθμό *κοινωνικής παρουσίας*, προκαλώντας αισθήματα ντροπής και δυσφορίας κατά εννέα φορές περισσότερο στους συμμετέχοντες που απογυμνώθηκαν παρουσία του εικονικού πωλητή. Επιπλέον, αναδείχθηκε η τάση προσφυγής σε κοινωνικά αποδεκτές συμπεριφορές, καθώς τα υποκείμενα αναγνωρίζουν το κοινωνικό πλαίσιο που τις επιβάλλει.

Λέξεις κλειδιά: Εικονική Πραγματικότητα, παρουσία, ψευδαίσθηση ιδιοκτησίας σώματος, κοινωνικό πλαίσιο, κοινωνική παρουσία.

ABSTRACT

Virtual reality (VR) recently breached into commercial use with the release of affordable VR headsets. However, there is still little understanding as to how the transcendence of social interactions into VR environments may impact users. An experiment was conducted, where 54 participants visited a virtual clothing store thinking they were trying out an outfit in front of a mirror, yet witnessed the exposure of their naked virtual body (VB) instead. Their emotional state was examined in relation to whether they had chosen the confined dressing room mirror or the mirror placed in the central open area of the store, under three experimental conditions where they were either alone, in the company of a virtual non-character player salesman or a virtual salesman motion-controlled by a real actor. Results refuted that the mere presence of a second character affects participants' level of presence and body ownership illusion. However, the social context assigned to the environment greatly impacted the level of social presence by causing emotions of embarrassment and discomfort by nine times more for those who were in the company of a salesman. It was also confirmed that individuals are prone to interpreting social context and thus reckoning appropriate social behavior in the same manner they would in their physical lives.

Keywords: Virtual reality, presence, body ownership illusion, social context, social presence.

ACKNOWLEDGEMENTS

I am deeply grateful to my thesis advisor, Associate Professor Damianos Gavalas, for providing guidance and teaching of immeasurable value. His dedication to science and intellectual progress is nothing short of inspiring. I am also grateful to Doctor Vlasios Kasapakis, for sharing his incomparable ingenuity, but even more so his friendship.

I would like to express my profound gratitude, to Associate Professor, Dimitris Papageorgiou, for selflessly investing in my education. My sincere gratitude also goes to Alexandros Spathis, for everything he has taught me during my time at the Image, Sound and Cultural Representation Laboratory of the Department of Cultural Technology and Communication of the University of the Aegean, which also facilitated the experiment of this thesis under his supervision as member of the Special Technical Staff of the University of the Aegean.

I would like to thank the fifty-four volunteers, who participated in the experiment of this thesis.

Finally, I am grateful to Professor Emeritus of the Department of Civil Engineering, of Aristotle University of Thessaloniki, Iraklis Chatziangelou, my beloved mentor and guardian, for infesting me with curiosity and love for science.

Table of Figures

Table of Contents

1. INTRODUCTION

1.1. Virtual Reality as a Social Medium

More often than not, unattainable science fiction turns into tangible technological advancement. Time and time again society generates an impalpable idea, reflects on its utilities and envisions its futuristic design. That initial moment of inspiration often turns out to be the starting point for innovations that -in reality- need decades before materializing, let alone become affordable commodities. Likewise, Virtual Reality (VR) was much closer to its centennial celebration than to its time of conception, when affordable VR headsets such as Samsung Gear VR[1], Oculus Rift[2] and HTC Vive[3] breached into commercial use. Of course, VR research has been around for much longer, diffusing into every possible field of science [1-4], yet once such technologies go mainstream it is guaranteed that their growth rate will skyrocket.

The key reasoning of this thesis is that such mainstream products eventually turn into social mediums. In fact, it took a split second for Starship[4] to develop vTime[5], whereas AltspaceVR[6] began developing marketable VR content in 2013, in anticipation of the above-mentioned VR devices. Such companies are already labeling their software as 'social VR' and generate immersive virtual worlds where users can meet and interact with one another. Although still under development, it will not be long before motion control and haptic feedback become affordable enough to add as expansions to such VR software, expanding the sensorial input and output between users and virtual environments (VEs). Thus, it is imperative to examine the possible impacts of experiencing VR not only in itself but as an uncharted space which recreates or even generates social context and facilitates social interaction.

However, due to the nature of any VR system, the ability for individuals to engage in social behavior is preceded by various technical and contextual features, with the most dominant in current VR research being *presence* and *body ownership illusion* (BOI). Achieving *presence,* which is the sense of *being there*, is mandatory for users to fully transcend their mental awareness into a VR environment. Whereas BOI, the perception that a virtual body substitutes a real body in real-time, allows for the virtual incorporation of the body as one of the most important communicative tools of any social engagement.

---

1 Released November 27th, 2015 (http://www.samsung.com/global/galaxy/gear-vr/).
2 Released March 28th, 2016 (https://www3.oculus.com/en-us/rift/).
3 Released April 5th, 2016 (https://www.vive.com/eu/).
4 Starship is a VR/AR Innovation company based in Liverpool, England (http://www.starship-group.com/).
5 Official vTime website: https://vtime.net/. In 2016, vTime was released for Google Cardboard, Oculus Rift and DK2, http://xinreality.com/wiki/VTime
6 AltspaceVR is a software startup company founded in 2013 and it develops social software for virtual reality environments. It features virtual spaces where users can interact, play games or watch films. It is available on HTC VIVE, Oculus and Samsung Gear VR.

1.2. Thesis objectives

The present thesis investigates the effect of social conditions on the perception of the virtual body as well as on the emotional and psychological state of the user; it also examines determinants of human behavior in VR social environments. Therefore, an experiment was executed where fifty-four (54) participants visited a virtual clothing store and were asked to try out an outfit by choosing either the virtual mirror placed in the central open area of the store, or a second virtual mirror which was behind a curtain, functioning as a dressing room. Participants were later asked to clarify their reasons for choosing one over the other.

In addition, this was a comparative study, as participants were divided in three groups and experienced three different experimental conditions. In the first condition they were alone in the clothing store, in the second a non-character player (NCP) in the form of a virtual salesman was present, and in the third a real actor controlled the salesman via real-time motion capture. In all three conditions, when participants reach one of the two mirrors to try out the outfit, their avatar's body is left naked with fully exposed genitals. Since participants were not previously informed of this development, their reaction was spontaneous and evaluated as such, along with any kind of fluctuation in regards of *presence*, BOI and emotional state between the three experimental conditions.

Once the experimental sessions were concluded, all participants were individually interviewed. The semi-structured interviews allowed for a more in-depth understanding of participants' experience, behavioral choices and emotional state in reference to the naked virtual body. These issues were specifically discussed in relation to the salesman's presence when participants were part of the respective experimental condition. Immediately after the semi-structured interviews all participants filled out questionnaires estimating their level of presence, BOI, comfort with the naked body, the salesman's presence and so on. Results were cross-checked and analyzed in relation to the literature review and the research hypotheses.

Results contribute to the current VR conceptualizations by proving that social components of any VR environment do in fact affect users and should thus be carefully studied for the effective design of shared and collaborative VR environments employed in educational, training, recreational and simulation applications.

1.3. Thesis structure

The structure of the present thesis contains five more chapters. The second chapter covers the historical development of the notion of Virtual Reality, along with the first implementations that most resemble current applications, as well as the theoretical framework that can be found in related research and which is in direct relevance to the experimental setup and conceptual basis of the present thesis. Chapters three and four present script-related development of the experiment and the architecture of the technical setup, along with detailed presentation of all software and hardware employed for the generation of the virtual experience. Finally, chapters five and six present the main findings of the present thesis and subsequent analysis and conclude the study by drawing directions for future work.

2. RELATED RESEARCH

2.1. A Short History

Virtual Reality (VR) is not a product of the Digital Revolution. Attempts of tracing its origins often place it in the beginning of the 20th century, which is somewhat accurate. However, the notion underlying VR, as a desire to transcend the tangible limitations of the material cosmos and experience an embodied illusion of transportation to an alternative environment, precedes any implementation. Biocca and Levy phrase it as the "search for the ultimate display" as they proceed to quote de la Roche's vision of a medium that would lead users to question reality; a vision expressed in 1760 [5]. Therefore, the desire underlying VR is a timeless pursuit of an experience or a sensation that is unhindered and free from the grounding realism that permeates natural life. In a twist of irony, that ideal can only be met with the use of natural materials.

In 1787, Robert Barker patent a design, where spectators standing in a centrally placed, elevated platform were surrounded by a circular canvas to create the illusion of a panoramic view [6]. This design became known as the "panorama" (see Figure 1) [6].

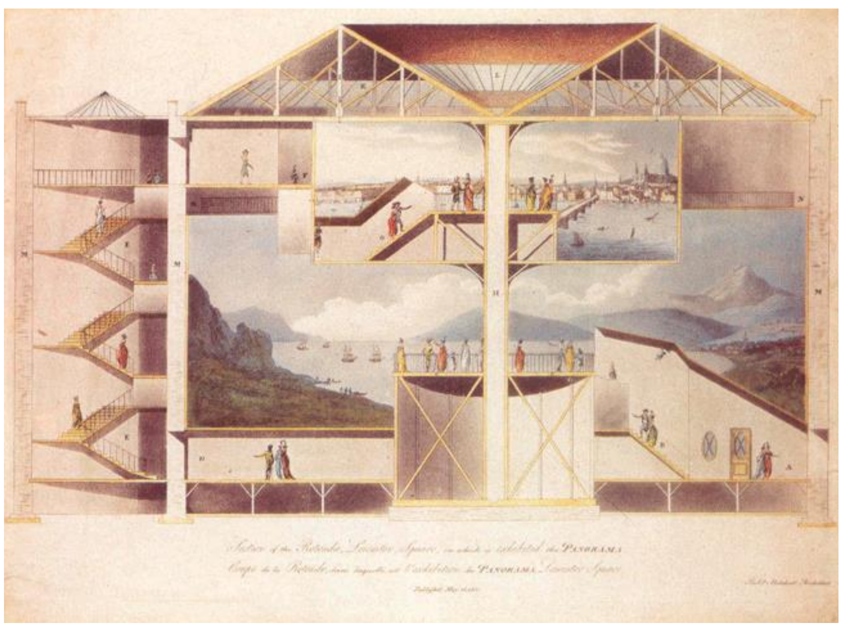


Figure 1: Robert Barker's Panorama Rotunda at Leicester Square London[7].

His technique in maintaining correct perspective with the use of a system of curves on the concave surface, allowed for viewers to feel that they are *in* the landscape, which appeared to be true and

[7] Image source:
http://oldemc.english.ucsb.edu/imprint/warner/protocols/protocols_of_liberty_chapter_6_barker_panoramas.html

undistorted [6]. In the spectrum of illusionism, such an innovation in depiction and representation, revolutionized the *image* [6]. As surprising as it may seem by today's standards, this illusion as an art form was controversial and a minority criticized the creation as having *too much* illusion in it [6].

This type of 360° imageries remained as the dominant way of transcending individuals *in the picture* [6]. Yet, in 1800, the *Institut de France*, requested the development of a smaller-scale apparatus and by 1838, Charles Wheatstone had invented the stereoscope [6]. The stereoscope freed the study of space perception from its object base [7]. The perception of three-dimensional space could be examined with paired two-dimensional pictures rather than with solid objects and the influence of disparity on perceived depth could be examined in isolation [7].

Years later, in 1857, Oliver Wendell Holmes would look through its lenses for the first time and that experience alone would result in a prophetic articulation of a technology that wouldn't arrive for another two centuries. In his words:

> *Form is henceforth divorced from matter. […] Matter will always be fixed and clear; form is cheap and transportable. […] The time will come when a man who wishes to see any object, natural or artificial, will go to the stereographic library and call for its skin or form* [5, 8].

The change of the century and the emergence of an avant-garde, which brought vastly different approaches, attempted to blend the observer *into* the experience by generating works of art in theatre, photography and cinema [6, 9]. The works of Futurists like Enrico Prampolini (1894 – 1956), Anton Giulio Bragaglia (1890 -1960) or Sergei Mikhailovich Eisenstein (1898 – 1948) echoed with aesthetic reform, which demanded from the audience to step into the picture. Such works have little to do with VR as it is understood today or even in the midst of the 20th century, but what they had to offer was a firm grasp of the underlying ideal of the VR experience [6]; a seamless union between the observer and the art-form, one that is soaked with emotional engagement.

Albeit, the materialization of VR was already approaching and the vision of it was clearer than ever. Aldous Huxley's *Brave New Word* (1931) introduced *feelies*, movies that involve touch in addition to sight and sound and Stanley Weinbaum's *Pygmalion's Spectacles* (1935) enclosed a literary definition of VR:

> *But listen -a movie that gives one sight and sound. Suppose now I add taste, smell, even touch, if your interest is taken by the story. Suppose I make it so that you are in the story,*

you speak to the shadows, and the shadows reply, and instead of being on a screen, the story is all about you, and you are in it. Would that be to make real a dream?

The time had come for a practical implementation and in 1957, Morton Heilig developed and patented the *Sensorama* [10]. This machine had users see a three-dimensional city display, hear the sound of the city, feel the wind and the vibrations of the seat and even smell certain scents, as the overall experience simulated a bicycle ride [10]. By all accounts, the Sensorama offered the first VR experience [10].

Soon after that came the first head mounted display, known as the Philco HMD and in 1968, Ivan Sutherland connected the first HMD to a VR environment [10]. The "search of the ultimate display" was not over, but the destination was set.

Ivan Sutherland and all his progenitors are the latest prophets in a long chain of VR prophecy. The vision that is expressed in this prophetic search for the ultimate display is more than just hype; it is desire. As with the Futurist manifestos, we often read and hear a technohubris fed by an age-old desire for physical transcendence [5].

2.2. Presence

In the early nineties numerous virtual environments (VEs) had already been designed in order to accommodate research towards an overall understanding of possible VR affordances. During those stages of development, it became clear that, as a field of research, it encrypted far more than its ever-present technical challenges, since even defining a VR environment proved to be an arduous task. For example, in 1991, Ellis defined VR environments as "interactive, virtual image displays enhanced by special processing and by nonvisual display modalities, such as auditory and haptic, to convince users that they are immersed in a synthetic space" [11].

However, such definitions -primarily concerned with the technological system of a VR environment- were inadequate to fully incorporate the resulting experience [12]. Steuer argued that, among other things, a device-driven definition left no ground for evaluating *medium* effectiveness, as well as impact, limiting social scientists or communication researchers [12]. A conceptual and analytical framework was required [12, 13], thus, *presence* received primary focus [12-15].

Several approaches arose, each relating *presence* to various VR experiential components. For instance, Heeter [14] distinguished three different types, based on whether *presence* is articulated in reference to the individual's feeling of being part of the VE (*personal presence*), the extent to which other beings also exist in the VE (*social presence)* and the extent to which the environment itself acknowledges and reacts to the immersed individual (*environmental presence*) [16]. Slate and Wilbur distinguish *presence*, as the sense of being in a VE, from *immersion*, which they define as an objective measurement referring to how immersive the VR system is, based on a set of technical features such as the field of view (FoV) [16]. The common conceptual denominator, found among the prominent approaches, is *presence as transportation*, that is the *sense of being there* [16].

Even though the concept of *presence* indeed assisted researchers towards a more in-depth understanding of the VR experience, similarly to the term *virtual reality*, no unequivocal definition can be found, but rather complementary views and theories. This possibly confirms Kalawsky's view that, *presence* serves as an "umbrella term for many inter-related perceptual and psychological factors" [17]. The *virtual body* and *social presence* are two of those factors.

2.3. Virtual Body and Body Ownership Illusion

The *virtual body* was introduced when Slater et al. [15] elaborated both on the concept and the technical aspects of self-representation in VR environments.

The VB in itself is usually an anthropomorphic [18] three-dimensional (3D) synthetic model which represents the user in the VR environment (avatar). Technical aspects of the VB refer to a centralizing flow of information towards the user, for which Slater et al. specifically use the word 'egocentric' [15]. This foremost, but not exclusively, relates to the viewpoint, which is better referred to as *first-person perspective*; a state where *all* is experienced in relation to the *self* since the viewpoint of the user is through the *eyes* of the VB [19].

The conceptual aspect of self-representation works by association; if my real-body movements are mapped to coincide with a 3D avatar's body movements, then, by association, that avatar's body is a representation of my own. This overall process of self-representation is what Slater et al. specifically term as *virtual body* [15]. To take matters a step further, if that real-body to virtual-body association had users stating, not just that "that avatar's body is a representation of my own", but "I am that avatar" then, *body ownership illusion* (BOI) has been achieved.

Several researchers have discussed, tested and experimented with BOI. For instance, initial studies attempted to cause *ownership illusion* over virtual limbs such as fingers and hands [20-23]. These attempts were an extension to Botvinick and Cohen's original, real-life 'Rubber Hand' experiment, where participants' vision, touch and proprioception were manipulated into achieving illusion of ownership over a fake rubber hand [24]. Techniques of this original experiment were in some way applied to VR as again users' vision, proprioception and occasionally sense of touch were manipulated into gradually achieving full *body ownership illusion* [25-31]. These studies also vastly contributed into determining the technical requirements and design features that may enhance BOI. For example, it has been proved that virtually reflecting real-time captured motion via a real-time virtual mirror may enhance BOI [32].

In addition, another interesting impact of the BOI is what Yee and Bailenson termed as the 'Proteus Effect[8]' [33, 34]. Their studies reveal how the physiological characteristics of an avatar affects users' behavior, for example, by causing variant levels of aggression based on how tall the avatar is [33, 34]. Most studies show similar impacts, as participants have been tricked into perceiving that a virtual entity of any ethnicity, gender, size or state could be them and thus, participants often appropriate behavioral and emotional traits that coincide with the appearance or state of that entity [26-31].

Researchers have indeed applied a plethora of experimental conditions, expanding the limits of the VB's effect on user experience. However, findings regarding the VB and BOI have not been exhausted in regards of their overall impact during a VR experience. As it is true for all VR-related features, the VB is also dependent on the technological implementations and capabilities of each VR system. Currently, VR technology is rapidly progressing, enhancing, among other things, the amount and quality of sensory information shared between the user and the VE. Sensorial input and output are the key elements of an embodied experience, thus, as the VR systems enhance level of realism, by implementing, for example, improved motion control and haptic feedback in real-time, the VB becomes a better, more elaborate communicative tool, a condition which relates to *social presence* and has not been studied so far.

2.4. Social Presence

Social presence is not exactly what Heeter suggests, even though it is relevant to whether other entities are present in a VE [14]. The prominent definition of *social presence* was coined by Short, Williams, and Christie. According to them, it determines the "degree of salience of the other person in the interaction and consequent salience of the interpersonal relationships" [35, 36]. Based on Bulu's review, this approach derives from a central hypothesis; that the level of *social presence* is directly proportional to the capability and quality of the communication medium [29]. For this to make better sense in relation

[8] In Greek mythology Proteus is either a minor god, a demon or a king and his name translates as 'the first' or 'the first born'. He had the ability to take any form he wished and some variations of the myth state that his matter generated all subsequent materials of the physical world.

to VR, it is important to clarify the context in which the term *social presence* has been occasionally used in VR research [16] and what the term actually relates to in communication studies, where it rightfully belongs.

In their survey paper, Schuemie et al. mention both *social presence* and *co-presence* as terms that appear in studies relevant to *presence* in general, and often the two terms describe the same thing; the sense of *being together* in a VR environment [16]. Related studies [37-39] examine the possibility of a positive correlation between *presence* and *social presence*, *co-presence* or even *togetherness* [40], alas, results are inconclusive as for instance Slater et al. do confirm a positive correlation [38], yet Axelsson et al. do not [39].

The underlying problem of these approaches, regardless of whether their results hold some truth, is that the term is not consistently defined. The definition by Short, Williams and Christie was in fact coined in reference to telecommunications [35]. Hence, Bulu's statement regarding the quality of the communication medium [36]. In other words, *social presence* measures the act of communication in itself and it is dependent on the medium used (e.g. face-to-face, telephone, computer-mediated communication) as well as the social dynamic between the individuals and subsequent social context under which the communication is taking place.

Therefore, *social presence* does not directly relate to the *sense of being together*, but rather, how that *sense* has an affective impact on individuals *when* their interaction is taking place within a VE. In short, *social presence* in relation to VR, makes sense only when the VR environment is addressed as a *communication medium* and compared to other mediums. This calls for an interdisciplinary approach, combining VR related concepts to methods and findings of communication studies [35, 41-47].

From a technical point of view, *social presence* requires the synchronous immersion into a VE of at least two individuals, who will engage in interaction and whose social characteristics will be taken into account and correlated not only to the interaction itself, but to the VE as well, since all aspects of the VE, the VB [48] and the technical system supporting the interaction may affect the social context of the interaction and thus the level of *social presence.*

As previously mentioned this thesis's motivation derives from a belief that VR will eventually turn into a *social medium*. As such, shared VEs and collaborative VEs will in time facilitate social interaction, hence the need to not only address user interaction with VR environments but also within them.

2.5. Social Context in VR research

Review of relating studies revealed that experiments specifically addressing the social factor of human-to-human interaction within VR environments are scarce. Some existing studies have focused on text-based mediums [49, 50] and online virtual worlds [36]. However, VR's potential as an affective social medium, an instrument that can elicit emotions as part of a broader social context, requires an extensive disquisition; before its commercial use breaches into established social networks. This thesis examines the impact of the social context within VR environments in direct relation to the VB and BOI.

3. THE NAKED VIRTUAL BODY EXPERIMENT

In our day to day lives, social context is defined by a vast number of factors, cues, signifiers and so on, which all individuals are expected to detect, abide by and therefore engage in socially and culturally appropriate behavior. Failure to do so has its own set of factors in determining necessity for correction; for instance, adults and toddlers are not similarly appraised for the same acts, making *age* a determinant for the assessment of an individual's behavior.

The basis for experimental design of this thesis, was an intent of generating social context within a VR environment. By simply labeling the VR environment of the experiment a *clothing store* and placing a few signifiers to support that, such as shelves with folded clothes and a register, participants drew a number of associated concepts based on their empirical understanding of what constitutes a typical clothing store. Thus, empirically, a *clothing store* is a public space, where the presence of a salesman or a saleswoman is expected, and most of all, undressing whilst in this space is neither uncommon nor frowned upon; in fact, change of clothes is often necessary even though it still needs to be visually confined from all other individuals. Therefore, all typical clothing stores are expected to facilitate at least one dressing room.

As already mentioned participants were arbitrarily separated in three groups (A, B and C), with each group experiencing a different condition (C1, C2 and C3 respectively). All participants visit the same clothing store, however group A (where C1 was implemented) does not encounter other characters, group B encounters a NCP salesman (C2) and for group C the salesman is controlled by a real actor via motion capture (C3).

Participants in all three conditions must collect and try-out a pre-ordered outfit. In order to take off their clothes they can choose one of two full-body virtual mirrors placed in the VR environment. One mirror is partially hidden behind a curtain, functioning as a dressing room (dressing room mirror – DrM) and the second is in the central open area of the store (central room mirror – CrM). As soon as participants are standing in front of the mirror they are instructed to push a button on their controller thus revealing – to their surprise – a naked female or male virtual body with realistic, fully exposed genitals.

This experiment's primary goal was to examine whether participants would engage in specific behavior due to the social context assigned to the VR environment. It is important to clarify that the social context is not in fact deriving from the VR environment in itself, but assigned to the VR environment by the participants. That being said, the abnormal element of a fully exposed naked virtual body was intentionally introduced, as an unexpected occurrence. The abnormality is meant to challenge participants' level of comfort and thus cause a state of alertness, but mostly to confirm that they did in fact assign a social context in which full nudity and/or public nudity is not appropriate social behavior.

Moreover, the clothing store is sufficient in order to generate a specific social context. However, similarly to everyday interactions, individuals feel more compelled to abide by a social norm when other individuals are present or engage in the interaction. That is why the variant experimental conditions are based on whether another character is present and by extent, how realistic that character is (NCP versus real actor).

Participants' reactions were closely observed and analyzed in combination to all of the VR research-related concepts presented in the second chapter of this thesis. The basic hypotheses were drawn in reference to the social context's impacts on participants':

a) behavior and emotional state, and

b) their level of *presence* and BOI.

More specifically, choice of mirror and subsequent justification of that choice, is regarded as a behavioral determinant, even more so since it precedes the VB's exposure which participants have no prior knowledge of. Also, during the moment of the VB's exposure, participants' emotional state is recorded and reviewed according to each condition. It is considered that an emotional variance may be confirmed even in C1, as a general anxiety of being watched due to the overall social context (public clothing store). Finally, the unexpected occurrence of the naked body may fluctuate level of *presence* and BOI, especially in C2 and C3.

4. MATERIALS AND METHODS

4.1 Participants

The VR experiment had been advertised around the university campus. No prerequisites were set and no script-related specifics were made public. The final sample consisted of 54 volunteers (31 females), mostly undergraduate students between the ages of 19 to 39. The vast majority had no previous experience with VR technology. Experimental sessions took place from the 21st till the 28th of September of 2016.

4.2. Experimental Design

All fifty-four (54) participants visited a virtual clothing store to collect a pre-ordered outfit. Eighteen (18) were arbitrarily assigned to group A – C1 (11 females), nineteen (19) to group B – C2 (11 females) and seventeen (17) to group C – C3 (9 females).

The first group (A) did not encounter other characters within the VR environment and instructions were text-based. The second (B) and third groups (C) encountered a virtual salesman, who in group B was a non-player character (NPC) and in group C was a 3D human model controlled via real-time motion capture data based on the motions of a real actor. Groups B and C received auditory scripted instructions, which were pre-recorded for group B, but spoken in real time by the actor via intercommunication for group C. All participants could hear their avatar's footsteps as well as an ambient sound resembling a silent room.

The experiment was carried out in two conjoint rooms of a research laboratory; the first room hosted private individual participant sessions, whereas in the second room was the actor who wore the motion capture equipment and controlled the salesman for C3. Participants encountered only the female researcher of the present thesis, who was responsible for scheduling and monitoring sessions, including orientation and interviews. Thus, participants did not encounter or had any knowledge of the male actor in the next room.

Upon arrival, participants were greeted by the female researcher and were provided with a written description of the equipment that would be used. This included a head mounted display (HMD), a standard gaming controller and an audio headset. Participants were not aware of the group division or the specific characteristics of each of the three conditions.

Before entering the virtual store, participants spent a few minutes in a smaller rectangle virtual room, referred to as *anteroom*, which only contained one full-body mirror (see Figure 2). Verbal instructions and assistance were provided by the female researcher who was monitoring the sessions. In the *anteroom* participants were given the chance to practice orientation and virtual locomotion. Also, the *anteroom* allowed participants to realize that their head movements were being tracked to match the avatar's head movements, therefore when looking towards the floor they saw the avatar's chest and legs and when facing the avatar's reflection all real-head movements were corresponding to the avatar's head movements in real-time. Finally, female and male avatars were assigned to female and male participants, respectively (see Figure 3).

Figure 2: Top view of the anteroom.

Figure 3: Female and male 3D human models.

Once in the clothing store the female researcher did not provide any further assistance and participants had to follow scripted instructions within the VR environment where the execution of the main experimental session took place.

The virtual clothing store was designed as a square room featuring a few shelves with folded clothes, a register, a full-body mirror opposite the register, therefore in the central open area of the store (CrM), and a second full-body mirror to the right of the register, partially hidden behind a curtain, forming a small dressing room (DrM) (see Figure 4). If behind the curtain, participants had no visual contact with the register and subsequently no visual contact with the salesman who took his place behind the register -in both C2 and C3- as soon as users entered the store.

Figure 4: Top view of the clothing store.

Upon entering the clothing store participants were encouraged via scripted instructions to explore the store until the appearance of their ordered outfit on top of the register, which was programmed to occur after forty (40) seconds. Once the outfit appeared, they were invited to approach the register and collect it by pressing a button on their controller. This activated the virtual hand's animation and participants could see it extending as if picking up the item (see Figure 5). The item then disappeared and it is assumed they have it in their possession.

Figure 5: Virtual hand reaching out to pick up the outfit.

To try out their outfit, participants were instructed to walk towards one of the two mirrors, stand directly in front of it and then press a button on their controller. Regardless of the mirror they would choose, the resulting outcome was the same; their avatars performed an animation – as if taking off their pants – and their original clothing instantly disappeared revealing a naked female or male VB with realistic, fully exposed genitals (see Figure 6).

Figure 6: Naked male and female avatar (no censorship was used for the experiment).

After being left for a few seconds without any further instructions and whilst still wearing the HMD, participants were asked to state their dominant emotion. This concluded the experimental session and they could take of the equipment.

4.3. Technical Setup

4.3.1. Design of Virtual Environment and Avatars

4.3.1.1. Virtual Clothing Store Space

The 3D modelling of the virtual clothing store space, along with the texture assignment and baking, was created using Cinema 4D[9], a 3D modeling, animation, motion graphic and rendering software developed by MAXON[10] (see Figure 7). The models used to represent the virtual clothing store were kept as simple as possible, featuring low number of polygons, in order to avoid high real-time rendering times which could affect participants' experience. However, the major challenge during the above process was the registration of the virtual clothing store coordinates to the ones of the real motion capture room, where the salesman actor would perform. To address this, during the modelling stage in Cinema 4D, the measurement unit of the virtual clothing store was set to meters, assisting into properly estimating the size and dimensions of the objects in the virtual space.

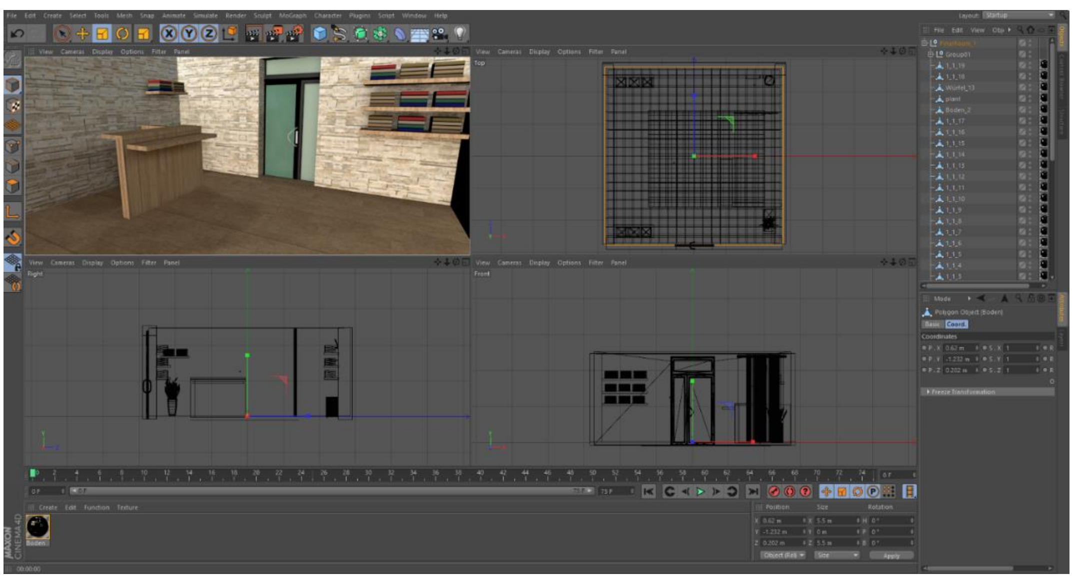


Figure 7: Virtual clothing store modelling in Cinema 4D.

[9] https://www.maxon.net/en/products/cinema-4d/overview/
[10] https://www.maxon.net/en/

Another issue that emerged during the virtual clothing store modelling process was the inability to virtually represent a clothing store of any surface area, since the virtual space's surface area had to coincide with confined space (10.5m^2) of the motion capture room where the salesman actor would perform. Therefore, the virtual space of the clothing store was set to 30.25m^2 of which only a section coincided with the actual motion capture room's surface area. Based on the limits of the surface area in which the actor was able to physically move, Figure 8a shows the respective virtual area where the Salesman could cover without causing inconsistencies during the virtual experience (for example, the model of the salesman 'freezing' or disappearing). Naturally, that area had to include the register, where the Salesman stays for the most part of the experimental sessions.

In order for the actor to be able to detect the possible areas of action, duct tape was used to mark the virtual objects' *location* (e.g. the register and the curtain) in the real world (Figure 8b). This way additional *incidents* were also avoided, such as the salesman walking through virtual objects.

(a) (b)

Figure 8: (a) Salesman actor performance area (highlighted in red color); (b) Virtual reception edges marked with duct tape on the motion capture room floor.

Upon finishing the modeling process, the virtual store was exported from Cinema 4D as an FBX[11] file and then imported into Unity 3D, one of the most prominent 3D game developing platforms[12].

The first task in Unity 3D was the adjustment of the lighting conditions of the virtual clothing store space, so that they appear seamless and natural. Several *Point Lights*[13] were placed in the store with their

[11] http://www.autodesk.com/products/fbx/overview
[12] https://unity3d.com/
[13] https://docs.unity3d.com/Manual/Lighting.html

Intensity[14] and *Range*[15] adjusted to ensure proper lighting conditions that would not distract participants, whilst still showcasing details of the virtual space and the 3D avatars (Figure 9).

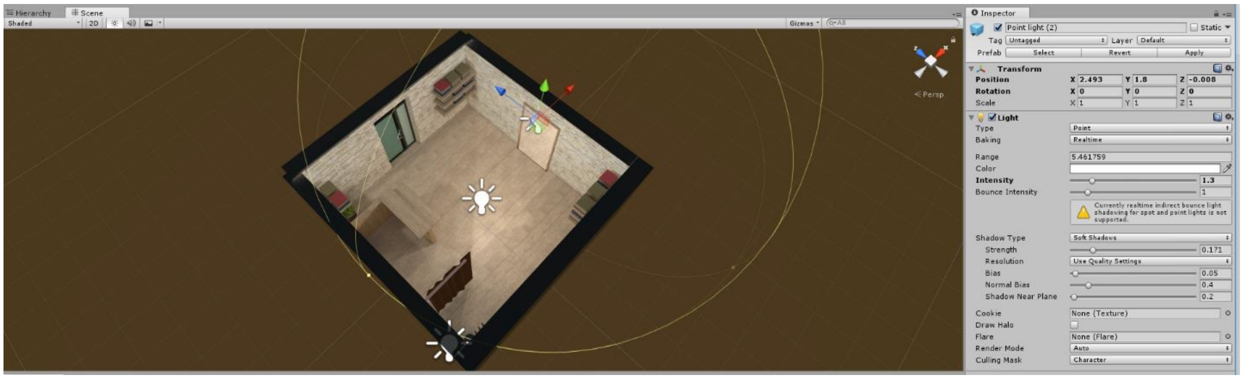
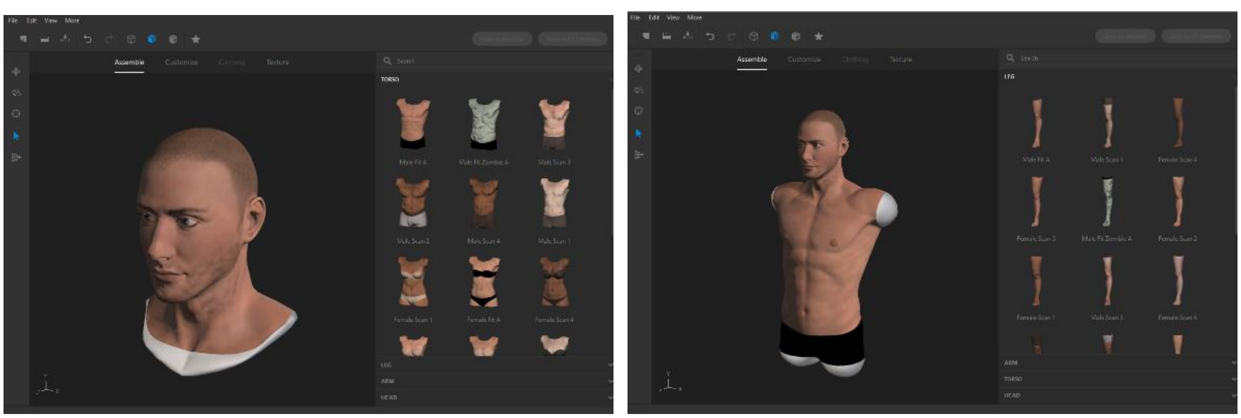


Figure 9: Using virtual lights to adjust the lighting conditions of the clothing store.

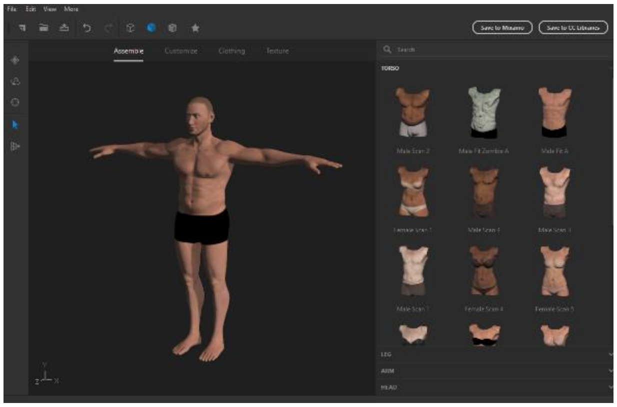
5.3.1.2. Avatars, animations & scripted behaviors

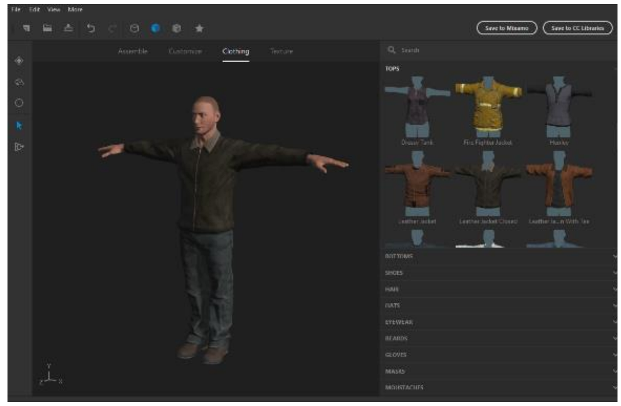
The main software used for the creation of the 3D avatars was Adobe Fuse[16], a character design software featuring customizable human 3D models. Adobe Fuse offers a pre-defined collection of basic human body parts, thus the user of the software may choose a head (see Figure 10a), a torso (see Figure 10b), and selecting legs and arms (see Figure 10c). The generated character may then be dressed utilizing a collection of *clothes* and *outfits* provided by the software (see Figure 10d). Finally, the generated 3D model can be manipulated in detail, adjusting characteristics like hair style, eye color and even facial expressions (see Figure 10e).



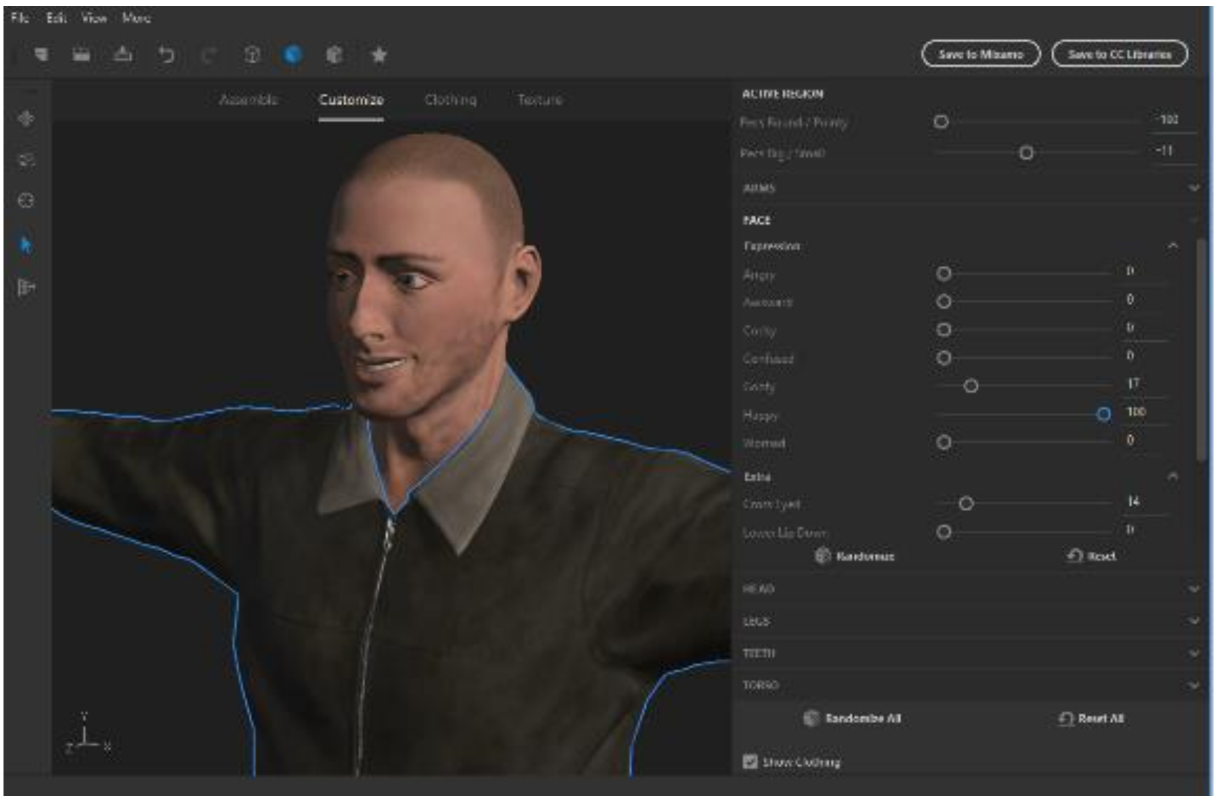
(a) (b)

[14] https://docs.unity3d.com/ScriptReference/Light-intensity.html
[15] https://docs.unity3d.com/ScriptReference/Light-range.html
[16] http://www.adobe.com/products/fuse.htmls





(c) (d)



(e)

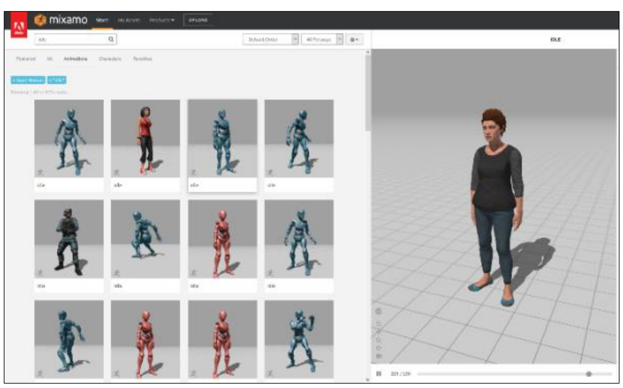
Figure 10: (a) Selection of 3D avatar head part; (b) Selection of 3D avatar torso part; (c) Completed 3D avatar physique; (d) Selection of 3D avatar clothing; (e) 3D avatar facial characteristics manipulation.

5.3.1.3. Animations & scripted behaviors

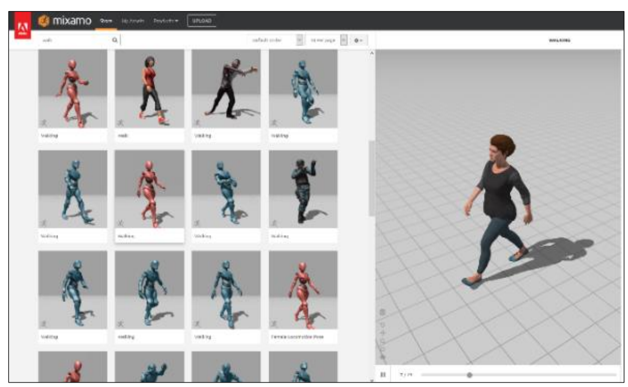
The 3D models created in Adobe Fuse can be directly imported to Mixamo[17], a cloud-based platform where 3D avatar models can be rigged, skinned[18] and assigned with a variety of pre-recorded motion capture animations of both female and male actors. Therefore, the female and male 3D avatars, used in the experiment application, were imported to Mixamo and assigned with:

- An *idle* animation where the 3D avatars stand in a resting pose (see Figure 11a).
- A *walking* animation activated when participants moved the 3D avatars (see Figure 11b).
- A *pick-up* animation where the 3D avatar appears to be picking up an object by reaching out a hand, activated when the participants selected their pre-ordered outfit (see Figure 11c).
- A *squat* animation where the 3D avatars appear to be taking off their pants, activated when participants approached one of the mirrors and tried out the pre-ordered outfit (see Figure 11d).

The above mentioned animations were used for animating the participants' 3D avatars, in all three conditions of the experiment (C1, C2, C3). The Salesman 3D avatar was also imported into Mixamo and assigned with *idle* and *walking* animations. Moreover, the Salesman 3D model was assigned with a *hand-wave* animation performed upon welcoming the participant when the latter entered the store (see Figure 11e). Salesman 3D avatar animations were only required for C2.



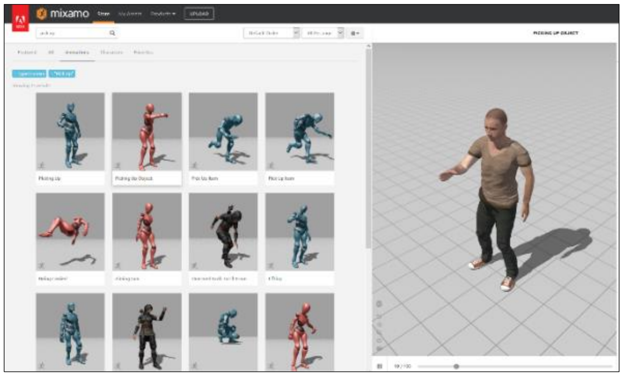
(a)



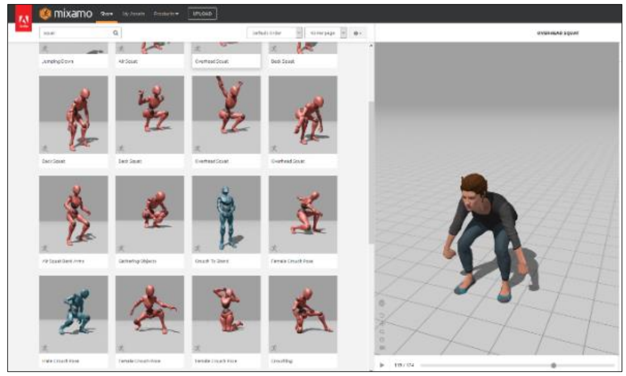
(b)

[17] https://www.mixamo.com/

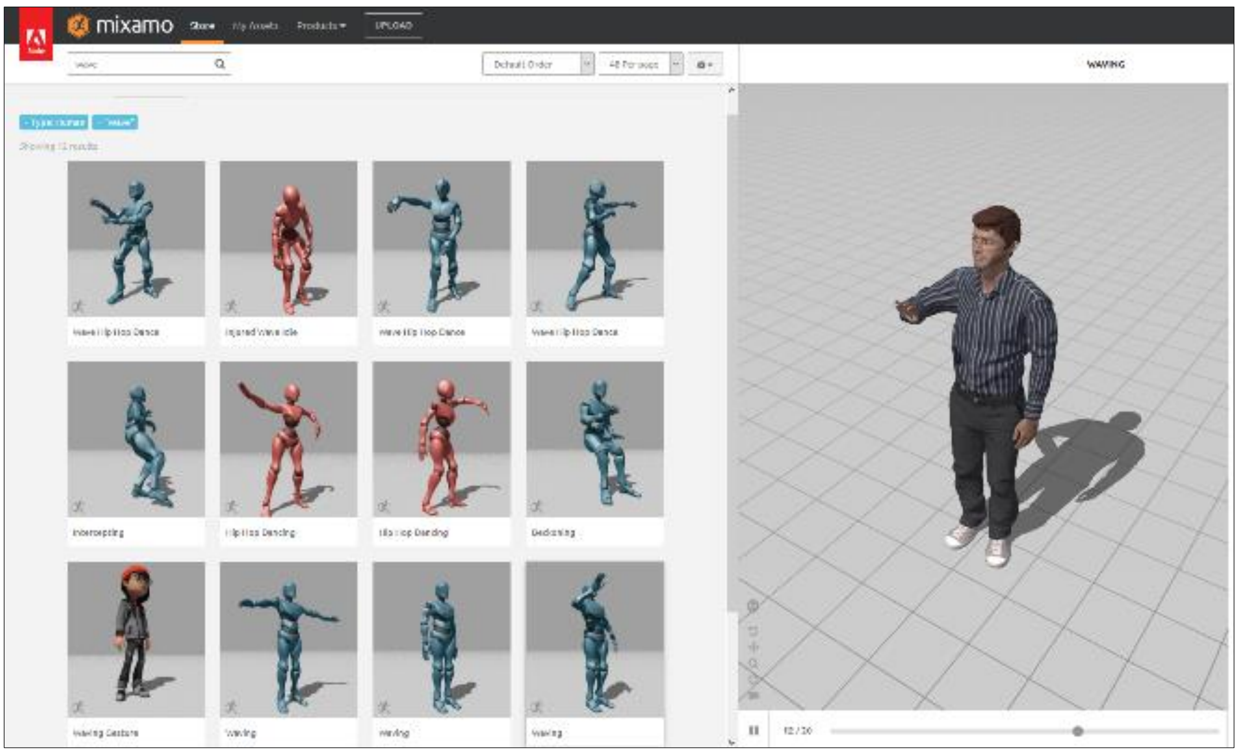
[18] Rigging refers to the process of creating a skeleton of joints (bones) to control the movements of a 3D character, while skinning includes the process of attaching the 3D character model mesh to the skeleton. (https://docs.unity3d.com/Manual/Preparingacharacterfromscratch.html)



(c)



(d)



(e)

Figure 11: (a) Female 3D avatar idle animation assignment; (b) Female 3D avatar walking animation assignment; (c) Male character pick-up animation assignment; (b) Female 3D avatar squatting assignment; (e) Salesman 3D avatar wave animation assignment.

Mixamo fully supports Unity 3D integration allowing the users to download a collection of animations assigned to a 3D avatar and import it into Unity 3D (see Figure 12).

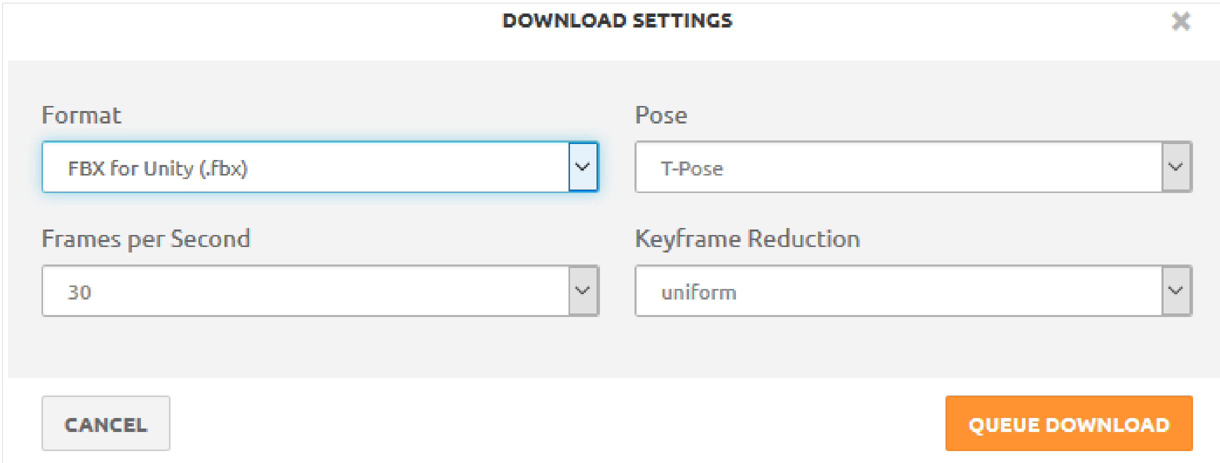


Figure 12: Mixamo to Unity 3D export platform.

After importing the 3D avatars into Unity 3D, its built-in Animator tool was utilized to adjust their behaviors. The Animator tool allows for setting conditions in order to control the playback of the animations assigned to a 3D avatar. Those conditions were associated with specific buttons of a Logitech wireless controller[19] so that the 3D avatar could *follow* participants' orders. For example, as Figure 13a shows, the 3D avatar was assigned with several animations. Upon the *Entry* state (executed when starting the application) the Animator arrow lead to the *idle* animation, set to *loop* as long as participants did not move their 3D avatar (see Figure 13a).

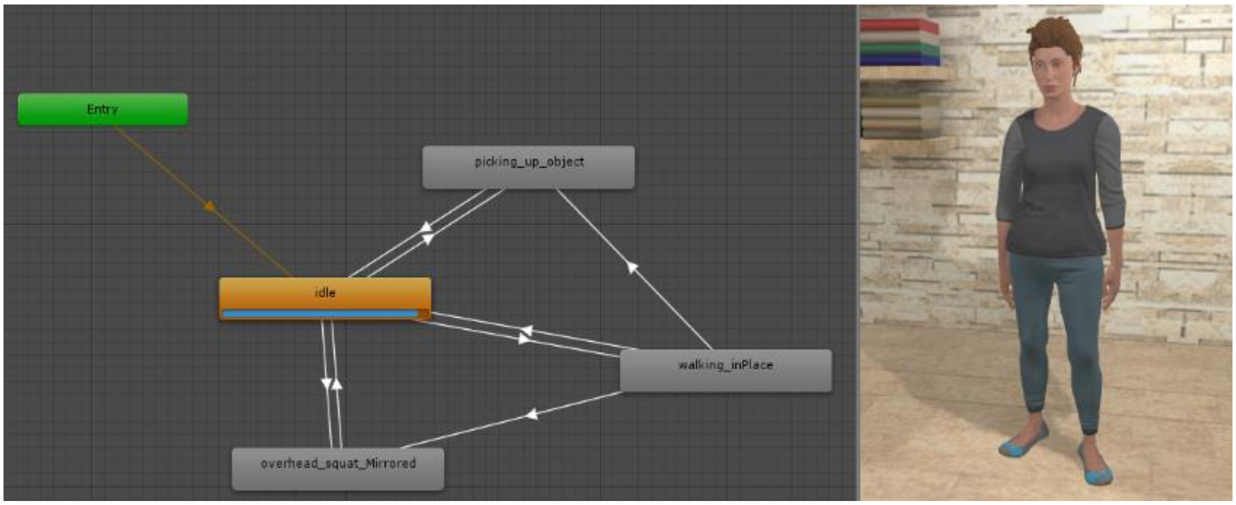
When participants pressed and held a button on the controller to move the 3D avatar, a C# script was executed setting as *true* an Animator condition which controlled the transition between *idle* and *walking* animations. Therefore, the 3D avatar would start moving, looping the *walking* animation (see Figure 13b), and transitioning back to *idle* animation when the button was released.

In some cases, more complex conditions were required for an animation to be activated, such as when the participants picked up the pre-ordered outfit. The *pick-up* animation required of the participants to press a button on the controller when in close proximity to the pre-ordered outfit. To test this condition Unity 3D Colliders[20] were used.

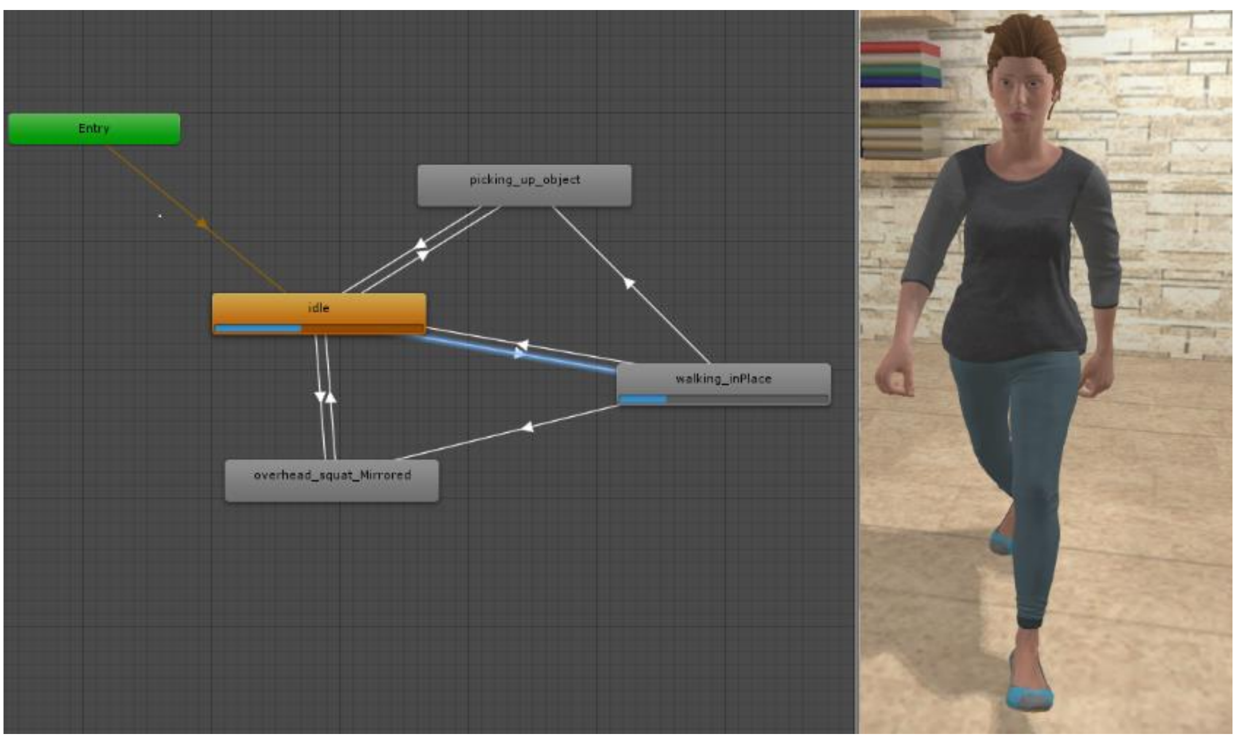
Colliders in Unity 3D feature as the shape of an object for the purposes of physical collisions, allowing developers to test via script if an object is in touch with another one. Therefore, a C# script was assigned to the 3D avatar, testing the collision between the avatar's collider and the collider of the pre-ordered

[19] http://gaming.logitech.com/el-gr/product/f710-wireless-gamepad
[20] https://docs.unity3d.com/Manual/CollidersOverview.html

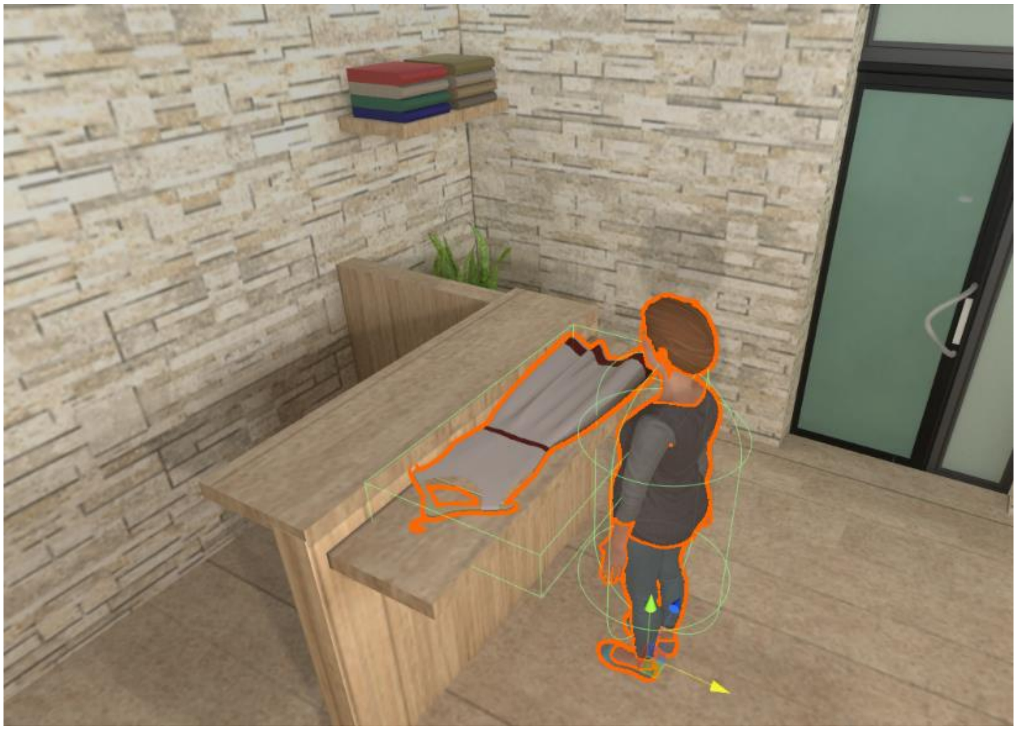
outfit, whenever the participant pressed the button assigned for picking up the pre-ordered outfit (see Figure 13c). Upon pressing the appropriate button, and If the collision existed, the *pick-up* animation was played and the avatar/participant picked-up the pre-ordered outfit. The same method was used to activate the *squat* animation when participants were in front of the mirrors, and also for scripting the behavior of the Salesman avatar in C2.



(a)



(b)



(c)

Figure 13: (a) Female 3D avatar idle animation loop; (b) Female 3D avatar walking animation loop; (c) Female 3D avatar collider, in collision with pre-ordered outfit collider.

4.3.2. Sound

In all three conditions, an ambient room atmospheric sound effect was played throughout the session in order to increase participants' *immersion*. Also, a *walking* sound effect was looped (footsteps) when the 3D avatars were walking. Additionally, in C2, pre-recorded instructions were played when participants performed certain actions, in order to simulate the salesman's voice. For example, when participants entered the store the salesman avatar welcomed them by waving his hand, whilst playing a pre-recorded sound message ("*Welcome, have a look around.*").

In C3, participants had the ability to verbally communicate with the salesman and vice versa via intercommunication. This was achieved by connecting two (2) headsets, equipped with microphones, to the computer where the VR application was executed (see Figure 14a). To support two (2) headsets in one (1) computer at the same time, VoiceMeeter[21] -a software which allows mixing audio sources and creating virtual audio devices (see Figure 14b)- was used.

[21] http://vb-audio.pagesperso-orange.fr/Voicemeeter/

(a) (b)

Figure 14: (a) VoiceMeeter software interface featuring multiple virtual audio devices; (b) Salesman actor and participant wearing headsets equipped with microphones.

4.3.3. Real-Time Motion Capture

Based on the experimental design, in C3, the salesman avatar's movements had to be based on a real actor's physical motion. In order to achieve this a number of technologies and software were combined.

4.3.3.1. Vicon Blade

Vicon[22] is a motion capture system which integrates both software and hardware to achieve optical capture, track and analyze motion. The motion capture process of Vicon starts with the calibration of several (10 for this experiment) Bonita cameras[23], commonly placed around the ceiling of a room and targeting its center (Figure 15).

Figure 15: Bonita cameras placed around the ceiling of the motion capture room.

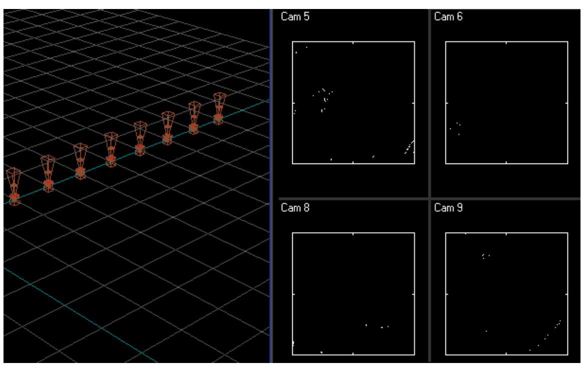
[22] https://www.vicon.com/

[23] https://www.vicon.com/downloads/documentation/vicon-documentation/vicon-bonita-quick-start-guide

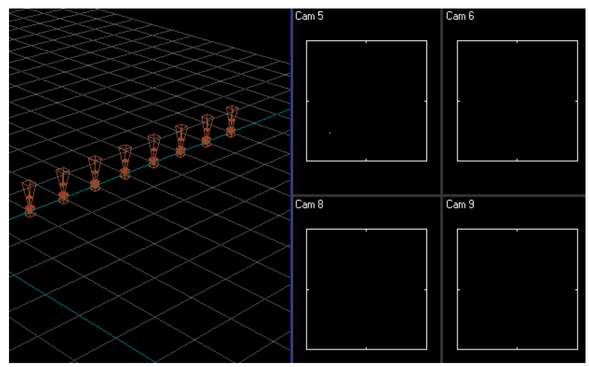
4.3.3.2. Camera calibration

To setup the Bonita cameras, Blade[24] was used. Blade features as the software part of the motion capture system providing full control of the Bonita cameras and the motion data they capture. The Bonita cameras calibration process, first requires aiming the cameras in order to properly focus based on the room environment. Next, an auto-threshold process is performed, were Blade decides which parts of the camera feed are affected either by lighting conditions or by retroreflective objects which should not be taken into account during the motion capture process to avoid errors (Figure 16b).

Then, the wand-wave process takes place. The wand is a cross-like item (Wand) featuring five (5) bright red lights. It is freely moved around the motion capture space (Figure 16c), until a specified number of frames are recorded (5000 was the limit for this experiment). This process allows Blade to understand the volume of the motion capture space in all three dimensions (Figure 16d). Finally, the wand is placed in the center of the motion capture room triggering the *Set Origin* process, in order for Blade to estimate the center of the motion capture area (Figure 16e). Upon finishing the above calibration process the Bonita cameras are relocated in the virtual space, based on their location in the real-world (Figure 16f).

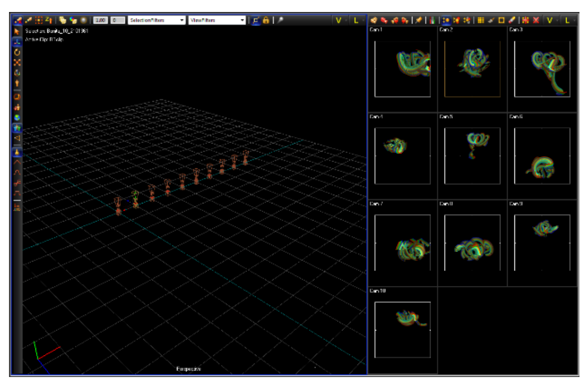


(a)



(b)

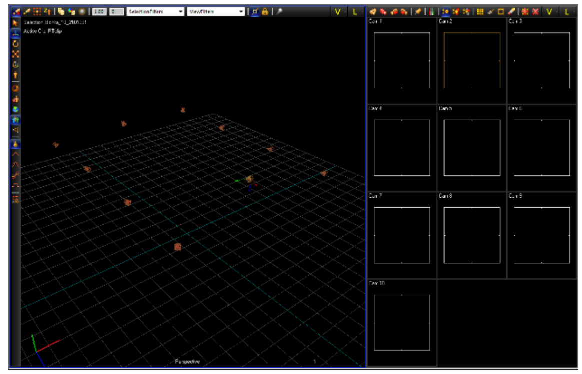
(c)



(d)

[24] https://www.vicon.com/products/software/blade

(e)



(f)

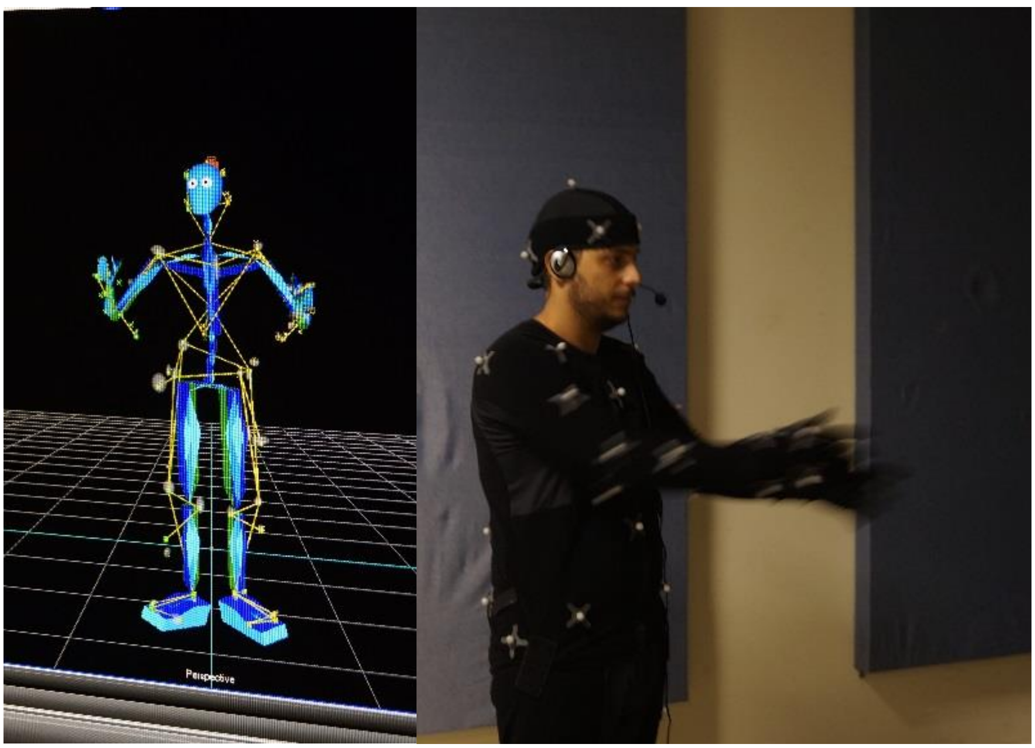
Figure 16: (a) Bonita camera feed prior to auto-threshold process; (b) Bonita camera feed after auto-threshold process; (c) Wand wave; (d) Data captured during wand wave process were red areas represent X axis, green areas Y axis, and blue areas Z axis; (e) Wand placed at the center of the motion capture room for the set origin process to take place; (f) Fully calibrated Bonita cameras.

4.3.3.3. Actor Calibration

When the Bonita cameras are calibrated, and for the motion capture to take place, Blade requires an actor to wear a number of retroreflective markers (54 used in this experiment), placed in certain places of the body (see Figure 17a), in order to detect core parts of the human physique (e.g. joints). Also, an actor calibration is required for Blade to acquire the Range of Motion (ROM) of each actor. ROM allows Blade to recognize the maximum distance a marker can travel, as well as distance among markers, thus personalizing actor's range of physical movement and physique. To determine ROM, the actor has to stand at the center of the motion capture room and perform a set of movements (e.g. raising both hands, bending, squatting etc.) which Blade will record accordingly (see Figure 17b). Blade then analyzes the recorded data and produces a temporary 3D avatar resembling the physique of the actor, and containing a number of *Bones*[25] which emulate the physique's skeleton (see Figure 17c). Once these calibration tasks are completed, Blade can solve the motion of the actor, recorded by the Bonita cameras, based on the retroreflective markers the actor wears, to the 3D avatar in real-time (see Figure 17c and Figure 17d).

[25] In 3D Skeletal animation the 3D avatar is represented by a mesh (a surface to draw the avatar) and a collection of interconnected bones (rig) used to animate the mesh.

(a) (b)



(c) (d)

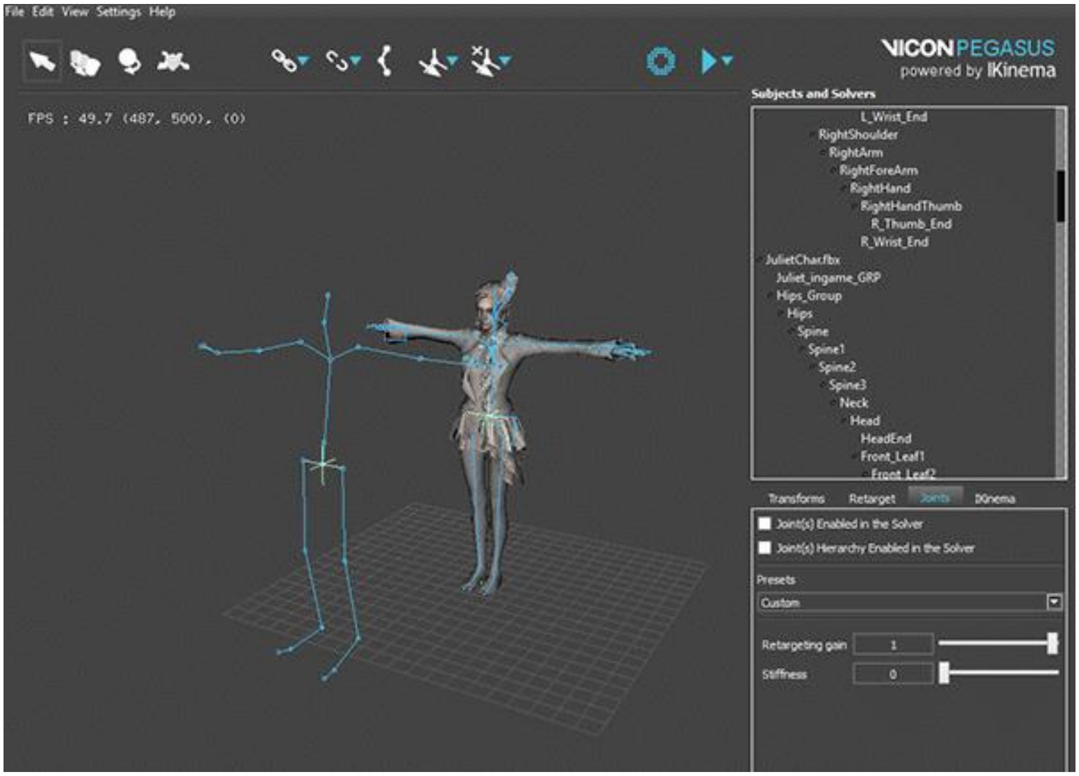
Figure 17: (a) Actor wearing retroreflective markers; (b) Actor performing for ROM capture; (c) Virtual representation of actor physique skeleton; (d) Actor performing with his motion transferred in real-time to the 3D virtual avatar.

4.3.3.4. Pegasus

Pegasus[26] is a retargeting and solving tool of the motion capture industry. It allows retargeting the motion capture data from Blade to other third-party applications, one of which is Unity 3D. Therefore, Blade provides Pegasus with motion capture data while the latter assigns it to 3D avatars, using the

[26] https://www.vicon.com/products/software/pegasus

skeletal information provided by Blade (see Figure 18a). Finally, utilizing the Pegasus Unity Plugin[27], the motion capture data can be transferred in real-time to a 3D avatar model in Unity 3D (see Figure 18b).



(a)

(b)

Figure 18: (a) Pegasus retargeting motion capture data from Blade to a 3D avatar model; (b) Real-time data retargeting from Blade to Unity 3D, through Pegasus, in real-time.

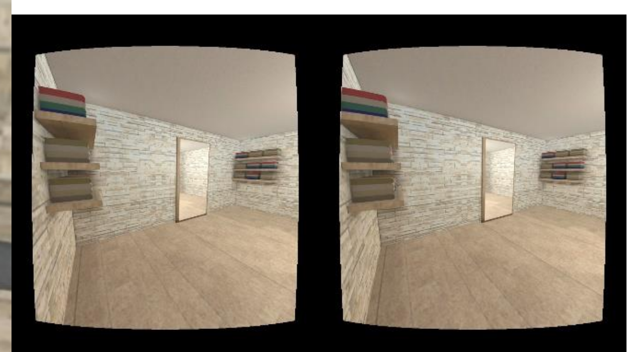
[27] https://www.vicon.com/downloads/3rd-party-plugins/3rd-party/pegasus-unity5-plugin

4.3.3.5. Virtual Reality

In order to allow participants to experience the navigation and interaction inside the clothing store using virtual reality, Trinus VR[28] was used. By importing the Trinus VR application into Unity 3D[29] and also by installing the Trinus VR application[30] on an Android smartphone, a two-way wireless communication between the smartphone and Unity 3D is allowed.

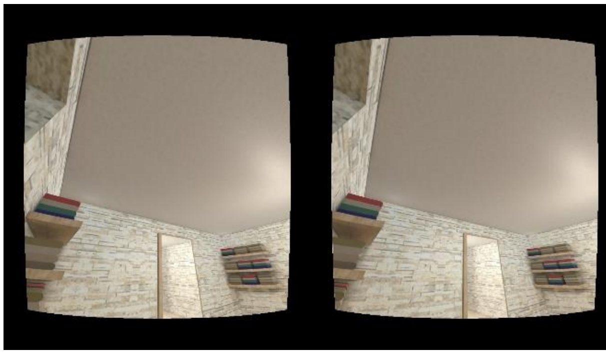
First, Trinus VR creates a virtual camera item inside Unity 3D, featuring as the eyes of the user (see Figure 19a), and creates a stereoscopic image of the virtual camera feed, wirelessly streaming it to the smartphone screen (see Figure 19b). Then, the gyroscope of the smartphone is used to track the users head rotation, accordingly adjusting the virtual camera rotation into Unity 3D (see Figure 19c). However, in the current experiment the rotation of the camera should be followed by the head of the 3D avatar. Also, the 3D avatar body should follow the horizontal rotation of user's head as well. Therefore, the original Trinus VR script was tweaked for the rotation vector provided by the smartphone gyroscope to affect the 3D avatar head rotation along with the rest of the body rotation as well (see Figure 19d). Finally, the smartphone was placed inside a Shinecon HMD equipped with two (2) magnifying lenses, allowing the participants to view the virtual reality content, and also be able to freely rotate their heads (see Figure 19e).

(a)



(b)

[28] https://www.trinusvirtualreality.com/
[29] https://www.assetstore.unity3d.com/en/#!/content/43781
[30] https://play.google.com/store/apps/details?id=com.loxai.trinus.full&hl=en



(c) (d)

(e)

Figure 19: (a) Trinus VR virtual camera adjusted to the 3D avatar eye level; (b) Trinus VR stereoscopic image streamed from Unity 3D to the smartphone; (c) Trinus VR virtual camera following the orientation of the smartphone; (d) 3D avatar head following the orientation of the smartphone.

4.4. Semi-structured interviews and Questionnaires

4.4.1. Semi-structured Interviews

Immediately after the completion of the main experimental session, semi-structured interviews, lasting up to fifteen minutes (15’), were carried out. All participants were asked to explain their criteria for choosing either the DrM or the CrM and whether they would have made a different choice had they known the outcome (nudity). They were also asked to elaborate on the dominant emotion they had previously stated whilst still wearing the HMD. Groups B and C where asked to express their overall impression about the salesman in regards of realism and level of *social presence*.

More specifically, participants were asked to discuss their level of awareness of other individuals’ presence, especially the salesman and specifically during the moment of the VB’s exposure. However, due to the variation in the experimental conditions, as well as choice of mirrors, this question was differently phrased for each participant. For instance, if in either C2 or C3 participants chose the CrM, they were asked to remember if they had looked through the mirror’s reflection to locate where the salesman was in an attempt to also check whether he was looking at them (which he was indeed programmed or scripted to do). Or for C1, participants were asked to remember whether during the moment of exposure they wondered who might be looking.

4.4.2. Questionnaires

All participants filled out a questionnaire immediately after the semi-structured interview. In total, group A answered 17 questions divided into three sets and groups B and C answered 30 questions divided into four sets. Questions were rated on a Likert scale from 1 (totally disagree) to 5 (totally agree).

For all three groups (A, B, C) the first two sets of questions were identical. Both the first set, measuring sense of presence, and the second, determining BOI (consisting of seven and three questions respectively), were formed by combining several previous studies, including analytical discussion of VR related questionnaires [30, 51, 52]. The third and fourth set of questions made reference to the effect of the scenery, the salesman’s and the researcher’s presence, participants’ sense of embarrassment and so on. These sets were combined into one for group A, as questions referring to the salesman were excluded.

The interviews were transcripted and later crosschecked against each participant’s questionnaire.

5. RESULTS

5.1. Presence and BOI

Out of the 54 individuals who participated in the experiment, 46 confirmed a feeling of *presence* and 40 confirmed experiencing BOI. Table 1 presents the average and median scores for the two set of questions that determine level of *presence* and BOI. Questions 1 to 3 are the most indicatory in determining success of *presence.* Both the median and the average scores for these questions indicate that *presence*, that is the *sense of being there*, was achieved. Questions 8 to 10, determining success of BOI, also reveal positive results.

Scores do not reveal any major fluctuation between the three conditions. Individuals responses are also evenly distributed between the three groups. Based on these results there is no indication that the mere presence of a second character in the VR environment, either in the form of a NCP or an actual user, enhances or decreases *presence* and BOI.

In addition, it was examined whether level of *presence* increased during the moment of the VB's exposure; out of the 8 participants who did not feel present in the VR environment, four confirmed an increase. Overall, 25 out of 54 participants confirmed an increase. However, these individuals are also equally distributed among the three study groups, which indicates that there is no correlation between the VB's naked state and the presence of a second character, at least not in a scenario were the second character is merely witnessing or standing close by to an event.

Table 1: Average and Median scores determining level of **presence** and **BOI**

	#	Item	Group A (C1)		Group B (C2)		Group C (C3)	
			AVER	MED	AVER	MED	AVER	MED
Presence	1	I had a feeling of *being inside* the virtual environment.	4.1	4	4.3	4	4.0	4
Presence	2	I felt surrounded by the virtual environment.	4.0	4	3.9	4	3.9	4
Presence	3	I felt as if I was acting from within the virtual environment (rather than manipulating it from above).	3.6	3.5	3.6	4	3.4	3
Presence	4	I was fully aware of the real room where the experiment took place (e.g. sounds, temperature, other individuals' presence).	3.2	3	3.5	4	3.3	4
Presence	5	Even though I felt *being inside* the virtual environment, I was still aware of the real room.	3.1	3	2.5	2	2.6	3
Presence	6	The virtual environment seemed completely realistic.	3.2	3	3.4	3	3.2	3
Presence	7	My experience in the virtual environment resembled my experiences in the real world.	3.3	3	3.3	4	2.8	3
BOI	8	When looking down I felt that the body I saw was my own even though it did not look like me.	3.7	4	3.8	4	3.4	4
BOI	9	When looking at the reflection in the mirror, I felt that that body was my own even though it did not look like me.	3.7	4	3.8	4	3.2	4
BOI	10	The matching of virtual body's movements to the natural movements of my head enhanced the feeling that that body is mine and I control its movements.	4.0	4	4.2	4	3.8	4

5.2. CrM versus DrM

Two categories were created based on the mirror participants actively chose. Those who chose the mirror in the central open area of the clothing store are placed under the CrM category and those who went for the dressing room, are placed under the DrM category. Out of the 31 participants who chose CrM, 13 expressed regret for doing so and that given the chance they would pick the mirror behind the curtain. That is why these individuals are also placed under the DrM category. Therefore, 36 participants are placed under the DrM category and 18 under CrM. Out of those 18 individuals who expressed no regret, sense of embarrassment or any form of discomfort, eight were in group A, four were in B and six were in C.

During the semi-structured interviews participants were asked to clarify their motives when choosing a mirror. Some motives, particularly proximity, were repeated several times and were used for both mirrors (DrM and CrM). Participants were always in front of the register when instructed to choose a mirror, since according to the script that instruction appears as soon as they receive their outfit from the register. However, there is no substantial difference whatsoever to validate that either of the mirrors is significantly closer to the register (see Figure 4).

In general, participants' responses in regards of their motives, were placed under three categories. The first category includes all responses that have no clear motive and were most likely a spontaneous reaction, such as: *it was closer*, *it was bigger*, *it felt more open*, *I just picked one*, *that's the one I remembered* and so on.

The second category includes all responses that do indicate some motive, but that motive is not to specifically cover the process of changing, from either the second character or the idea of other individuals entering the store. This category includes the *out of habit* response which also appears several times. Even though the *habit* of going to the dressing room in our everyday lives is in all respects related to an exposed body, it is considered that it is not necessarily an indication of self-consciousness, but may also be consideration towards other individuals or the norm of how regular shops function. In other words, even a conscious choice of the DrM does not equal coverage. Other responses of the second category include: *because it is more reasonable* (which again translates as socially acceptable) and *to experience the virtual dressing room*, as part of the VR environment.

Finally, the third category includes all responses that reveal intent for covering the process of changing either from the salesman or from the idea of other individuals. Naturally, most of the participants who are placed under this category come from C2 and C3. In total 11 individuals chose the DrM to specifically conceal the process of changing clothes even though they had no prior indication that the VB would be fully exposed.

5.3. Effect of the scenery: clothing store

Participants were asked to state whether the scenery – the fact that the VR environment was designed and labeled as a clothing store and thus a public space, rather than a private room – had any impact on their feelings in regards of the naked VB. There is a clear indication of a small increase for the two groups in which a second character was present. The exact same 3D model of the store was used in all three groups. Thus, at least two complementary conclusions can be drawn out of this:

a) The concept of *public*, as much as it might be *de jure* considered as such, is not in force until other individuals enter the premises or are at least noticed.

b) A character – in this case, the salesman – may be treated by users or players of a VR environment as an additional descriptive feature of the space. A store is not perceived as a store in practice, until an owner, a manager or a salesman appears.

Interestingly, a few of the participants made distinct comments referring to the possibility of 'other' people entering the store and seeing them. When asked why the salesman is not part of this 'other-people' group, they were baffled and unsure; one participant compared the salesman to a doctor, meaning that his position as a salesman makes it appropriate for him to witness a naked or exposed body. In general, participants could not validate this distinction with a clear answer.

5.4. Sense of embarrassment

Out of the 18 individuals who were assigned in group A and experienced C1, only one female confirmed a sense of embarrassment. That number increased by nine times for each of the other two groups. Overall, 18 out of 36 participants of C2 and C3 stated a feeling of discomfort, most of them naming it as *embarrassment*, *being uncomfortable* or feeling *awkward*. 16 stated that the source of their discomfort was the salesman, without being previously asked such a thing; meaning that they weren't directly asked to point the salesman as their source of discomfort. Two male participants, who both confirmed being present in the VR environment, named the female researcher, who was with them in the room during the experiment, as the main source of their discomfort. The same female of the first group was the only participant to also name the researcher as an additional source to her feeling of embarrassment. Overall, out of the 19 participants who experienced a sense of embarrassment during the moment of the VB's exposure, only two males indicated the researcher as the solemn cause for their embarrassment.

In total, during the moment of the VB's exposure 19 out of 54 participants experienced negative emotions such as embarrassment, discomfort and awkwardness. At least 8 individuals expressed positive emotions, such as amusement, sense of comfort and sense of freedom. The remaining 27 used terms such as *normal* or remained completely neutral stating they have no particular emotion towards the state of the naked VB. 12 of those were in group A, where there was no other character present. Additionally, 12 out of 27 who did not express any emotion towards the body had chosen the dressing room mirror (5 in group A, 5 in group B, 2 in group C).

6. CONCLUSION

The most important indication of this thesis is that the majority of participants assigned the expected social context to the clothing store. This conclusion is drawn based on the DrM versus CrM results, where in total, 36 participants are placed under DrM. Choice of the DrM is not solemnly associated with a sense of embarrassment or intention to conceal the process of changing clothes. The *out of habit* responses and the *because it is reasonable* responses are also an indication of assigning a specific social context to the VR environment and subsequently the virtual experience. Based on these results, it is considered that individuals are prone to handling information or events of a VR environment according to their existing social skills and knowledge.

In addition, the fact that individuals from groups B and C experienced negative emotions by nine times more than group A, proves that, even in a VR environment, individuals feel more compelled to abide by a specific social context when others are present or engage in the interaction. Therefore, even though the mere presence of the second character did not enhance or decrease *presence* or BOI, it did cause a drastic emotional response, which is almost nonexistent in C1. This means that even if *presence* and BOI are confirmed based on the prevalent methods of measurement, this confirmation is not indicatory of the quality of the experience, and, at least in regards of social interaction within VR environments, it should be complimented with measurements relevant to *social presence*.

The most unexpected outcome of this experiment relates to the juxtaposition of all relevant indicators between C2 and C3. In short, participants simply did not show any acknowledgment that the salesman was a real actor. A few were surprised at how intelligent the avatar was, by providing real-time answers, yet, none of the participants attempted to initiate conversation and test out the 'realness' of the salesman. Had they tried to do so, the actor was prepared to engage in conversation. It is assumed that they did not consider the probability of another user sharing the VR environment; it was regarded as implausible and as such it was more sensible for participants to perceive all verbal statements and movements of the C3's salesman to be pre-recorded or programmed. A different experimental setup could of course encourage participants to pay closer attention, nonetheless, this begs the question as to how easy will it be in future applications to determine whether an avatar is controlled by a real user, or whether we are interacting with an intelligent agent.

Virtual worlds and experiences are likely to induce real and most importantly, embodied experiences. In itself this is hardly a groundbreaking concept, it is however an uncharted one, as we are not aware to what extent and in what ways individuals will engage in social interactions within VR environments, what sort of virtual communities will be formed and how this medium will reform various spheres of social behavior especially under various social contexts.

Future research should incorporate the social context as a determinant of the VR experience and in addition, examine the level and impact of *social presence* when user's interaction is mediated via a VR system, taking place in socially defined VEs. Moreover, human-to-human interaction with the incorporation of motion control and haptic feedback, taking place in bigger and more complex environments is also in need of thorough investigation as this appears to be the direction towards which VR development is currently headed.

Although there is still much to examine regarding the technical and contextual parameters of VR in itself, its commercial use as a space that facilitates social interaction needs to be addressed before it overtakes ongoing research by simply generating too much data.

REFERENCES

[1] G. Lorenzo, A. Lledó, J. Pomares, and R. Roig, "Design and application of an immersive virtual reality system to enhance emotional skills for children with autism spectrum disorders," *Computers & Education,* vol. 98, pp. 192-205, 2016.

[2] M. Ferrer-García and J. Gutiérrez-Maldonado, "The use of virtual reality in the study, assessment, and treatment of body image in eating disorders and nonclinical samples: a review of the literature," *Body Image,* vol. 9, pp. 1-11, 2012.

[3] J. Psotka, "Immersive training systems: Virtual reality and education and training," *Instructional science,* vol. 23, pp. 405-431, 1995.

[4] C. R. Larsen, J. L. Soerensen, T. P. Grantcharov, T. Dalsgaard, L. Schouenborg, C. Ottosen*, et al.*, "Effect of virtual reality training on laparoscopic surgery: randomised controlled trial," *Bmj,* vol. 338, p. b1802, 2009.

[5] F. Biocca and M. R. Levy, *Communication in the age of virtual reality*: Routledge, 2013.

[6] O. Grau, *Virtual Art: from illusion to immersion*: MIT press, 2003.

[7] N. J. Wade, "On the late invention of the stereoscope," *Perception,* vol. 16, pp. 785 - 818, 1987.

[8] O. W. Holmes, "The Stereoscope and the Stereograph [1859]," *Photography: Essays and Images, London: Seeker & Warburg,* p. 54, 1980.

[9] A. G. Bragaglia, "Futurist photodynamism (1911)," *Modernism/Modernity,* vol. 15, p. 363, 2008.

[10] M. Mihelj, D. Novak, and S. Beguš, *Virtual reality technology and applications*: Springer, 2014.

[11] S. R. Ellis, "What are virtual environments?," *IEEE Computer Graphics and Applications,* vol. 14, pp. 17-22, 1994.

[12] J. Steuer, "Defining virtual reality: Dimensions determining telepresence," *Journal of communication,* vol. 42, pp. 73-93, 1992.

[13] W. Barfield, D. Zeltzer, T. Sheridan, and M. Slater, "Presence and performance within virtual environments," *Virtual environments and advanced interface design,* pp. 473-513, 1995.

[14] C. Heeter, "Being there: The subjective experience of presence," *Presence: Teleoperators & Virtual Environments,* vol. 1, pp. 262-271, 1992.

[15] M. Slater, M. Usoh, and A. Steed, "Depth of presence in virtual environments," *Presence: Teleoperators & Virtual Environments,* vol. 3, pp. 130-144, 1994.

[16] M. J. Schuemie, P. Van Der Straaten, M. Krijn, and C. A. Van Der Mast, "Research on presence in virtual reality: A survey," *CyberPsychology & Behavior,* vol. 4, pp. 183-201, 2001.

[17] R. S. Kalawsky, "The validity of presence as a reliable human performance metric in immersive environments," in *proceedings of the Presence Workshop'00*, 2000.

[18] K. L. Nowak and F. Biocca, "The effect of the agency and anthropomorphism on users' sense of telepresence, copresence, and social presence in virtual environments," *Presence: Teleoperators and Virtual Environments,* vol. 12, pp. 481-494, 2003.

[19] M. Slater and M. Usoh, "Body centred interaction in immersive virtual environments," *Artificial life and virtual reality,* vol. 1, pp. 125-148, 1994.

[20] K. Kilteni, J.-M. Normand, M. V. Sanchez-Vives, and M. Slater, "Extending body space in immersive virtual reality: a very long arm illusion," *PloS one,* vol. 7, p. e40867, 2012.

[21] K. Ma and B. Hommel, "The virtual-hand illusion: effects of impact and threat on perceived ownership and affective resonance," *Frontiers in psychology,* vol. 4, pp. 604-604, 2012.

[22] M. González-Franco, T. C. Peck, A. Rodríguez-Fornells, and M. Slater, "A threat to a virtual hand elicits motor cortex activation," *Experimental brain research,* vol. 232, pp. 875-887, 2014.

[23] K. Ma and B. Hommel, "The role of agency for perceived ownership in the virtual hand illusion," *Consciousness and cognition,* vol. 36, pp. 277-288, 2015.

[24] M. Botvinick and J. Cohen, "Rubber hands' feel'touch that eyes see," *Nature,* vol. 391, pp. 756-756, 1998.

[25] L. D. Walsh, G. L. Moseley, J. L. Taylor, and S. C. Gandevia, "Proprioceptive signals contribute to the sense of body ownership," *The Journal of physiology,* vol. 589, pp. 3009-3021, 2011.

[26] D. Banakou, R. Groten, and M. Slater, "Illusory ownership of a virtual child body causes overestimation of object sizes and implicit attitude changes," *Proceedings of the National Academy of Sciences,* vol. 110, pp. 12846-12851, 2013.

[27] K. Kilteni, I. Bergstrom, and M. Slater, "Drumming in immersive virtual reality: the body shapes the way we play," *IEEE transactions on visualization and computer graphics,* vol. 19, pp. 597-605, 2013.

[28] T. C. Peck, S. Seinfeld, S. M. Aglioti, and M. Slater, "Putting yourself in the skin of a black avatar reduces implicit racial bias," *Consciousness and cognition,* vol. 22, pp. 779-787, 2013.

[29] S. A. Osimo, R. Pizarro, B. Spanlang, and M. Slater, "Conversations between self and self as Sigmund Freud—A virtual body ownership paradigm for self counselling," *Scientific reports,* vol. 5, 2015.

[30] I. Bergström, K. Kilteni, and M. Slater, "First-person perspective virtual body posture influences stress: a virtual reality body ownership study," *PloS one,* vol. 11, p. e0148060, 2016.

[31] E. Kokkinara, K. Kilteni, K. J. Blom, and M. Slater, "First Person Perspective of Seated Participants Over a Walking Virtual Body Leads to Illusory Agency Over the Walking," *Scientific Reports,* vol. 6, 2016.

[32] M. Gonzalez-Franco, D. Perez-Marcos, B. Spanlang, and M. Slater, "The contribution of real-time mirror reflections of motor actions on virtual body ownership in an immersive virtual environment," in *2010 IEEE virtual reality conference (VR)*, 2010, pp. 111-114.

[33] N. Yee and J. Bailenson, "The Proteus effect: The effect of transformed self-representation on behavior," *Human communication research,* vol. 33, pp. 271-290, 2007.

[34] N. Yee, J. N. Bailenson, and N. Ducheneaut, "The Proteus effect: Implications of transformed digital self-representation on online and offline behavior," *Communication Research,* 2009.

[35] J. Short, E. Williams, and B. Christie, "The social psychology of telecommunications," 1976.

[36] S. T. Bulu, "Place presence, social presence, co-presence, and satisfaction in virtual worlds," *Computers & Education,* vol. 58, pp. 154-161, 2012.

[37] S. Thie and J. Van Wijk, "A general theory on presence," *1st Int. Wkshp. on Presence,* 1998.

[38] M. Slater, A. Sadagic, M. Usoh, and R. Schroeder, "Small-group behavior in a virtual and real environment: A comparative study," *Presence,* vol. 9, pp. 37-51, 2000.

[39] A.-S. Axelsson, Å. Abelin, I. Heldal, R. Schroeder, and J. Wideström, "Cubes in the cube: A comparison of a puzzle-solving task in a virtual and a real environment," *CyberPsychology & Behavior,* vol. 4, pp. 279-286, 2001.

[40] N. Durlach and M. Slater, "Presence in shared virtual environments and virtual togetherness," *Presence: Teleoperators and Virtual Environments,* vol. 9, pp. 214-217, 2000.

[41] T. W. Malone, K. R. Grant, F. A. Turbak, S. A. Brobst, and M. D. Cohen, "Intelligent information-sharing systems," *Communications of the ACM,* vol. 30, pp. 390-402, 1987.

[42] S. Kiesler and L. Sproull, "Group decision making and communication technology," *Organizational behavior and human decision processes,* vol. 52, pp. 96-123, 1992.

[43] R. Spears and M. Lea, "Panacea or panopticon? The hidden power in computer-mediated communication," *Communication Research,* vol. 21, pp. 427-459, 1994.

[44] J. B. Walther, "Computer-mediated communication: Impersonal, interpersonal, and hyperpersonal interaction," *Communication research,* vol. 23, pp. 3-43, 1996.

[45] T. Postmes, R. Spears, and M. Lea, "Breaching or building social boundaries? SIDE-effects of computer-mediated communication," *Communication research,* vol. 25, pp. 689-715, 1998.

[46] J. B. Connell, G. A. Mendelsohn, R. W. Robins, and J. Canny, "Effects of communication medium on interpersonal perceptions," in *Proceedings of the 2001 International ACM SIGGROUP Conference on Supporting Group Work*, 2001, pp. 117-124.

[47] E. B. Kerr and S. R. Hiltz, *Computer-mediated communication systems: Status and evaluation*: Academic Press, 2013.

[48] R. L. Birwhisttell, *Kinesics and context: Essays on body motion communication*: University of Pennsylvania Press, 1970.

[49] C. N. Gunawardena and F. J. Zittle, "Social presence as a predictor of satisfaction within a computer-mediated conferencing environment," *American journal of distance education,* vol. 11, pp. 8-26, 1997.

[50] L. Rourke, T. Anderson, D. R. Garrison, and W. Archer, "Assessing social presence in asynchronous text-based computer conferencing," *International Journal of E-Learning & Distance Education,* vol. 14, pp. 50-71, 2007.

[51] B. G. Witmer and M. J. Singer, "Measuring presence in virtual environments: A presence questionnaire," *Presence: Teleoperators and virtual environments,* vol. 7, pp. 225-240, 1998.

[52] M. Slater, "Measuring presence: A response to the Witmer and Singer presence questionnaire," *Presence: Teleoperators and Virtual Environments,* vol. 8, pp. 560-565, 1999.