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Transformative Realities: Unleashing the Potential of Virtual Reality for Enhancing Usability and Behavioural Change

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Abstract

In this thesis, we have explored how to enhance the usability, applicability, and practical implications of Immersive Virtual Reality by considering the challenges and opportunities associated with this technology. The thesis encompassed various domains from a multidisciplinary perspective to investigate these topics and advance the knowledge in the field. The research areas included addressing the usability aspect to provide solutions for simulator sickness in VR, investigating the relationship between embodiment and gradual changes in the light of the change blindness phenomenon to expand our understanding of their applicability in VR, and finally, exploring the practical, real-life applications of VR self-counselling through different virtual body representations in the context of personal problems and nicotine dependence.

Our research first addressed the significant technical challenge of simulator sickness, which is still prevalent in virtual reality systems. In **Simulator Sickness Experiments**, we found that altering the lighting parameter within a virtual environment could significantly mitigate simulator sickness by allowing faster movement, presenting a simple solution for future virtual environment design. Building on prior knowledge, our results showed that introducing a darker light at the beginning of the VR scenario could lead to faster movements of participants by enhancing the VR's overall usability and participant experience.

Subsequently, we extended our investigation to the embodiment, a fundamental aspect of immersive VR. In the **Qigong Experiment**, we focused on the issue of change blindness - a phenomenon where alterations in visual stimuli go unnoticed by the observer. This relationship is studied in a VR scenario of a Qigong training session, during which the participant's and the instructor's virtual bodies underwent gradual but profound transformations. Our findings revealed that these changes in the instructor body essentially went unnoticed by most participants, providing insights into the applicability of the intriguing intersection of these two phenomena for VR applications.

Moving forward, we investigated and exploited a paradigm for VR self-conversation, a method previously used to help change perspectives on personal problems. In **Self-Dialogue with a Virtual Future Self Experiments**, we considered the potential of VR self-counselling by comparing different counsellor representations to alleviate personal problems and its potential application in nicotine addiction research. Our first study, which compared lookalike, future, and generic counsellor representations in self-conversations about a personal problem, showed that a generic, gender-matched virtual body as the counsellor representation significantly improved psychological outcomes. In our second study that investigated VR self-conversation for nicotine dependence, we adopted a perspective that used the future self-continuity approach with VR self-counselling, enabling participants to have a self-conversation with smoker and non-smoker versions of their future selves, and compared these representations with their lookalike counsellor representation. Our results revealed considerable differences in pre-VR and post-VR behavioural nicotine dependence measures when the counsellor was depicted as a future self who continued to smoke.

This thesis investigated technical challenges and the usability of VR technology, offered new insights into the embodiment and change blindness, and expanded knowledge on the applications of VR self-conversation in dealing with personal and addiction-related issues. Overall, the transformative potential of VR was explored through multiple facets of VR, starting from a technical challenge, and moving to practical applications that demonstrated how immersive VR can lead to behavioural change.

Resumen

En esta tesis, exploramos la mejora de la usabilidad y aplicabilidad de la Realidad Virtual Inmersiva (RVI) desde una óptica multidisciplinaria, abordando tanto desafíos técnicos como prácticos. Central en nuestro trabajo fue la mitigación de la cinetosis en RV, donde identificamos que ajustes en la iluminación de entornos virtuales pueden mejorar notablemente la experiencia del usuario.

En el campo de la personificación virtual, investigamos cómo la percepción humana interactúa con cambios sutiles en entornos virtuales. Nuestro experimento en un escenario de Qigong virtual reveló que transformaciones graduales en los cuerpos virtuales a menudo pasan desapercibidas, aportando una comprensión valiosa sobre la ceguera al cambio en la RVI.

Además, nuestra investigación se extendió al auto asesoramiento en RV, evaluando su efectividad en la gestión de problemas personales y la dependencia de la nicotina. A través de estudios comparativos de diferentes representaciones virtuales del terapeuta, descubrimos impactos significativos en la conducta y perspectivas de los participantes, abriendo nuevas vías en el tratamiento de adicciones.

En resumen, esta tesis contribuye significativamente al entendimiento de los desafíos técnicos y la usabilidad de la RVI. Ofrecemos nuevas perspectivas sobre la personificación virtual y la ceguera al cambio, y evidenciamos el potencial de la RV en el auto asesoramiento y la terapia de adicciones. Nuestros hallazgos destacan el poder transformador de la RVI en aplicaciones técnicas, prácticas y terapéuticas.

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1. Introduction

"I felt the world needed a tool for the spontaneous invention of new virtual worlds that would express the stuff of the mind that was otherwise impenetrable. If you could conjure just the right virtual world, it would open up souls and math and love." (**Jaron Lanier**, Dawn of the New Everything: Encounters with Reality and Virtual Reality)

The public perception of Virtual Reality (VR) technology comes with the assumption and the misconception of it being a new technology with a short history. However, the development of the first virtual reality technology can be traced back to the 1960s. Ivan Sutherland created the first known augmented reality machine called The Sword of Damocles in 1968. This system was designed to be the ultimate display (Sutherland, 1965) and laid the foundation for the fundamental VR concepts in use today. Later, NASA Ames's The View system in the 1980s also contributed to the development of VR technology (Rosson, 2014). Around this time, Jaron Lanier coined the term "virtual reality" (Lanier, 1988) while working on the "Reality built for two: a virtual reality tool" (Blanchard et al., 1990).

Over recent years, computer graphics and display technology advances have significantly improved virtual reality systems' visual quality and immersion. The launch of VR head-mounted displays (HMDs) with higher resolution displays and broader fields of view, hand-held controllers, and other input devices such as the Oculus Rift (Hayden, 2021) and HTC Vive (Kumparak, 2015) contributed to the growth in sales of VR technology during the recent years. Concurrently, the later release of standalone VR headsets that do not require a connection to the PCs or additional cables, such as Oculus Quest in 2019 (Oculus VR, 2018), likely accelerated the expansion of the global VR headset market, the volume of the VR headsets worldwide was projected to reach a new peak of 27.25 million pieces by 2028 (Alsop, 2022).

Due to the advancements in hardware and the accessibility of VR technology, VR is gaining the public's attention. The powers of immersive virtual environments that produce various illusions, such as the feeling of "being there" (presence) (Held & Durlach, 1991; Held, 1992; Sheridan, 1992; Barfield & Weghorst, 1993; Sheridan, 1996; Slater & Wilbur, 1997; Draper et al., 1998; Bystrom et al., 1999; Sanchez-Vives & Slater, 2005), have become more prominent in research. The fields of cognitive neuroscience and psychology have been using immersive virtual reality as an experimental tool to investigate various research concepts, including those that would be impossible to test in the physical world, such as the outcomes of encountering near-death experiences (Barberia et al., 2018) and out-of-body experiences (Bourdin et al., 2017), being embodied in the body of a child (Banakou et al., 2013), Einstein (Banakou et al., 2018), Lenin (Slater et al., 2018), having conversations with Freud (Osimo et al., 2015; Slater et al., 2019) or interacting with oneself (Bailenson et al., 2001; Bailenson et al., 2005). When participants feel physically present in a virtual environment and perceive the experience as real, they are more likely to interact with and respond to the virtual environment naturally and realistically. Two essential components of "the feeling of presence", the sense of being physically there in the virtual environment, known as the "Place Illusion" (PI), and the feeling of what is happening in the virtual environment are happening, known as the "Plausibility Illusion" (Psi), can lead participants to exhibit more realistic responses to the virtual reality (Slater, 2009). Moreover, these illusions of VR are not limited to the experience of the virtual environment itself, and they can be originated from the experience of the virtual body. Both the "Body Ownership Illusion", the illusion of perceiving the surrogate body part (Lackner, 1988; Botvinick & Cohen, 1998; Ramachandran & Hirstein, 1998), or the virtual body as one's own body (Slater et al., 2008; Petkova & Ehrsson, 2008; Slater et al., 2010; Petkova et al., 2011; Kilteni et al., 2012), and "Illusory Agency", the attribution of the authorship over one's own actions even though the action was carried out by a virtual body (Tsakiris et al., 2006; Banakou & Slater, 2014: Kokkinara et al., 2016) contribute to the current excitement and anticipation of this technology by providing participants with the VR experiences that are difficult or impossible to replicate in real life.

It was proposed by Sanchez-Vives & Slater (2005) that "the feeling of presence" in virtual reality should be included as a subject of neuroscience in the study of its own right because of its potential for enhancing knowledge about consciousness; hence it should not be neither be limited to the technology-based fields nor solely used for understanding perception, self-representation, sense of self, and pathfinding. Therefore, the potential of immersive virtual reality technology can be intriguing as it can open up multiple possibilities, such as the case of engaging in conversations with one's future self, including enabling a form of mental time travel.

Besides, virtual reality can be used for a variety of purposes, including general applications for providing the treatments of mental health disorders; military, medical and surgical training; educational goals (Freeman et al., 2017; Spiegel, 2018; Slater, 2020) and for personal use that can offer opportunities for physical training, entertainment (Slater & Sanchez-Vives, 2016) and the movements with Yoga or Qigong exercises while embodying a virtual body in a virtual environment all while staying in the comfort of one's own home.

Given the numerous applications of VR technology in different fields, overcoming the physical world's limitations is likely achievable with the help of immersive virtual reality. However, despite the captivating nature of immersive virtual reality technology, it still has some shortcomings that need to be resolved, such as simulator sickness. Consequently, an in-depth understanding of the relationship between sensory, perceptual, and illusory mechanisms that contribute to the usability and the realistic experience of virtual environments while discussing these concepts from a general framework with the exploration of technical issues as well as the practical implications of this technology, is essential for unlocking the doors of *the right virtual worlds*.

1.1 Research Problem

This thesis explores specific challenges and opportunities within virtual reality (VR) technology, focusing primarily on addressing the problem of simulator sickness, investigating the relationship between embodiment and gradual change in virtual environments, and extending the applicability of VR self-conversation for addressing personal and addiction-related issues. The findings from these specific studies will be interpreted within a predictive coding framework to yield a more general understanding of the practical implications of VR technology.

Previous research facilitated the use of virtual reality to create immersive experiences and realistic simulations that cannot be replicated in real life. However, even though participants responded realistically to these immersive environments, the technology still comes with some disadvantages that can disrupt its *usability*. Simulator sickness (SS) is a condition characterised by symptoms similar to motion sicknesses, such as nausea, dizziness, and headaches that can occur because of prolonged exposure to VR environments (Kennedy et al., 1993). Unfortunately, these unpleasant symptoms decrease the enjoyment of the virtual environment (Lin et al., 2002), and to this date, SS remains a problem that needs to be resolved. For this reason, we will initially investigate simulator sickness and present a method to decrease this fundamental problem for the *usability* of VR technology.

Later, we will extend our research to deeply understand one of the key illusions of immersive virtual reality, the body ownership illusion. Even though the body ownership illusion in virtual reality has been researched extensively, our goal is to extend the research of embodiment to explore *its relationship with the gradual change* in the virtual environments and *the impact of this relationship* on participants' perceptions to extend the current knowledge on *applicability* of virtual reality research for future work. During this investigation, we will broaden the research on body-ownership illusion by introducing *change blindness*, the visual perception phenomenon that happens when a stimulus in the visual scene undergoes a change without being noticed by the observer (Simons & Levin, 1997; Simons & Rensink, 2005), in a virtual reality scenario of Qigong training while exploring the impact of the gradual change when it occurs in the virtual body of the participant as well as in the virtual body of the instructor that participants interact within the virtual environment. One of the prior VR studies that explored change blindness-influenced methods in virtual reality demonstrated a promising technique called "change blindness redirection", which facilitated participants to navigate a larger virtual environment than the real environment without visual-vestibular conflicts or loss of presence (Suma et al., 2011). Correspondingly, the association between change blindness and bodily illusions must be investigated further to extend this phenomenon.

Additionally, we will continue our examination of the body-ownership illusion within the framework of VR self-conversation to delve into the applicability and practicability of virtual reality technology that is applied to real-life problems. Self-conversation in VR has been used in previous studies to enable the participants to converse with an alternate virtual version of themselves during body swapping by switching back and forth between two virtual bodies while simultaneously maintaining a self-conversation from the two different embodied perspectives. This self-conversation framework in virtual reality was previously demonstrated as a method to change the perspectives of the participants about a personal problem (Osimo et al., 2015; Slater et al., 2019), but we aim to carry forward this line of research to examine the impact of different representations of the virtual body of the counsellor during VR self-conversation for personal problems as well as test the feasibility of this technology for self-counselling of addiction situations, particularly for populations who suffer from nicotine dependence. During this investigation, we also consider the counsellor representations from the perspective of different temporal self-representations by facilitating a dialogue between one's present and future selves to provoke the mechanisms of future self-continuity (Hershfield et al., 2011).

Finally, the last goal of this thesis is to attempt to interpret the results of the experiments with a general framework to provide a better understanding of the underlying components of the findings. We aim to use the predictive coding framework (Friston, 2002; Friston, 2003; Friston, 2005), which views the brain as an empirical Bayesian device that operates by using prior experiences and expectations to create predictions about the incoming sensory information and updating these predictions as new information arrives while minimising the prediction error, to guide the interpretations of our findings.

1.2 Research Questions

To investigate the research problems mentioned earlier, we developed four hypotheses that are listed below:

Hypothesis 1: "*When moving through a dark virtual environment, participants can travel at a higher velocity and with less simulator sickness than when moving through a bright environment.*" To investigate this hypothesis, we created a virtual reality environment that consisted of a street where participants were instructed to move as fast as possible (Simulator Sickness experiments). In the first experiment, participants went through this street divided into four segments of alternating lighting conditions: dark-light-dark-light or light-dark-light-dark sections. While our initial hypothesis posited that the lighting conditions would affect participants' velocity, our findings revealed that the first environment encountered played a critical role in the experience of participants. To further conclude our results from the first experiment, we ran a second experiment using the same street with different lighting conditions. Participants moved through a purely light street or a street that started dark and gradually became light.

Hypothesis 2: "*The gradual changes in the owned and seen virtual bodies can lead to "change blindness" in virtual reality. Therefore, due to the special status of the self-representation giving rise to embodiment, changes to participants' own virtual bodies would be more noticeable than changes to another virtual body*". To explore this question, we created a virtual reality gym scenario to practise Qigong lessons where participants were embodied in gender-matched virtual bodies while following the exercises given by a gender-matched virtual instructor (Qigong Experiment). Both the body of the participant and the body of the instructor changed gradually during this scenario.

Hypothesis 3: "*Having a self-conversation about a personal problem by swapping between two virtual bodies, explaining the situation from a present-day lookalike body, and swapping bodies with a counsellor representation of a future self, will help participants to solve their personal problems*". We extended the previous studies of VR self-conversation by exploring the impact of different counsellor virtual bodies in the self-conversation framework (Self-Dialogue with a Virtual Future Self about Personal Problem, Experiment 1). To investigate the impact of different counsellor body representations on personal problem-solving, we created a virtual reality scenario in that participants had a self-conversation by swapping back and forth between two virtual bodies while explaining the problem in the self-body and trying to solve the problem in the counsellor body. Participants were provided with the counsellor's representations of different temporal selves, including their future and current selves as well as the gender-matched, general representation of the counsellor.

Hypothesis 4: "*Having a self-conversation about nicotine dependence by swapping between two virtual bodies, explaining the situation from a present-day lookalike body, and swapping bodies with a counsellor representation of different future selves, will help participants to decrease their behavioural and physical nicotine dependence scores*". Continuing from our previous hypothesis, in this study (Self-Dialogue with a Virtual Future Self about Nicotine Dependence, Experiment 2), we used the same virtual scenario but focused on understanding whether having a self-conversation with different counsellor representations of future selves, either a future self who quit smoking or a future self who still continues to smoke, can have an impact on different levels of nicotine dependence on people who are in the different stages of change of their smoking addiction.

1.3 Overview of the Thesis

This thesis presents the testing of the hypotheses mentioned above, analysing, and discussing the findings from these studies within the context of existing literature. It assesses how this research contributes to existing literature and identifies areas for future exploration.

Chapter 2 provides an overview of the relevant literature, establishing a theoretical foundation for the research presented in this thesis. Chapter 3 details the standard methods and materials utilised across all studies. Chapter 4 delves into the first hypothesis, examining the influence of varying lighting conditions on both speed and simulator sickness for enhancing the usability of virtual reality technology. Chapter 5 explores the second hypothesis by probing the relationship between the embodiment and the change blindness phenomenon. The goal is to understand how gradual changes in virtual environments affect participant perceptions on their own body versus the other body. Chapter 6 considers the third and fourth hypotheses, focusing on the usability, applicability, and feasibility of virtual reality technology for tackling personal issues and addictions within the framework of VR self-counselling. Finally, Chapter 7 encapsulates the research by concluding the findings and interpreting the results within a broader framework. It discusses the impact of these studies and their limitations and proposes directions for future research.

1.4 Scope of the Thesis

This thesis employs a multidisciplinary approach to explore ways to achieve its objectives, test its hypotheses and draw on theories from various fields outlined in Chapter 2 by tackling existing challenges of this technology, such as simulator sickness, providing an understanding of the gradual change these mechanisms concerning embodiment and further discussing the applicability and feasibility of body-ownership and immersive virtual reality with regards to different counsellor representations within the VR self-counselling framework for non-clinical and addiction settings while interpreting the results of all these experiments from the predictive coding perspective to present them with a general framework. The thesis also explores the effects of body ownership illusions and various virtual representations in immersive virtual environments on perceptual and behavioural changes. However, it does not detail the biological, neurobiological, or philosophical aspects of these mechanisms and the mechanisms of embodiment. We address that, throughout the experiments conducted in this thesis as a part of all three studies, we used the same brand of Head Mounted Displays (HMDs), specifically the Meta Quest 1 and Meta Quest 2, to present immersive virtual reality environments as described in detail in Chapter 3; therefore, some outcomes and limitations of these experiments are may only apply to this brand of HMDs.

In addition, one of the objectives of this thesis is to understand the underlying mechanisms to reduce simulator sickness in virtual environments, as mentioned in Chapter 4, and subsequently it offers a method to decrease simulator sickness and increase velocity by minor adjustments to the visual sensory input in the virtual environment. Similarly, our study explained in Chapter 5, is limited to exploring the relationship between change blindness and embodiment, specifically on the virtual bodies in virtual environments from the context of gradual changes in visual sensory input in virtual environments. Furthermore, the future self-continuity approach for self-conversation studies specified in Chapter 6 is used to specifically test the impact of different counsellor representations for solving daily problems or exploring the possible decrease in behavioural dependence scores for nicotine dependence to help participants to envision a version of the future self, one's aged rendered version of resembling a virtual body in the VR, but theoretical underpinnings of future self-continuity hypothesis and the methods of decreasing temporal discounting with the help of virtual reality are not investigated in this thesis. Finally, this thesis employs predictive coding theory solely to understand and interpret the outcomes of the experiments conducted; on the other hand, formulating and supporting the hypotheses with the help of predictive coding is out of the scope of this thesis.

1.5 Contributions of the Thesis

This thesis contributes to knowledge of immersive virtual reality research on how people perceive and interact with virtual environments. It presents techniques to improve the usability, applicability, and practicality of virtual reality technology, shows the impact of embodiment on change blindness, as well as illustrates the potential of VR in the context of self-counselling and consolidates these findings within a general framework.

As a consequence of the multidisciplinary approach of this thesis, it started with exploring one of the technical challenges in virtual reality research, simulator sickness. In Chapter 4, we designed a virtual street environment where between-group participants were instructed to move at the fastest velocity while experiencing different lighting to investigate this fundamental issue. We conducted two experiments for this study and found that the initial exposure influenced participant velocity and simulator sickness in a virtual environment. Overall, there was no velocity difference between light and dark streets but starting on a darker street increased participant speed. Therefore, we argued that our findings offer a contribution to the VR research on simulator sickness by presenting an easy solution for the future design of virtual environments that require fast movements throughout the virtual scenario.

Secondly, this thesis examined another fundamental theoretical concept in virtual reality research, embodiment and its association with the change blindness phenomenon. To explore this association in Chapter 5, we developed a virtual reality Qigong session in which the participant's and instructors' virtual bodies gradually transformed into different virtual bodies during the Qigong session. Our results revealed that both the change in the bodies of the participants and the change in the bodies of the instructor went unnoticed by aarge proportion of participants (Senel, Macia-Varela, Gallego, Jensen, Hornbæk, & Slater, 2023).

The thesis further explored the potential of virtual reality self-counselling to help participants with personal issues that cause moderate levels of stress in their lives as well as examining its possible utilisation of the same VR self-counselling framework in nicotine addiction research in Chapter 6. Our results from the first study that investigated the impact of different counsellor representations in the self-conversation framework showed that the generic-looking, gender-matched avatar could lead to improved outcomes in psychological variables compared to lookalike and future self-representations of the counsellor. Hence, our findings added new insights to the existing literature by proposing a new counsellor representation insight for future VR self-conversation studies. During the investigation of our second study of VR self-conversation that focused on nicotine dependence, we proposed the original idea of using the future self-continuity approach with VR self-conversation for addiction research in VR in our paper (Senel & Slater, 2020), which has also been taken up by other researchers (Shen et al., 2022) to investigate substance use disorders. Nonetheless, our findings indicated considerable differences between pre-VR and post-VR scores of participants to behavioural nicotine dependence measures for the counsellor's body represented as a future self who continues to smoke.

The overall conclusions about the findings from these studies not only demonstrated different ways to provide implications for future research to design virtual reality environments to create realistic and immersive experiences conveniently but also expanded the current knowledge on the possible applied utilisation of immersive virtual reality technology for both non-clinical and clinical settings. Besides, the interpretation of these general outcomes within the predictive coding framework also presented novel debates about how the brain can use previously acquired knowledge to deduce missing information and how sensory information can be encoded and processed effectively in virtual reality scenarios while shedding new light on the future research that is needed to understand these.

2. Background

“Any sufficiently advanced technology is indistinguishable from magic.” (**Arthur C. Clarke**, Profiles of the future: an inquiry into the limits of the possible)

In this chapter, we will introduce the concepts of presence and immersion, and we will discuss two illusions, place illusion (PI) and plausibility illusion (Psi), that are fundamental for understanding the virtual reality research. Next, we will explain body ownership illusions and how these illusions may be induced in virtual reality. We will also describe the concepts of the first-person perspective, third-person perspective, embodiment, and illusory agency in virtual reality, which are crucial concepts for explaining our studies in this thesis. After that, we will continue to provide information about simulator sickness, the current solutions for decreasing it, and why it still poses a challenge for virtual reality. Subsequently, we will explain what change blindness is and how is it used previously in virtual reality, along with the literature that explains why it relates to our research line.

Furthermore, we will elucidate what future self-continuity is, how previous studies embraced applying this idea to their investigation and why we chose to use it for our self-conversation studies. In addition, we will illustrate previous virtual reality research about addiction. We will explain our path towards the proposition that self-conversation with a future self can benefit smoking populations. Finally, we will annotate what predictive coding is and our reasons for utilising it to interpret our experiments’ results.

2.1 Presence, Immersion, Place Illusion & Plausibility Illusion

Delving into key concepts fundamental to VR technology to build a solid understanding of the hypotheses presented is crucial. Among these concepts, we look at presence, immersion, place illusion, and plausibility illusion, and how they collectively contribute to the experience of the participants by directly influencing their perception and interaction within virtual environments.

The concept of “*presence*” was originally defined as the feeling of being there in the virtual environment (VE) rather than being in the physical location of the participant (Held, 1992; Sheridan, 1992; Barfield & Weghorst, 1993; Sheridan, 1996; Slater & Wilbur, 1997; Draper et al., 1998; Bystrom et al., 1999; Sanchez-Vives & Slater, 2005). Slater (2009) argued that presence could be divided into two orthogonal illusions: Place Illusion (PI) and Plausibility (Psi). PI refers to the feeling of actually being in the virtual environment despite knowing that this is not the case. Psi refers to that the events happening in the VR are actually occurring, even though they are generated digitally, and are not actually occurring. PI and Psi together lead participants to respond to the virtual environments realistically. However, it is significant to note that participants in both PI and Psi know these are illusions, not reality. Slater (2009) also defined “*immersion*” as an objective characteristic of a virtual reality system. Higher or lower immersion corresponds to the degree to which the system supports natural sensorimotor contingencies for perception. For this reason, immersion can be referred to as a concept related to the actual physical substructure of the virtual reality system and what this system provides. Hence different levels of immersion may lead to different levels of the presence illusions and how people respond to events in the virtual world (Slater, 2018).

Although PI and Psi both form the sense of “*presence*”, they need to be considered as separate concepts because they depend on different mechanisms. PI depends on natural sensorimotor contingencies (O’Regan & Noë, 2001), the bodily actions we instinctively perform to perceive our environment. These instinctual actions allow participants to perceive the virtual reality the same way they perceive the real world: by using their bodies in the VR to turn their heads, bend down, reach out, and look around objects. A VR system provides the participants with sensorimotor contingencies for carrying out their perception, based on the VR system's combination of display and tracking technologies ranging from head tracking to haptic feedback, ultimately leading their brain to locate them in that place. Although participants know it is not their real location, PI is a perception illusion that creates the feeling of "this is where I am in this place".

PI, as the first component of the presence, can be associated with the form itself and how it is presented in the VR system; on the other hand, the second component of the presence, called Psi, can have a connection with the matter of the content and what is presented. Psi refers to the illusion that situations and events in the virtual environment are actually happening. This perception is contingent upon the responsiveness of the virtual environment to participant actions, the degree of personal engagement when virtual characters respond to the participant, and the congruence of the virtual events with participant expectations. This sense of "realness" in the VR experience can stem from the unique relationships the participant forms with virtual characters or events directly related to them (Slater et al., 2022). Furthermore, PI and Psi are not mutually inclusive and can happen at different times. For example, (Spanlang et al. (2007) presented participants with a fire scenario in a high-quality VR system called CAVE, with the best rendering of its time. However, the results of this study demonstrated that participants indicated very low PI scores due to a glitch in the environment where a character sitting by the bar was doing repetitive, unnatural motions, leading to the participants focusing on this unnatural character over the actual fire. The findings shed new light on the research on "presence" by adding the plausibility component (Slater et al., 2022).

Psi can be a complex phenomenon. Participants can react to unrealistic situations without scepticism, as demonstrated in a study of acrophobia (Freeman et al., 2019). Participants were presented with a virtual reality scenario where they witnessed a whale swimming between tall buildings. In spite of the unrealistic nature of the event, they accepted it. For this reason, due to the complex nature of perception of plausibility, investigating Psi can require additional strategies other than solely relying on traditional questionnaires and physiological responses. The utilisation of alternative measurements can give additional insights, such as incorporating psychophysical methods to allow participants to make choices between alternatives that were presented by a reinforcement learning to modify the configurations of the system, which leads to a deeper understanding into participants' preferences in a VR scenario (Llobera, Beacco, Oliva, Şenel, Banakou, & Slater, 2021) or using sentiment analysis to get responses about the virtual rock concert study which reveals edge cases such as high plausibility with negative sentiment (Slater, Cabriera, Senel, Banakou, Beacco, Oliva, & Gallego, 2022).

These concepts of Presence, Immersion, Place Illusion, and Plausibility Illusion lay the groundwork for understanding why VR works and why participants respond realistically to these environments. They form the basis for all the studies conducted in this thesis. In the next section, we will examine the integral concepts that focus on the participant's sense of self within these environments by moving forward from the theoretical landscape of immersive virtual reality. We will discuss body ownership illusion, perspective taking, illusory agency, and embodiment - all essential elements that also play a vital role in shaping participants ' perception and overall experience of virtual environments.

2.2 Body Ownership Illusion, Perspective Taking, Illusory Agency & Embodiment

This section provides an overview of the existing literature surrounding the embodiment of virtual bodies. This section is particularly relevant to our Qigong and Self-Conversation with Future Self-studies. In the Qigong study, where we examined the relationship between embodiment and change blindness. In the Self-Conversation with Future Self experiments, we investigated the impact of various counsellor representations in virtual reality and how participants responded to these virtual bodies. Therefore, this section serves as our research's foundational background for hypotheses 2, 3, and 4.

The feeling of an external object being part of the body or the sense of ownership over the entire body or the parts of the body is known as *body ownership* (Botvinick, 2004). The process of self-identification and feelings of ownership toward the body have been suggested to be fundamental aspects of bodily self-consciousness. This also includes self-location, or the sensation of being in a particular space, and a first-person perspective, which is perceiving the world as “I” based on personal experience (Blanke, 2012). This feeling of “this is my body” is mainly caused by bodily multisensory integration (Botvinick & Cohen, 1998; Ehrsson, Spence, & Passingham, 2004; Ehrsson, 2012).

Multisensory integration refers to the brain’s neural process of combining information from various sensory modalities to create a unified perception of the world (Stein & Stanford, 2008). For example, when ventriloquists create the illusion that a puppet is talking itself, the unified perception is that the voice is coming from the puppet’s mouth instead of the mouth of the ventriloquists; thus, the perceived location of the voice is dominated by the vision. This ventriloquist effect depends on integrating visual and auditory information (Alais & Burr, 2004). As a result of multisensory integration, one's perception of their own body's shape and orientation could be distorted due to incorrect proprioceptive information about limb positioning. This misattribution was exemplified in the Pinocchio Illusion, a psychological experiment developed by Lackner in 1988. In this experiment, participants were made to touch their noses while a vibration was applied to their biceps. This caused a sensation that made participants believe their noses were stretching, which was actually a false perception resulting from the miscommunication of sensory information. However, these changes and distortions in perception can also occur towards an artificial body part due to the interplay between vision, touch, and proprioception (Botvinick & Cohen, 1998).

Botvinick and Cohen (1998) conducted a pioneering study to explore how our perception can incorporate an alien limb into our body image via synchronous tactile stimulation. In this experiment, participants were observing a rubber hand placed in front of them, stimulated by a brush. Meanwhile, their hidden real hand received the same touch stimuli simultaneously. Due to the combined influence of vision, touch, and proprioception, the participants experienced an intriguing illusion where they felt as if the feeling of touch was originating from the rubber hand, despite it being an alien object. This phenomenon, known as the "Rubber Hand Illusion (RHI)", suggests an altered perception of bodily self. This specific study (Botvinick&Cohen,1998), as well as its variations (Naito & Ehrsson, 2001; Ehrsson et al., 2005; De Vignemont et al., 2005), offered the necessary means to investigate the "bodily self" with experimental studies (Botvinick, 2004; Ehrsson, 2012).

In addition to experiencing illusions of ownership over individual body parts, Petkova and Ehrsson (2008) have explored how one might perceive ownership over an entire different body. Their study used perceptual illusions to create a sense of body-swapping. This was achieved by manipulating participants' visual perspectives using Head-Mounted Displays (HMDs), leading the participants to experience a feeling of full-body ownership over someone else's body. Later, the researchers emphasised the significance of having the "*first-person perspective*" (1PP), the viewpoint of one's own body where observation occurs in an egocentric reference frame, as opposed to having the "*third-person perspective*" (3PP) frame (Vogeley et al., 2004), for the operation of the multisensory integration processes to induce full-body ownership illusions (Petkova et al., 2011). However, in situations similar to out-of-body experiences where participants have the illusion that they are located outside of their physical bodies and observe their own physical bodies from the external perspective with the help of HMDs, they were able to feel ownership over their own bodies from the 3PP when the stimuli to achieve the multisensory integration were provided (Ehrsson, 2007). The study of Lenggenhager et al. (2007) also showed that out-of-body experiences can be emerged by the multisensory conflict. When participants saw and felt their body being tapped from behind while their tactile sensation was drawn towards the seen body in front, they felt a displacement of their perceived physical location, as they experienced the illusion of the virtual body observed in front of them being their own, positioning them outside their actual bodily boundaries and closer to the virtual body.

Immersive virtual reality also has been used by researchers to study the intricacies of body ownership illusions. Similar to the RHI, in virtual reality, the ownership over a virtual arm was observed for participants who experienced visuotactile synchrony, the synchronous tapping of their real arms and virtual arms at the same time (Slater et al., 2008), as well as for participants who experience visuomotor synchrony, the synchronous movement of their real hands and their virtual hands (Sanchez-Vives et al., 2010). In the study of Normand et al. (2011), participants were placed in a virtual reality environment where they saw a virtual body with an inflated belly from a first-person perspective, substituting their own body. Using a rod, they prodded their actual belly and saw a corresponding action on the virtual body in real time. The experiment demonstrated that synchronous multisensory stimulation—in this case, the visual input of the virtual belly and the tactile input from prodding—could alter the participants' body representation to perceive an increase in belly size. Similarly, Kilteni et al. (2012) explored the manipulation of body representation with a different approach. An illusion of an unusually long arm was produced using immersive virtual reality. Participants viewed a virtual body, coinciding with their real body, where the dominant virtual arm was disproportionately extended. The study found that participants could incorporate this asymmetry into their body representation up to three times their real arm's length, demonstrating that multisensory and sensorimotor information could reshape our perception of body size and proportions, even when these are inconsistent with normal body proportions. In addition to sensing ownership over a surrogate body part corresponding to the part of the actual body, the *full-body transfer illusion* was also demonstrated to be induced through immersive virtual reality for the entire virtual body as demonstrated by Slater et al. (2010) with male participants who felt ownership with respect to a female virtual body. In VR, *illusory agency* can also occur when we attribute an action to ourselves that we did not do. "Agency" refers to attributing the action to oneself (Wegner, 2004). The study by Banakou & Slater (2014) investigated the sense of illusory agency when participants embodied a virtual body performing actions they did not execute. The results of their study demonstrated that when the participants' movements were synchronised with the virtual body's movements and vibrotactile stimulation was applied to the thyroid cartilage, participants erroneously ascribed the virtual character's speech to themselves. This illusory agency occurred even though they merely embodied a life-sized virtual body and were not actually speaking. Similarly, in another study, seated participants who viewed a virtual body walking from a first-person perspective experienced an illusory sense of agency over the walking (Kokkinara et al., 2016). These studies highlighted the critical role of body ownership illusions in shaping our sense of agency.

The body ownership illusions in immersive virtual reality are caused by the virtual *embodiment*, which is the process of replacing a person's actual body with a life-sized virtual body where the virtual body is aligned and coincides with the actual body's spatial position and with the first-person perspective of that body (Kilteni et al., 2012; Kilteni et al., 2015; Slater & Banakou, 2021). Several studies have revealed that altered body representations in virtual reality could change participants' attitudes, perceptions, behaviours, and cognitive performance. For example, in the context of racial bias, changes in attitudes have been observed through the virtual embodiment of a social outgroup (Maister et al., 2015). Studies have found that embodying a virtual body of a different race can decrease implicit racial bias scores among white participants (Peck et al., 2013), and this reduction in bias can be sustained (Banakou et al., 2016). However, these changes in participants' attitudes can be influenced by the social context in the virtual environment in a way that adverse effects can interfere with forming new positive associations with the virtual body belonging to a different race (Banakou et al., 2020). The type of body in which embodiment takes place can lead to perceptual and behavioural changes. For instance, when participants embodied a child's body, they overestimated the size of objects and indicated faster reaction times for classifying themselves with child-like rather than adult-like attributes (Banakou et al., 2013). Cognitive performance can also vary depending on the body that is embodied. In a study by Banakou et al. (2018), participants who embodied a virtual body resembling Einstein, an icon of superintelligence, showed improved performance on a cognitive task compared to those embodied in a body similar to their own age. Furthermore, a study that examined chronic pain patients found that the embodiment of virtual bodies with the modifications of transparency and size of the virtual body, particularly the arm, can further decrease the pain ratings of these patients (Matamala-Gomez et al., 2019). Virtual embodiment was also utilised to investigate whether prolonged experiences of life, death or near-death experiences impact attitudes towards life and death (Bourdin et al., 2017; Barberia et al., 2018).

Following studies that have demonstrated the feasibility of inducing bodily illusions through the embodiment of virtual bodies in immersive virtual environments, and the impact of these altered representations on attitudes, behaviours, and perceptions, we posit that virtual reality provides alternate realities that trigger realistic responses from its participants. In the following sections, we will examine an example of these transformations with experiments involving virtual bodies transitioning in appearance from one form to another in Chapter 5 and a self-conversation in a virtual reality setting involving body-swapping in Chapter 6. However, before we delve further into our studies, we must address a significant VR issue: simulator sickness. The subsequent section will discuss the causes of simulator sickness, its impact on users, and strategies to mitigate its effects. This key issue still poses a barrier to the broader usability of VR, and the next section will provide a foundation for our first study and hypothesis in Chapter 4.

2.3 Simulator Sickness

Virtual reality technology can induce unwanted adverse symptoms in its participants that might elicit unpleasant responses. This condition, called "*simulator sickness*", can be similar to the symptoms of "*motion sicknesses*", such as drowsiness, dizziness, fatigue, and nausea (Kennedy & Frank, 1985). Even though there is a resemblance to symptoms with other conditions, simulator sickness occurs as a by-product of modern simulation technology, and the intensity and patterns of its symptoms differ from motion sickness (Kennedy et al., 1993). The terms "*Visually induced motion sickness*", a type of motion sickness triggered by visual stimulation without physical movement (Keshavarz et al., 2015) and "*cybersickness*", a type of motion sickness arising from the illusory self-motion in virtual environments (McCauley & Sharkey, 1992) are also used to refer to "simulator sickness". Although some researchers have emphasised the terminology differences between cybersickness and simulator sickness due to symptoms which are caused by different platforms, such as virtual reality environments and flight simulators (Stanney et al., 1997), other researchers suggested the assumption that all conflicts that cause motion sickness symptoms can be attributed to one underlying conflict (Bles et al., 1998). Nevertheless, both terms have been used interchangeably by researchers investigating these symptoms evoked by virtual reality technology.

The most common subjective measurement of simulator sickness in virtual environments is the "Simulator sickness questionnaire" (SSQ) (Chang et al., 2020; Rebenitsch & Owen, 2016). This questionnaire, developed by Kennedy et al., 1993, categorises simulator sickness symptoms into three categories: those related to stomach awareness, Nausea (N), those related to eye strain and fatigue, Oculomotor (O), and those related to dizziness, Disorientation (D). Previous research that examined the impact of display types on the experience of these symptoms revealed that HMDs compared to desktop and projection display systems, evoked higher simulator sickness (Sharples et al., 2008), and HMDs elicited more symptoms compared to other virtual reality systems such as the CAVE (Kim et al., 2014). These symptoms were found to be negatively correlated with the user experience scores (Somrak et al., 2019) and intention to use VR technology (Sagnier et al., 2020). Simulator sickness symptoms can continue to persist even after the virtual reality experience (Tanaka & Takagi, 2004; Moss & Muth, 2011), the longer exposure time to virtual environments can increase the severity of these symptoms (Dużmańska et al., 2018). Therefore, developers of immersive virtual environments should adopt strategies to reduce the prevalence of these symptoms. However, several factors can lead to these symptoms (Kolasinki, 1995; LaViola, 2000), and efforts to resolve this condition are ongoing.

Several theories that initially explain motion sickness have been proposed about the causes of simulator sickness symptoms (LaViola, 2000). The sensory rearrangement theory (Reason & Brand, 1975) proposes that when the past experiences of sensory systems, including eyes, vestibular and non-vestibular systems, are not consistent with the present information from the spatial environment, conflict arises for predicting sensory rearrangements. The Neural Mismatch Model (Reason,1978) further argues that the sensory mismatch between past and present information can lead to sickness symptoms due to different sensory systems perceiving the external environment differently. For instance, when the physical movement in a virtual environment perceived by the visual system does not correspond to the sensory information received by the vestibular system, the conflict between sensory systems elicits sickness symptoms. As a response to the sensory mismatch arguments, Postural Instability Theory (Riccio & Stoffregen, 1991) mainly emphasises the relationship between the vestibular system and the external environment. It suggests that feeling postural instability because of the inability to maintain the balance for the stimulus in the external environment or not knowing yet about strategies to maintain postural stability results in sickness symptoms. Finally, Evolutionary Theory (Treisman, 1977), also known as Poison Theory, approaches this condition from the evolutionary perspective and hypothesises that nausea occurs as a natural response when the poison is ingested, which affects the coordination between different sensory systems. Similarly, sickness symptoms are triggered due to the misinterpretation of sensory information received by the unpredictable environmental changes that our species have not adapted to yet, as they were poisoned.

Previous research has incorporated different strategies to prevent simulator sickness symptoms. These concern the hardware, as well as the software, include balancing participant-initiated and pre-determined controls in virtual environment navigation, termed active-passive control (Stanney & Hash, 1998); reducing the field of view by half (Dizio & Lackner, 1997 as cited in Rebenitsch & Owen, 2016), utilising dynamic simulators and creating a level of detail with low textured cues rather than richly textured simulated environments (Jaeger & Mourant, 2001); providing a degree of peripheral vision of the outside world (Moss & Muth, 2011); using dynamic depth of field blur (Carnegie & Rhee, 2015); modifying the field of view strategically and automatically in a dynamic way (Fernandes & Feiner, 2016); using a frame of references for the participants like a virtual cockpit (Prothero, 1998) or virtual nose (Wienrich et al. 2018); considering the exposure time of the virtual environments and the severity of simulator sickness symptoms during the initial exposure (Tanaka & Takagi, 2004; Dużmańska et al., 2018); implementing habituation and adaptation protocols for the participants (Reinhard et al., 2017). The symptoms of simulator sickness can increase with the high speed of movement, but increasing the velocity over a certain degree can break this relationship due to lack of presence (So et al., 2001). Moreover, simulator sickness and presence, “the feeling of being there” in VR, were also negatively related (Weech et al., 2019).

Given the necessity to develop new methods for reducing simulator sickness, in Chapter 4, we will present two experiments investigating the role of various lighting conditions in virtual environments on velocity and simulator sickness. However, before transitioning to the experimental sections of this thesis, our exploration leads us to the literature about “change blindness." This cognitive phenomenon is relevant to our investigation into the “embodiment” and its relationship with the gradual transformation of virtual bodies within a virtual environment during a Qigong training session, as detailed in Chapter 5.

2.4 Change Blindness

The phenomenon where the observer fails to detect changes in their visual scene even though the objects undergo significant changes is called “*change blindness”* (Simons & Levin, 1997; Simons & Rensink, 2005). This inability to perceive changes in the scene was suggested to be the result of the observer’s lack of detailed depiction of their environments. Hence, attention was attributed as a fundamental mechanism for the observer to perceive changes in their surroundings (Rensink, O’Regan, & Clark, 1997). However, it was discussed that attention alone might not be sufficient to detect such changes (Simons, 2000). For instance, the study of Levin & Simons (1997) showed that observers could fail to detect changes not only when the objects were in arbitrary locations within the scene but even when they were in the centre of attention, as performed by an actor in a motion pictures scene who instantly turned into another person due to a change in camera angle. In a real-world experiment conducted by Simons & Levin (1998), pedestrians engaged in conversation with an experimenter who was replaced by a different individual midway through. Surprisingly, half of these participants failed to notice the switch. The participants who identified the change were predominantly students roughly the same age as the experimenters (around 20 to 30 years old), while those who overlooked the change tended to be a bit older than the experimenters (approximately 35 to 65 years old). Therefore, the study also demonstrated that the likelihood of detecting this change was influenced by social group membership; pedestrians belonging to the same social group as the experimenters were more likely to notice the change. Additionally, these studies of change blindness usually presented a visual disruption like a camera cut in motion pictures (Levin & Simons, 1997) or carrying a door between the experimenter and the pedestrian (Simons & Levin, 1998), and visual disruption was assumed to be a necessary factor for the change blindness.

Nonetheless, the study of Simons, Franconeri & Reimer (2000) demonstrated that change blindness could also happen without presenting observers with visual disruptions but by introducing changes *gradually*, like two computer images going through a morphing process. The results of this study revealed that change blindness was more prominent in the gradual condition compared to the disruption condition for the detection of colour changes and the detection of addition/deletion changes. David, Laloyaux, Devue & Cleeremans (2006) extended the results of the previous study (Simons et al., 2000) and they further investigated the relationship between gradual changes and change blindness by applying changes in human facial expressions in a realistic scenario. They showed that the change detection for the facial expressions in the gradual change condition, where only 15% of observers noticed the change, was three times less than in the disruption condition.

Moreover, change blindness was also demonstrated to occur in virtual reality. For example, the study of Steinicke et al. (2011) introduced various techniques to implement alterations that can cause change blindness in stereoscopic virtual environments. Moreover, change blindness-influenced methods were used for redirecting participants in the virtual environments where the virtual space is bigger than the actual physical walking space (Suma et al., 2011) as well as for mapping two or more virtual objects into a single physical prop when the objects are invisible to the participant in the virtual environment (Lohse et al., 2019; Martin et al., 2023).

Although numerous studies have been conducted, there is a gap in the literature investigating gradual changes in one's virtual body representation. Thus, how change blindness can occur with transformations in participants' own bodies or another person's body remains unclear. For this reason, in line with the previous research, in Chapter 5, we will present our study that explored the relationship between change blindness and embodiment when the change occurred gradually both in the participant's virtual body and in another virtual body within the environment. After explaining our study, we will also discuss the possible applications of this method for future VR studies.

After establishing an understanding of change blindness and its potential effects on participants' experiences in VR, we are now prepared to delve into the concept of future self-continuity. Future self-continuity is a crucial framework we explored in our studies, detailed in Chapter 6. Our investigation aimed to determine the potential impact of embodying a counsellor avatar that mirrors the participant's future self during VR self-counselling sessions. These self-conversations in VR focused on personal stressors in participants' lives, addiction issues like physical and behavioural nicotine dependence, and the behaviour change that transpired over time.

2.5 Future Self-Continuity & Nicotine Dependence

In this section, we examine the interconnectedness of the concepts of our past, present and future selves, a phenomenon termed by Markus and Nurius (1986) as “possible selves”. These representations influence how we view our aspirations and our fears and shape our choices along with our personal identities. This chapter explains how positive or negative interpretations of one’s future self can significantly impact the health, well-being, longevity as well as performance of individuals. Furthermore, the section explores how the differentiation of one’s current self from the future self, as well as how temporal discounting, that is the tendency to discount the value of future outcomes influence decision-making. The chapter also delves into the effects of the strength of future self-continuity on saving habits and ethical decision-making. How high discount rates, and in turn, weak future-self continuity leads to addictive behaviours and how increasing this continuity by lowering the discount rate can lead to healthier lifestyle choices are explored. The implications of these insights, specifically how virtual reality can be used in enhancing future-focused decision making and mitigating harmful behaviours, along with the potential use in mental health treatment are discussed.

Markus and Nurius (1986) argued that the function of possible selves is significant for giving incentives for future behaviour to approach and avoid certain situations and to guide one's self-view. Moreover, a positive perception of the potential future self plays a crucial role in one's own health and well-being. For instance, some longitudinal studies demonstrated that positive self-perception of ageing could lead to better functional health (Levy, Slade & Kasl, 2002) as well as significantly increased longevity (Levy, Slade, Kunkel & Kasl, 2002), while negative perceptions could anticipate a decrease in cognitive functioning (Robertson, King-Kallimanis & Kenny, 2016).

The "subjective temporal distance" was defined as people's perceived proximity to their past selves Wilson & Ross, 2000; Wilson & Ross, 2003; Ross & Wilson, 2003). One's emotional connection to their past self—previous identities defined by former thoughts, actions, and experiences—hinges on this perceived distance. Their "current self", or present identity, is informed by immediate experiences and the accumulation of past selves. Meanwhile, the "future self" is a perceived future identity shaped by aspirations, fears, and expectations. While typically correlated with actual time, this subjective temporal distance is not a perfect relationship, as individuals might feel closely connected to events from long ago yet distant from recent occurrences.

The past selves and future selves are generally perceived differently. For example, it was shown that the general conditions of the future self tend to be attributed to external conditions unless the attention is shifted to thoughts and feelings; in contrast, the general conditions of the past self are attributed to internal conditions (Pronin & Ross, 2006), implying a difference in the perceived agency of these different selves. Moreover, the decision-making process for one's future self could differ from the current self, mostly resembling that of another person's decision-making process (Pronin, Olivola, & Kennedy, 2008). Neuroimaging research also displayed that evaluation of the current self vs future self-ratings could indicate differences in the activation of the rostral anterior cingulate cortex (rACC), the region that also elicits activation during self vs other assessments. These individual differences could be used to predict the behavioural differences in temporal discounting regarding financial decisions (Ersner-Hershfield, Wimmer, & Knutson, 2009).

Temporal discounting refers to the tendency to assign less value to future outcomes than immediate rewards (Chapman & Elstein, 1995). For example, during intertemporal decision-making that involves both future monetary gains and health, the worth of future outcomes is tended to be discounted. However, the discounting effect is considerably more pronounced for health outcomes, suggesting that people often underestimate the importance of long-term health decisions (Chapman & Elstein, 1995; Chapman, 1996).

According to the future self-continuity hypothesis (Ersner-Hershfield, Wimmer, & Knutson, 2009), it was predicted that when the future self is viewed as a stranger, and the self-continuity between the current and future selves does not exist, then monetary saving behaviour does not occur for the future self. A follow-up study that investigated the future self-continuity hypothesis and tested the index of future self-continuity scale validated that the more robust continuity between one's current and future selves could encourage future saving behaviour (Ersner-Hershfield, Garton, Ballard, Samanez-Larkin, & Knutson, 2009). In line with this hypothesis, it was also shown that when the future self is perceived as similar to the current self, as well as when it is seen as vivid and realistic, and it is anticipated in positive terms, the intertemporal decision-making can be influenced in a way that people tend to make decisions for a better future today (Hershfield, 2011). The study of Hershfield et al. (2011) introduced a novel intervention for increasing future-oriented decisions by allowing participants to interact with their different temporal selves in virtual reality. The results of their study revealed that participants in the future self condition who interacted with aged-rendered, future versions of themselves in immersive virtual reality compared to the current self condition that looked like their nonaged digital versions had decreased rates in temporal discounting and started to invest more money in their retirement funds. In addition to money-allocation tasks, the future self-continuity approach was evaluated in various situations. For example, future self-continuity was found to be positively correlated with ethical decision making and low future self-continuity was shown to be a predictor for unethical behaviour such as lying, cheating and giving false promises (Hershfield, Cohen, & Thompson, 2012). Meanwhile, vivid perception of the future self by enabling participants to interact with their age-rendered avatars in virtual reality decreased cheating and predicted delinquency (Van Gelder, Hershfield, & Nordgren, 2013).

Future self-continuity has also been shown to be linked with health behaviour. Rutchick et al. (2018) investigated the connection between current and future selves for healthy decision-making. Their study revealed that improving the future self-continuity by engaging participants with a letter-writing task to their future selves within 20 years accelerated exercise behaviour after the writing and increased adaptive long-term health behaviour. On the other hand, temporal discounting rates are known to be larger for health decisions, making it hard to implement preventative strategies for long-term well-being (Chapman & Elstein, 1995). Moreover, the effect of temporal discounting could be illustrated in specific unhealthy behaviours, such as addiction. For example, it was shown that college students with higher discounting values were prone to initiate earlier and engage more in the consumption of alcohol, smoking and other substances (Kollins, 2003). Cigarette smoking alone was further associated with higher temporal discounting, not only for future outcomes but also for discounting the past (Bickel et al., 2008). In addition, the challenge of quitting smoking is due to struggling to realise long-term consequences (Murphy-Hoefer, Alder, & Higbee, 2004), as the incremental and extended nature of the risks makes them easy to disregard and undervalue long-term hazards related to smoking (Arnett, 2000; Masiero et al., 2015). Besides, on a positive note, this relationship between smoking and discounting was indicated to be reversible, as shown by decreasing smoking behaviour which led to decreased discounting (Yi et al., 2008). Moreover, a potential method called "*Episodic Future Thinking*" that allowed participants to involve in imagining a positive autobiographical future event had a significant effect on reducing cigarette smoking and temporal discounting at the same time (Stein et al., 2016).

While these studies emphasised the integral role of future self-continuity and the influence of temporal discounting on health behaviour, particularly concerning addictive behaviours like smoking, they also underline the challenge of modifying these behaviours. The complexity of addiction and the difficulty of prioritising long-term health over immediate gratification makes this process of breaking addictive habits a challenge. However, promising solutions like Virtual Reality (VR) are arising to help people to overcome these challenges. It is known that

VR has been utilised in investigating, assessing, and treating various mental health problems such as anxiety, schizophrenia, eating disorders and substance use disorders (Freeman et al., 2017; Riva & Serino, 2020). The most common application of virtual reality for enhancing smoking cessation has been "*cue-exposure therapy*" (Lee et al., 2003; Lee et al., 2004; Bordnick et al., 2005; Moon & Lee, 2009), a method that has been previously used for addictive disorders to break the link between substance-related cues and substance use by repeatedly exposing participants to substance-related triggers that generate withdrawal and craving (Heather & Bradley, 1990; Heather & Greeley, 1990). Virtual reality cue-exposure techniques were significantly effective for triggering cravings, even more than traditional methods (Lee et al., 2003), while leading to related physiological reactions as a response to the smoking cues in virtual reality (Bordnick et al., 2005). Correspondingly, the smoking-related cue exposure in virtual reality elicited activation in the brain regions associated with nicotine cravings, including the inferior and superior frontal gyrus (Moon & Lee, 2009). Finally, it was concluded by Pericot-Valverde, Germeroth, & Tiffany (2016), as a result of the meta-analysis of 18 studies, that smoking cues in virtual environments lead to strong cravings compared to virtual environments where these cues were not present.

Furthermore, other behavioural and coping strategies were also integrated into virtual reality to induce smoking cessation. For example, exposing participants to four weekly sessions of crushing virtual cigarettes in virtual reality decreased nicotine dependence, also verified by an exhaled carbon monoxide biomarker (Girard et al., 2009). Thus, virtual reality skills training programme combined with nicotine replacement therapy with a duration of 10 weeks reduced smoking and cravings for cigarettes compared to nicotine replacement therapy without incorporating virtual reality (Bordnick et al., 2012).

Since virtual reality has been established as an effective tool to study addiction, with promising findings highlighting the relationship between future self-continuity and health behaviour, and the link between temporal discounting and cigarette smoking, we aim to explore the potential of expanding VR applications in smoking cessation.

To expand our understanding in this field of research, we propose employing a method known as “VR Self-Counselling“, which would allow participants to engage in self-dialogue within a Virtual Reality (VR) environment. A significant aspect of our exploration will involve participants communicating with virtual representations of their future selves. Subsequently, the following section will clarify the literature surrounding self-conversation in virtual reality, which was crucial in formulating our hypotheses 3 and 4, discussed in Chapter 6.

2.6 Self-Conversation in Virtual Reality

Virtual reality self-counselling is a method that enables participants to engage in self-conversation by swapping between two virtual bodies (Osimo et al., 2015; Slater et al., 2019). During this interaction, participants are able to maintain a self-dialogue from two different embodied perspectives, including first-person and second-person perspectives, while alternating between two virtual bodies.

The idea behind self-counselling has been inspired by two concepts: inner speech and Solomon’s paradox. Inner speech or self-dialogue concerns the human cognitive tendency to engage in continuous self-conversation with oneself, which is employed for obtaining and processing self-related information (Morin & Everett, 1990). Analogous to this proposal, the brain region called the left inferior frontal gyrus, which is related to self-referential thinking and self-reflected processes, was shown to be activated during inner speech (Morin & Hamper, 2012; Morin & Michaud, 2007). Moreover, our voice inside us while having this inner dialogue was observed to reflect our natural voice, including our regional accents (Filik & Barber, 2011). On the other hand, the idea for Solomon’s Paradox derives from the story of the famous biblical King Solomon, reputed for his exceptional wisdom. Nevertheless, in personal matters and familial issues, he displayed actions that contradicted his wisdom and led to troubles within his kingdom, indicating a paradox between his public wisdom and personal matters (Parker, 1992). This general leaning toward better advising others while not benefiting from the same level of wise reasoning for personal issues is called Solomon’s paradox (Grossman & Kross, 2014). S*elf-distancing* about the problem, shifting the focus to a third person and referring thoughts and feelings with the third-person pronouns was demonstrated by Grossman & Kross (2014) as a way to help people to apply wise reasoning for their own problems as they did for others rather than *self-immersing*, keeping the focus on thoughts and feelings with the first-person pronouns.

After combining these concepts and merging them with the power of immersive virtual reality, the initial study of VR self-conversation was conducted by Osimo, Pizarro, Spanlang and Slater (2015). The study involved two experiments, one exploring the role of different counsellor representations and the second investigating the impact of visuomotor synchrony and asynchrony. Both experiments included male participants alternating between two virtual bodies and trying to advise themselves about their problems. At the beginning of the experiments, participants started the session by explaining their problem while being embodied in a virtual doppelganger body resembling their real-life appearance. Participants later switched to the counsellor's virtual body to advise themselves, and this back-and-forth switch continued until they decided to finish. In the first experiment, which investigated counsellor representations as either as Freud or as a lookalike body, the researchers discovered that when the counsellor's body was represented as Sigmund Freud's virtual body rather than the participant's doppelganger virtual body, participants exhibited a greater improvement in their happiness scores. Later, the results of the second study, which investigated visuomotor asynchrony, pointed out that participants displayed improved scores and felt more ownership of the counsellor's virtual body when it moved synchronously instead of asynchronously. After this experiment, a follow-up study was carried out by Slater et al. (2019) to determine the underlying mechanism behind this effect by testing the difference between conditions that involved engaging participants in embodied self-conversation or enabling them to talk about their problems in virtual reality to a pre-animated Freud. The results of this study demonstrated that embodied self-conversation in virtual reality by swapping bodies between a lookalike body and a counsellor body that looked like Sigmund Freud increased the perception of change and helped participants to overcome their problems compared to the condition that participants had a conversation with a scripted Freud character.

Overall, these results shed new light on VR self-counselling by illustrating the effectiveness of virtual reality's embodied self-conversation as a promising self-counselling method. Subsequently, recent research has suggested that VR self-counselling could be utilised not only for non-clinical conditions but also for understanding and treating various clinical conditions. For example, we proposed the potential application of this method with future self-continuity approach for addictions, specifically for nicotine dependence (Senel & Slater, 2020). It has also been shown that the offenders who had an interaction with their future selves in VR reported reduced self-defeating behaviour (Van Gelder et al., 2022). In addition, VR-Self counselling was also suggested as a potential tool for understanding and treating eating disorders and obesity (Anastasiadou et al., 2021; Anastasiadou et al., 2023).

In Chapter 6 of this thesis, set within the context of VR self-counselling research, we will present two studies. In the first study, we delved into the effects of distinct virtual counsellor representations—Future Self, Current Self, and General Self—and assessed their effectiveness in dealing with personal problems via self-conversation. Subsequently, in the second study, we examined the potential of this method for research on cigarette smoking and nicotine dependence. This study involved the exploration of different representations of the Future Self, including versions of both a smoker and a non-smoker. We also incorporated a Current Self condition as a control measure. It is important to emphasise that self-conversation was the fundamental framework of the experiences of the participants in both studies to extend our understanding of the role of VR in non-clinical and clinical applications of virtual reality that involve behavioural change and addiction recovery.

Lastly, before concluding this background chapter, we will introduce the predictive coding framework in the next section. Predictive coding served as the tool to interpret and synthesize the diverse findings from our studies. Comprehending the literature related to this theoretical model is instrumental in enhancing our discussion and interpretation of the results.

2.7 Predictive Coding

According to the predictive coding framework (Friston, 2002, 2003, 2005), the brain has been proposed to function as an empirical Bayesian device that predicts incoming sensory information based on previous experiences and expectations. These predictions have been shown to be updated as new information became available while minimising prediction error. One of the early representations of this framework was introduced by Rao & Ballard (1999) as a hierarchical learning process in the visual cortex that indicated the visual cortex might not only be fuelled by feedforward processes but also by feedback across cortical regions; hence each level predicts the activity below it. Prediction errors were explained as a way to adjust both top-down predictions to improve perception and learning over time when mismatches happen. On the other hand, another approach called the "Bayesian coding hypothesis" (Knill & Pouget, 2004) proposed that the brain uses probabilistic representations for sensory information. Hence, humans act as ideal Bayesian observers by modifying cue weights based on stimulus, accounting for sensory and motor data uncertainty and utilising Bayesian models for perceptual biases. Both proposals emphasised the probabilistic nature of the brain's way of representing sensory stimuli which can be explained by the adaptation for minimisation of the free energy or the prediction error (Friston, 2010). As well as explaining the neuroscience underlying various cognitive processes, the predictive approach to the brain also allowed for philosophical discussions regarding the mind and cognition (Howhy, 2020). It did so by proposing a concept for a unified model of perception, action, and attention in the context of adaptive processes (Clark, 2013), as well as a self-evident understanding of the brain that can be discussed concerning mind-world relations. (Howhy, 2016). For these reasons, instead of employing predictive coding as a basis for our research hypotheses, we will use it to discuss our study results and to extend the interpretation of our findings in virtual reality research.

We have reviewed the relevant literature on which our studies are based. In summary, this chapter has offered a comprehensive examination of relevant literature, laying the foundation for the remainder of the thesis. We discussed various key elements of VR research, including concepts of presence, immersion, and the body ownership in virtual environments.

Current challenges encountered in VR, such as simulator sickness and the past applications of change blindness, were presented to deepen the understanding behind or hypotheses that aimed to explore potential obstacles and opportunities in enhancing participants' experiences.

In addition, we discussed key ideas, including future self-continuity, health behaviours, addiction, and the use of VR in mental health. We focused on VR self-counselling—a novel approach that enables individuals to engage in dialogues with themselves. The original studies presented in the literature provided an entry point into the domain of self-conversation in VR, introducing research that forms the foundation for new explorations in personal problem-solving and addiction recovery.

Furthermore, we introduced the predictive coding framework— that we used to help interpret our findings during the discussion. The insights from this chapter pave the way for our subsequent ones, where we will further investigate VR's potential in influencing behaviours and addressing addiction.

Subsequently, we will outline the materials and procedures used in our research in the following chapter.

3. Materials & Methods

"*Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful.*" (**George E. P. Box**, Empirical Model-Building and Response Surfaces)

In this chapter of the thesis, we provide an overview of the materials and methods that were used in our experimental studies. We discuss the hardware details, software and implementation aspects, and implementation aspects, participant recruitment and ethical considerations that were strictly followed during the execution of all experiments, experimental procedures and data analysis methods. However, it is important to note that each subsequent chapter will provide a more detailed explanation of the specific materials and methods used for the particular experiment discussed in that chapter.

3.1 Overview

First, we provide a description of the virtual reality hardware used in our experiments. We will present an overview of the recent advancements in Head-Mounted Display Systems (HMDS), focusing specifically on the Meta Quest 1 and Meta Quest 2 VR headsets. We will provide descriptions of their features, capabilities, and technical specifications and explain why we chose these headsets for our research.

Then, we will explore further the implementation aspects of our studies. This section will highlight the software development tools used to construct immersive virtual environments. We will discuss the various technologies and techniques employed to design and build virtual environments for our studies. Additionally, we will describe the methods used for creating realistic 3D avatars with Character Creator software. These 3D avatars were utilised in Qigong Experiment and Self-Dialogue with a Future Self Experiments.

Subsequently, we will focus on the participants and the general procedures followed in all studies. This section will cover participant recruitment strategies, selection criteria, and steps taken to ensure a diverse and representative sample. Furthermore, we will describe the data collection methods and discuss the protocols followed during data collection sessions. As ethical considerations play a fundamental role in our studies, we will address the ethical guidelines followed throughout all stages of the research. We will discuss the protocols implemented to ensure participant confidentiality and privacy, including the use of informed consent forms that detail the study's purpose, potential risks and benefits, and data handling procedures.

In addition, we will clarify the additional experimental procedures that were commonly followed in our studies. These will include the description of the embodiment exercises and COVID-19 protocols.

Finally, we will conclude this chapter by explaining the data analysis methods and tools used to examine the collected data. This section will outline the statistical tools, qualitative and qualitative analysis techniques, or other relevant methods utilised to examine and interpret the data.

3.2 Hardware

In this section, we delve into the virtual reality hardware specifics used in our investigations by providing descriptions of the technical aspects of the virtual reality systems.

Since Sutherland’s The Sword of Damocles (Sutherland, 1965), virtual reality research has incorporated multiple hardware systems during its evolutionary path. These systems consisted of projection systems such as CAVE (Cruz-Neira et al., 1992) and many varieties of head-mounted displays (HMDs). Still, during this evolution, the prior VR hype of the late 1980s and early 1990s was displaced by winter from the 1990s to the 2010s until recent developments in display and computer graphics technology dramatically changed the situation. Advances in graphics technology, in particular the advent of the SmartPhone made it possible for companies like Oculus (later taken over by Facebook which then became Meta), HTC, and Pico to focus on developing VR systems with increased affordability and advancements in terms of weight and field of view which later led to an evolution in the current expansion of VR technology. Although the Oculus Rift was already offering relatively high-quality resolution (1080 x 1200 per eye) with positional tracking since its launch in 2016, the release of Meta Quest in 2019 (formerly known as Oculus Quest) specifically brought profound changes in the VR field, not only by improving the display by enhancing the resolution (1440 x 1600 per eye) with the 72Hz refresh rate but also making the virtual reality experience standalone and portable with built-in tracking and non-cable controllers by removing the need for a cable connection to a PC and external sensors (Hayden, 2019). In addition, the Link cable developed explicitly for the Quest and later Airlink connection enabled the participants to enjoy still the applications that required high computational power that could not be executed in the standalone Quests (Meta Quest Blog, 2021). A year later, the release of Meta Quest 2 (previously known as Oculus Quest 2) provided a greater resolution of 1832 x 1920 per eye, a refresh rate of up to 90 Hz, and a lighter, more comfortable usability (Oculus VR, 2020).

We utilised Quest 2 (Figure 3.1.B) in the Simulator Sickness and Qigong experiments described in Chapters 4 and 5 and Quest 1 (Figure 3.1.A) in the Self-Dialogue with a Virtual Future Self studies explained in Chapter 6. The technical specs of these headsets are presented in Table 3.1. For our participants, the built-in cameras of the Quests facilitated a certain level of upper body tracking, including 6 degrees of freedom for hand tracking with each controller, all without separate tracking hardware. While devices like the VIVE can offer full body tracking capabilities, we chose to use the Quests in these experiments due to their affordability and the advantage of not requiring any cable connections, despite the broader tracking capabilities of other devices.

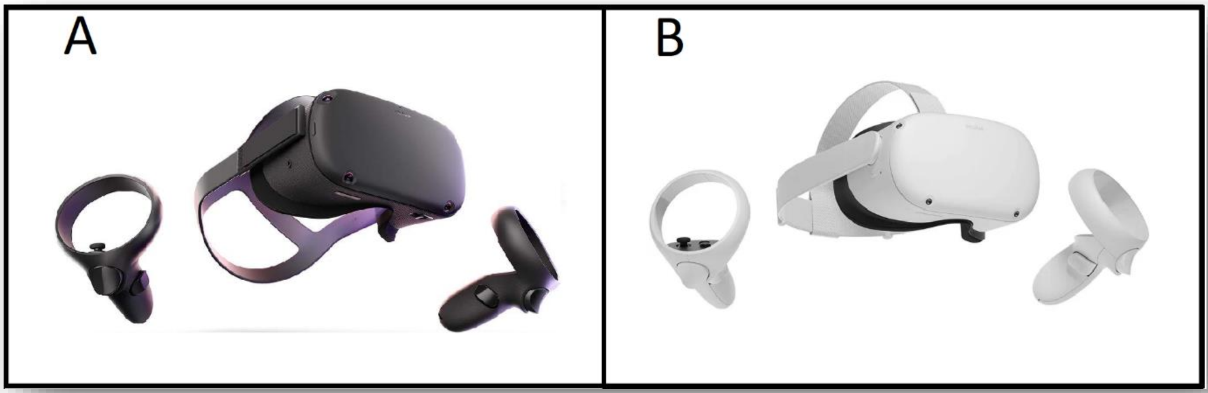

Figure 3.1 *Meta Quest Headsets.* ***A)*** *Meta Quest 1 and its controllers* ***B)*** *Meta Quest 2 and its controllers*

Table 3.1. The technical specs of the Meta Quest 1 and the Meta Quest 2 VR headsets

Meta Quest 1	**Meta Quest 2**
128 GB Storage 4 GB Memory 1440 x 1600 Display Resolution 72 Hz Refresh Rate Integrated Stereo Speakers 4 Built-in Cameras 571 g Mass	128 GB Storage 6 GB Memory 1832 x 1920 Display Resolution 90 Hz Refresh rate 2 Built-in Speakers 4 Built-in Cameras 503 g Mass

3.3 Implementation and Software

In this section, we will explain the specifics of the implementation of the virtual reality environments and the software used for the environment creation and virtual avatar generation.

We utilised Unity 3D to build VR applications for all of our experiments. The Unity 3D game engine is a cross-platform software framework that enables programming immersive virtual environments for different head-mounted displays. The virtual environment of the ConVRSelf software for the Self-Dialogue with a Virtual Future Self studies was developed by Event Lab's spin-off company Virtual Bodyworks, and later modified by us. Our modifications to ConVRSelf included alterations to the environment scene, changes to the VR software's instruction recordings to better suit our experiments, and adjustments to the virtual bodies within the software. We employed the Character Creator 3 software, detailed further below, to develop both the participant's virtual bodies and the counsellor representations for the Self-Dialogue with a Virtual Future Self studies in Chapter 6. To develop our Simulator Sickness and Qigong experiments, we employed the QuickVR library, which is built using the Unity platform (Oliva, Beacco, Navarro & Slater, 2022). QuickVR facilitated the creation of interactive content and offered a wide range of customisation options for developers of all levels. This open-source library provided us with advanced capabilities, such as rapid prototyping and extensive customisation, allowing us to significantly reduce production time and quickly adapt to the unique requirements of our experiments.

We used Character Creator 3 (CC3) software, developed by Reallusion (https://www.reallusion.com/character-creator/), to generate realistic-looking 3D virtual bodies for the Qigong study discussed in Chapter 5 and the Self-Dialogue with a Virtual Future Self studies presented in Chapter 6. CC3 is an adaptable software that supplies a solution for character generation, animation rigging, asset management, and rendering. It enables the facilitated creation and customization of 3D characters, exportation of these characters to the Unity 3D platform.

Specifically, in the Self-Dialogue studies, we utilised the Headshot Plug-in, Skin Editor, and Ultimate Morphs features of CC3 to create lookalike and age-rendered virtual bodies representing the participants in the role of counsellors. The Headshot plug-in enabled us to create unique virtual bodies and counsellor representations of participants, using photogrammetry to convert their frontal face pictures into 3D models, eliminating the need for any additional 3D scanning methods. We manually modified the body of the 3D avatars, estimating the body parameters using the CC3 software and participants' full-body pictures. An example of character generation with the Headshot Plug-in is illustrated in Figure 3.2. The Ultimate Morphs and Skin Editor features were advantageous when we created the future-self versions of the participants' virtual counsellor representations. The Skin Editor feature facilitated the ageing of the skin texture of the participants, while the Ultimate Morphs allowed us to modify the morphing of the 3D characters to display ageing, example aged avatar was demonstrated in Figure 3.3.

Detailed descriptions of the avatar creation processes will be outlined in the methods sections of both the Qigong and Self-Dialogue with a Virtual Future Self studies in chapters 5 and 6.

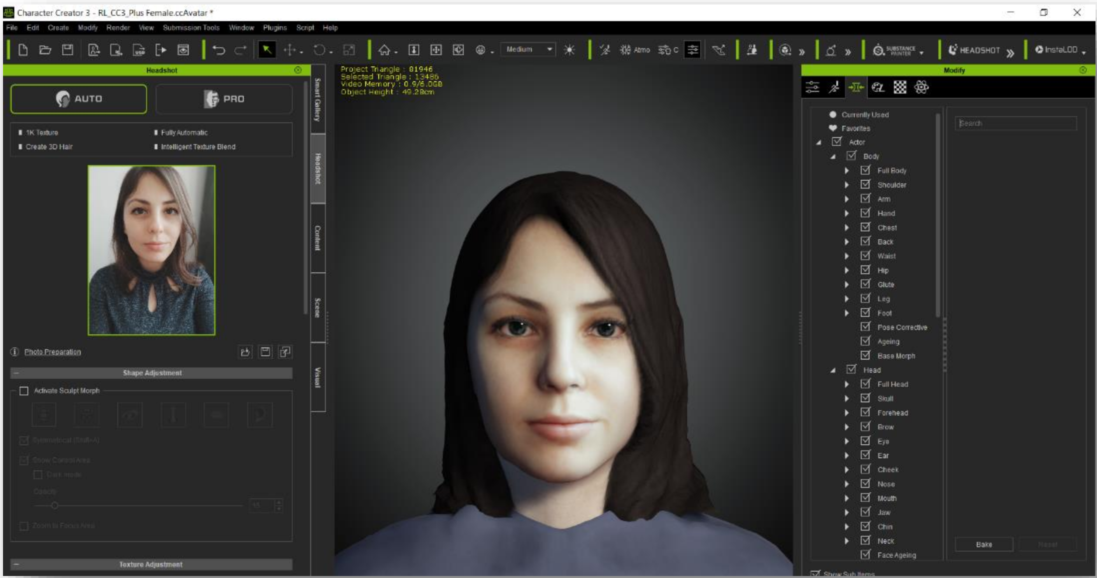

Figure 3.2 3D Virtual Body Generation with Headshot Pipeline. *Using Headshot pipeline of the Character Creator 3 software to generate a lookalike virtual body of the participant's by using their frontal picture.*

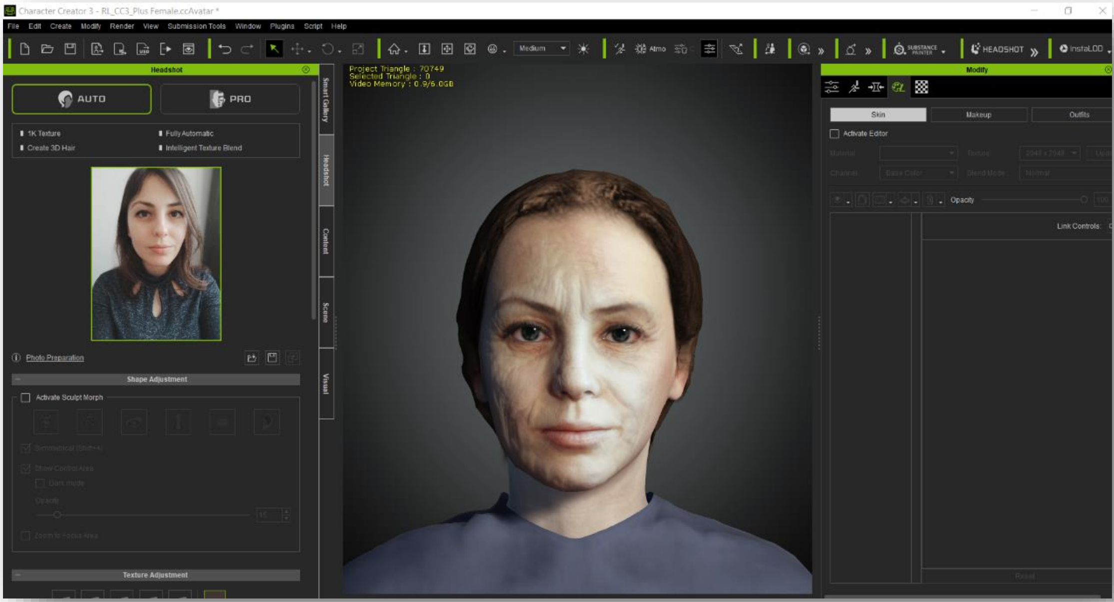

Figure 3.3 3D Virtual Body Generation with Skin Editor and Ultimate Morphs. *Using Skin Editor and Ultimate Morphs features of the Character Creator 3 software to generate the 3D virtual body for the future-self version of the participant.*

3.4 Participants

In this section, we will cover the important procedural details that were followed for participant recruitment, informed consent, data collection, and data protection. We made sure to use effective strategies for participant recruitment to ensure a diverse and representative sample. All participants were informed about the nature, purpose, and potential risks of the study before they agreed to participate. We used various methods and tools for data collection, and we will describe them in detail. We also followed stringent measures to protect the participants' data and privacy, maintaining confidentiality and anonymity as required by ethical guidelines and data protection protocols.

3.4.1. Participant Recruitment

In all experiments except the Self-dialogue with a Virtual Future Self about Nicotine Dependence experiment, participants were recruited from the Event Lab database available on the UB-approved Qualtrics platform. Participants registered to this database from the advertisements in the Mundet Campus, the University of Barcelona. A separate database was created for the Self-dialogue with a Virtual Future Self about Nicotine Dependence experiment, and the study was advertised on the HCB platforms. Only participants who met the inclusion and exclusion criteria were recruited for all experiments. All studies required the following exclusion criteria: participants must be 18 years or older, should not have consumed alcohol on the day of the experiment, must not be on any psychoactive medication, must not be suffering from dizziness caused by any underlying condition, must not have epilepsy, must not have a high susceptibility to motion sickness, and must not intend to operate a motor vehicle within three hours after the conclusion of the study. Additionally, participants who scored lower than 13 on the WHO-5 Well-Being Index were not included in the Self-Dialogue with a Future Self experiments and they were referred to their local health service for further examination.

3.4.2. Participant Informed Consent

Before conducting all experiments, we provided participants with an information sheet to read and asked them to sign a participant consent form. We ensured that participants were informed verbally and in writing and were aware of their freedom to withdraw from the experiment at any time without providing reasons. Appendices containing the information sheet and consent form are provided for the experiments: Simulator Sickness (Appendix A), Qigong (Appendix B), Self-Dialogue with a Virtual Future Self about a Personal Problem (Appendix C), and Self-dialogue with a Virtual Future Self about Nicotine Dependence (Appendix D).

3.4.3. Data collection

The data collection process followed the institutional ethical guidelines. The experiments as a part of the Simulator Sickness study in Chapter 4 and the Qigong study in Chapter 5 as well as the Self-Dialogue with a Virtual Future Self about a Personal Problem experiment in Chapter 6 were approved by the Bioethics Committee of the University of Barcelona (La Comissió de Bioètica de la Universitat de Barcelona). Self-dialogue with a Virtual Future Self about Nicotine Dependence experiment in Chapter 6 was approved by the Research Ethics Committee of the Hospital Clinic Barcelona (Comité Ético de Investigación Clínica del Hospital Clínic de Barcelona). To ensure that participants' data was safe, we used the UB Approved Qualtrics platform to store it. The rights of information concerning the data processing are included in Appendix E.

The gathered data contained various forms, including both quantitative and qualitative data. The measures ranged from demographic information and VR response measures to questionnaires, measurements, and scales that exhibited high validity and reliability. Some open-ended questions were also utilised to gain a more extensive understanding of the participant's responses. The details of these measures were summarised in the separate methods sections for each study.

3.4.4. Data Protection & Privacy

We took the necessary steps to ensure that participants' data was safe and private by assigning a unique code to each participant's data. Only the researcher involved who carried out the experiment had access to the list that matched the code with the corresponding data, so no one else could identify the participants. The University of Barcelona's General Secretary was responsible for managing the data.

We informed participants that we would keep the pseudo anonymous data as long as needed to finish the project and ensure we followed all the rules. We would not share participants' data with anyone else unless required by law. Participants were informed that they have the right to access their data, correct any errors, have it deleted or moved to another location, and could contact us if they do not want us to use their data anymore. They could also contact the General Secretary and provide a copy of their ID to exercise these rights.

Finally, data protection and privacy information that followed a similar protocol for the Self-Dialogue with a Virtual Future Self about Nicotine Dependence study can be found in the Confidentiality section of the participant consent form in Appendix D.

3.5 Experimental Procedures

This section will deliver further insight into the standard experimental procedures commonly employed in our studies. The focus will be on describing the embodiment processes and outlining the protocols adopted for the prevention of the spread of COVID-19 between researchers and participants.

3.5.1 Embodiment

In our research studies that involved a virtual body, we included embodiment exercises to help the participants become familiar with their virtual bodies. In the studies that investigated “Simulator Sickness Experiments", participants did not have a virtual body. However, in the studies that examined "Qigong Experiment" and “Self-Dialogue with a Virtual Future Self Experiments", participants were provided with a virtual body during the experiment. To create the illusion of body ownership and illusory agency while adjusting to their virtual bodies, the participants engaged in a series of specially designed instructions called "embodiment exercises". These exercises were customized to suit the unique requirements of each experiment. Here, we will offer a general overview of why we incorporated embodiment processes. Later, we will detail the specific embodiment exercises for each study in the respective chapters dedicated to these studies.

One of the critical aspects of the embodiment process was the participant's viewpoint. When participants started the experiment and began interacting with the virtual environment, they experienced their virtual bodies and the environment surrounding them from the first-person's view. Moreover, a virtual mirror within the environment allowed participants to see the reflection of their virtual bodies. The instructions such as "Let's start by getting used to your new virtual body. Look at your arms and body, then wave in the mirror. Do you see yourself?" were used to allow these elements of the embodiment.

Another crucial element of the embodiment process was visuomotor synchrony, which ensured the virtual bodies of the participants moved synchronously, at the same time as their real bodies. This real-time coordination enhanced the body ownership and agency over their virtual bodies. Participants did not need to be equipped with additional tracking systems as the built-in cameras of the Quest made real-time tracking possible. Participants were instructed to observe their surroundings and to look at their right and left sides. Then, they were prompted to follow exercises to move their bodies and part of their bodies, such as "Keep your arms raised while keeping your legs still and look down at your legs. It is possible that you feel them as yours. Look up and then to the right, and then extend your right hand and wave it up and down. Feel your hand as you watch it move gently. Slowly turn your head to the left and do the same with your left hand. Concentrate on your left hand and see it as you move it."

On top of these embodiment exercises, in the Self-Dialogue with a Virtual Future Self studies, participants additionally followed similar embodiment exercises for the counsellor's virtual body when they first swapped from their virtual body to the virtual body of the counsellor.

In conclusion, all embodiment exercises incorporated elements like first-person viewpoint and visuomotor synchrony for participants to establish body ownership illusion and illusory agency over their virtual bodies.

3.5.2. COVID-19 safety procedures

Due to the timing of our data collection process, which coincided with the height of the Coronavirus disease pandemic, we implemented COVID-19 safety protocols on top of the standard ethical guidelines. These protocols were designed to protect the well-being and health of both participants as well as the researchers while assuring the cleanness of the virtual reality equipment used in our experiments.

To comply with COVID-19 safety procedures, we secured that only one researcher and one participant were present in the experiment room designated for the VR session at a time. Upon their arrival, participants were screened for COVID-related symptoms, and their temperature was taken. Participants who exhibited any symptoms were not permitted to participate in the study. In addition, both the researcher and participant were mandated to wear FFP2 face masks throughout the procedure.

To ensure the safety of the equipment, we utilised a device called CleanBox (Figure 3.4), which uses Ultraviolet-C radiation to kill contagions on shared devices (https://cleanboxtech.com/). After cleaning the HMD and controllers with the CleanBox, the experimenter wore nitrile gloves to remove the equipment from the CleanBox. Furthermore, the participant put on the disposable VR cover mask (Figure 3.5) to the HMD independently. Once the HMD was in place, the experimenter retrieved the controllers from the CleanBox using nitrile gloves and gave them to the participant. The participant was then instructed to put on the HMD, and the experimenter started or instructed the participant to start the Virtual Reality application.

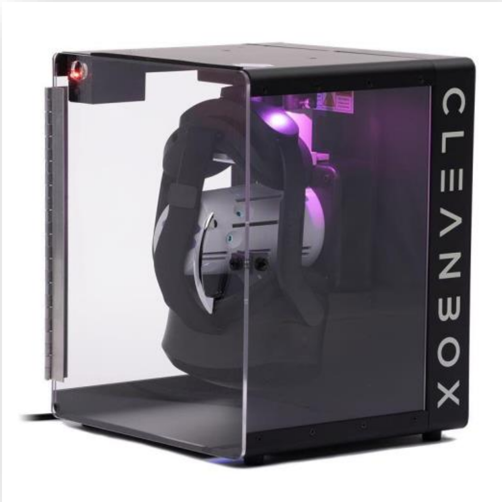

Figure 3.4 Clean Box Device with the Meta Quest Headset.

Figure 3.5 Disposable VR cover mask.

3.6 Data Analysis

Our data analysis was conducted using a variety of statistical packages and data visualisation libraries available in Python. We used Python's statistical packages including pandas and NumPy, to manipulate and process our data. Using SciPy's statistical functions, we conducted tests such as Pearson Correlation, Mann-Whitney U, Wilcoxon, ANOVA, and T-test. The statsmodels library facilitated more complex analyses with its models. We also employed the seaborn and matplotlib libraries for data visualisation.

Our data analysis was carried out using Python 3 within the Jupyter Notebook environment. It is important to note that our analyses for this thesis only utilised Frequentist statistical approaches.

We described the general methodology and common materials in this chapter. In the next chapter, we will continue by explaining the first study of the thesis, Simulator Sickness experiments.

4. Simulator Sickness Experiments

This chapter will examine our first hypothesis "*When moving through a dark virtual environment, participants can travel at a higher velocity and with less simulator sickness than when moving through a bright environment*". As we introduced the background in Section 3 of Chapter 2, simulator sickness still remains a critical concern for virtual reality regarding the broader use of this technology across different fields. Therefore, our primary objective was to propose a potential solution to decrease its effects. We carried out two experiments inspired by our anecdotal observations that indicated a lower probability of experiencing simulator sickness in dark, low-contrast virtual environments, even when navigating at high speeds. Our experiments focused on identifying factors that can decrease simulator sickness, ultimately improving the usability of virtual reality technology. For these studies, we will begin with a general introduction followed by an overview of the specific materials and methods employed for each study. Later, we will demonstrate the results and discuss our findings from these studies.

4.1 Introduction

The utilisation of Virtual Reality (VR) technology is still hampered by simulator sickness. Even though several strategies have been attempted to reduce simulator sickness, as we presented in Chapter 2, it still causes unwanted symptoms in the participants of the virtual reality experience under certain conditions. These symptoms could be associated with stomach awareness and nausea, linked to eye strain and fatigue, and oculomotor, or connected to dizziness and disorientation (Kennedy et al., 1993), and could persist even after the VR exposure (Tanaka & Takagi, 2004; Moss & Muth, 2011; Dużmańska et al., 2018).

Various theories, such as Neural Mismatch Model (Reason, 1978), Postural Instability Theory (Riccio & Stoffregen, 1992), and Evolutionary Theory (Treisman, 1977), have been proposed to understand this issue. In virtual environments, illusory self-motion, the sensation of virtually moving through a scene despite being stationary in reality, has been suggested to lead to these undesirable symptoms (McCauley & Sharkey, 1992). It was also proposed that in virtual reality, simulator sickness commonly occurs because of the discrepancy between the perception of the virtual movement and the actual head movements of the participants (Palmisano et al., 2017) when participants navigate the virtual environment using a handheld controller.

Although making the velocity slower may help to decrease these symptoms, based on our informal observations, simulator sickness may be less prevalent in dark, low-contrast virtual settings, even when moving at fast velocities.

To test this previous observation, we developed a virtual reality scenario in which participants moved through virtual streets in different lighting conditions while determining the velocity of their movements with the controller. We hypothesised that when moving through a dark virtual street, participants could travel at a higher velocity and with less simulator sickness than when moving through a bright street. We tested this hypothesis with two experiments. With the first experiment, we demonstrated that the brightness of the first street strongly influences velocity. We confirmed our findings with the second experiment by revealing that the dark environment at the beginning of the virtual reality experience has an advantage in decreasing simulator sickness.

4.2 Experiment 1: Materials and Methods

In the first experiment, we developed the virtual environment as a street which was segmented into four alternating dark and light sections. We tested the impact of different sequences of street lighting conditions on participants' movement velocity and simulator sickness. In the "dark first" condition, participants started experiencing the virtual environment in the order of dark-light-dark-light streets. In the "light first" condition, participants experienced a sequence of light-dark-light-dark streets.

4.2.1. Participants

We recruited a total of 34 participants for the first experiment from our lab database. We used the standard protocol of participant recruitment, as explained in the general materials and methods in Chapter 3. Participants were randomly assigned to one of the experimental conditions. The "light first" condition consisted of 17 participants who identified as male (N=5) and female (N=12) genders with a mean age of 24.2 ($\pm$ 6.17) and spoke either Spanish (N=11) or English (N=6). The "dark first" condition consisted of 17 participants who identified as male (N=5), female (N=11) and other (N=1) genders with a mean age of 27.5 ($\pm$ 10.21) and spoke either Spanish (N=8) or English (N=9). Prior to their attendance at the experiment, participants read the safety notice about simulator sickness symptoms, and they were informed both verbally and in a written format that at any point in the study, they wished to stop due to sickness symptoms or any other reason, they were free to do so (Appendix A, Information Sheet). Participants also read and signed the consent form, which also checked for the exclusion criteria such as being under the age of 18, consuming alcohol on the day of the experiment, taking psychoactive medication, experiencing dizziness due to any pathology, having epilepsy, being highly prone to motion sickness (e.g., in cars, boats, or aeroplanes), and planning to drive a motor vehicle within 3 hours of completing the study (Appendix A, Participants Consent Form). After the VR exposure and completion of the post-experiment questionnaire, participants were given 10 euros as gratitude for their time and confidentially debriefed about the purpose of the experiment.

4.2.2. Experimental Design

We implemented a between-groups experiment design with independent measures to allocate participants randomly in one of the two experimental conditions. The virtual street developed for creating these conditions involved two dark and two bright zones in an alternating sequence. The objective was to determine whether participants would navigate faster in the dark streets. In the "dark first" condition, participants began moving in the virtual environment of a street featuring dark-light-dark-light lighting segments. Conversely, in the "light first" condition, they experienced an order of a street that had light-dark-light-dark segments. The virtual street with different lighting conditions is illustrated in Figure 4.1.

Figure 4.1 The virtual street. *A and B show different locations during the dark segment of the street. C and D show different locations during the light segment of the street.*

4.2.3. Experimental Procedures

After contacting the participant list in our database, we invited participants interested in participating in this study to our Virtual Reality laboratory. Upon arrival, we presented participants with the information sheet and participant consent form. After obtaining the signed consent form, we told participants that they would face a virtual street when they entered the virtual reality. Then, we physically showed participants the controllers and described all the buttons on the controllers and their functioning (Figure 4.2). We explained to participants that their task would involve moving forward in the virtual street by using the trigger buttons (Figure 4.2.B) in the Quest 2 controllers (Figure 4.2.A), and the application would stop when they get to the very end of the road. We also informed participants that they could use either the right or left hand to adjust the speed of moving by modifying how much they engage with the trigger button. We explained the simulator sickness and clarified that participants should move as fast as possible but slow enough not to experience simulator sickness. We explained that if they experience simulator sickness, they should slow down by adjusting their speed with the trigger button. Finally, we cautioned them that they could stop the application by pressing the B button on the right controller (Figure 4.2.B).

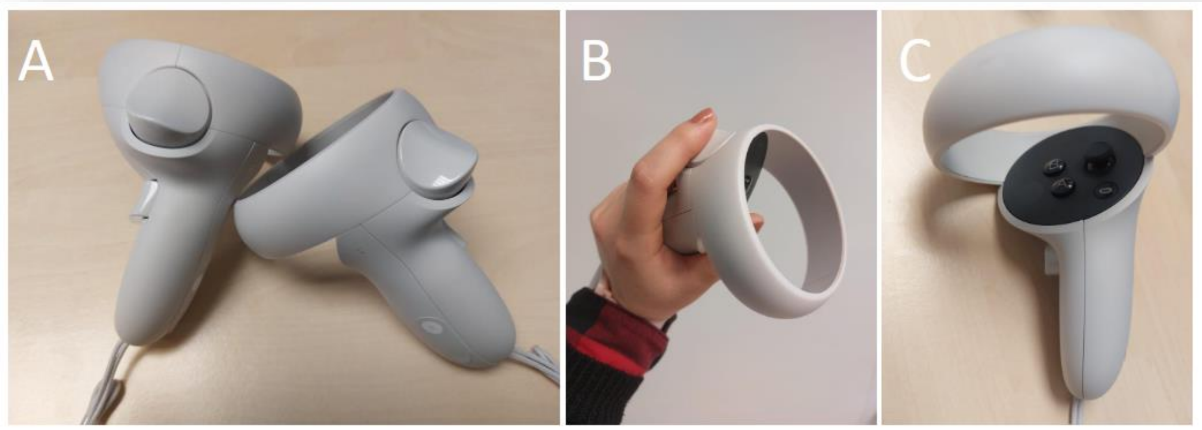

Figure 4.2 Meta Quest 2 Controllers. A) *Right and Left Controllers.* ***B)*** *Trigger button.* ***C)*** *A and B buttons and Joystick on the controller.*

In addition to verbally presenting the information, we encouraged participants to ask questions if they had any doubts. After the study description and information, participants answered the questionnaire and entered their participant ID on the UB-approved Qualtrics platform. The Qualtrics questionnaire included a pre-questionnaire and a post-questionnaire. The pre-questionnaire before the VR exposure consisted of demographic questions about gender and age, questions regarding previous VR experience, knowledge of computer programming, video game playing times and hours in the past year and in the past week, as well as participants' proneness to motion sickness. After completing the pre-questionnaire, we gave participants the Meta Quest 2 headset and the controllers but following the COVID-19 protocols mentioned in the experimental procedures section of Chapter 3.

When participants completed the virtual reality task, which took approximately 15 minutes at most, and removed the Quest 2 headsets, participants continued with the post-questionnaire, which included the Simulator Sickness Questionnaire (SSQ) by Kennedy et al. (1993) and some questions about their differential reactions to the light and dark parts of the street. All questionnaires were both available in English and Spanish. The whole experimental session, including the ethics protocols, pre-and-post questionnaires, as well VR-exposure, lasted a maximum estimation of 30 minutes. All the participants were given 10 euros as a token of appreciation for their time. We also debriefed participants about the purpose of the experiment at the end of the experimental session.

4.2.4. Response Variables

In this experiment, the velocity of the participants' movements in each segment of the street while they were moving through different orders of darker and brighter parts of the street were the main response variables. Participants moved at speeds ranging between 0 and 12 metres per second, with 0 indicating the minimum velocity and 12 metres per second indicating the maximum velocity. Additionally, the scores obtained from the SSQ, although calculated after the VR exposure, were also incorporated to understand the overall SSQ experienced by participants during the VR exposure (SSQ is explained as one of the main subjective measurements of simulator sickness, as explained in Chapter 2). We specifically considered the computed scores for Nausea (N), Oculomotor (0), and Disorientation (D) variables. SSQ computation method was directly obtained from the article of Kennedy et al. (1993). Moreover, pre-questionnaire responses (Table 4.1), including the demographics and prior VR and computer game exposure, were included as independent variables that might have an influence on the response variables.

Table 4.1 Pre-questionnaire before the VR exposure and participant responses per condition

question	response	light first condition	dark first condition
What is your preferred experiment language?	English Spanish	6 11	9 8
What is your gender?	1 = male 2 = female 3 = other	5 12 0	5 11 1
What is your age?	Mean $\pm$ SD	24.2 $\pm$ 6.17	27.5 $\pm$ 10.21
How much have you experienced VR before? *1=never* *7 = a great amount*	Median (IQR)	2(2)	4(2)
What is your level of knowledge of computer programming? *1 = none* *7 = expert*	Median (IQR)	3(3)	4(3)
How many times have you played video games in the past year? *1 = 0 times* *2 = 1-5 times* *3 = 6-10 times* *4 = 11-15 times* *5 = 16-20 times* *6 = 21-25 times* *7 = more than 25 times*	Median (IQR)	3(3)	3(5)
How many hours have you played video games in the past week? *1 = 0 hours* *2 = 1-2 hours* *3 = 3-4 hours* *4 = 5-6 hours* *5 = 7-8 hours*	Median (IQR)	1(1)	1(2)

6 = 9-10 hours *7 = more than 10 hours*			
Are you prone to motion sickness? *1 = never* *7 = always*	Median (IQR)	3(2)	2(1)

In the following section, we present the results of our analysis.

4.3 Experiment 1: Results

The pre-questionnaire variables displayed in Table 4.1 showed no significant impact on the outcomes, and the demographics across the groups were uniformly distributed. Table 4.2 presents the post-questionnaire responses collected after the VR sessions. Utilising Pearson correlation, we identified a weak negative relationship between overall speed and SSQ scores. Nonetheless, this relationship was not statistically significant (Pearson correlation = -0.26, p-value = 0.12). Interestingly, our results deviated when we examined the specific variables of the SSQ scores. We found a significant negative correlation between the participants' overall speed and the Disorientation (D) scores (Pearson correlation = -0.40, p-value = 0.01). Conversely, despite the relationship being insignificant, the Nausea (N) variable displayed a weak positive correlation (Pearson correlation = 0.02, p-value = 0.87), and the Oculomotor (O) variable exhibited a slight negative correlation with overall speed (Pearson correlation = -0.25, p-value = 0.14). Although the overall SSQ was not correlated with velocity, some of the individual components were.

Table 4.2. Post-questionnaire after the VR exposure and participant responses per condition in Experiment 1.

question	**response**	**light first condition**	**dark first condition**
SSQ Scores *Nausea(N)* *Oculomotor (O)*	Mean ± SD	 14.0 ± 12.67 17.8 ± 13.91	 12.9 ± 18.45 16.0 ± 12.81

Disorientation (D) *Overall SSQ Score*		36.0 ± 26.52 23.9 ± 16.62	21.2 ± 25.62 18.7 ± 16.40
In which part did you feel the symptoms?	1 = light 2 = dark 0 = both the same	12 1 4	5 2 10
Did you have to stop moving along the street at any moment during the task?	1 = stopped light part 2 = stopped dark part 0 = did not stop at all	10 2 5	4 0 13
Which part of the street did you prefer to walk through?	1 = light 2 = dark 0 = both	5 6 6	7 3 7
Velocity *Street 1* *Street 2* *Street 3* *Street 4*	Mean ± SD	 8.8 ± 2.5 9.2 ± 2.7 10.1 ± 2.3 10.2 ± 2.5	 9.71 ± 2.2 10.8 ± 2 11.4 ± 1.1 11.5 ± 1.1

Our post-questionnaire results showed that the overall SSQ scores were higher for the “light first” condition (mean = 23.9, SD = ± 16.62) compared to the “dark first” condition (mean = 18.7, SD = ±16.40). However, when we performed a Mann-Whitney U test to determine the significance of these differences in the SSQ scores between the “dark first” and “light first” conditions, the difference was not statistically significant (u-statistic = 116.5, p-value = 0.34). The boxplot visualised in Figure 4.3 provides a view of the overall SSQ scores under the “dark first” and “light first” conditions. The box represents the Interquartile Range (IQR) and the dark horizontal line inside the box indicates the median score. The lower whisker ranges from Lower Quartile down to max (smallest value, lower quartile - 1.5*IQR). The upper whisker ranges from upper quartile to min (highest value, upper quartile + 1.5*IQR).

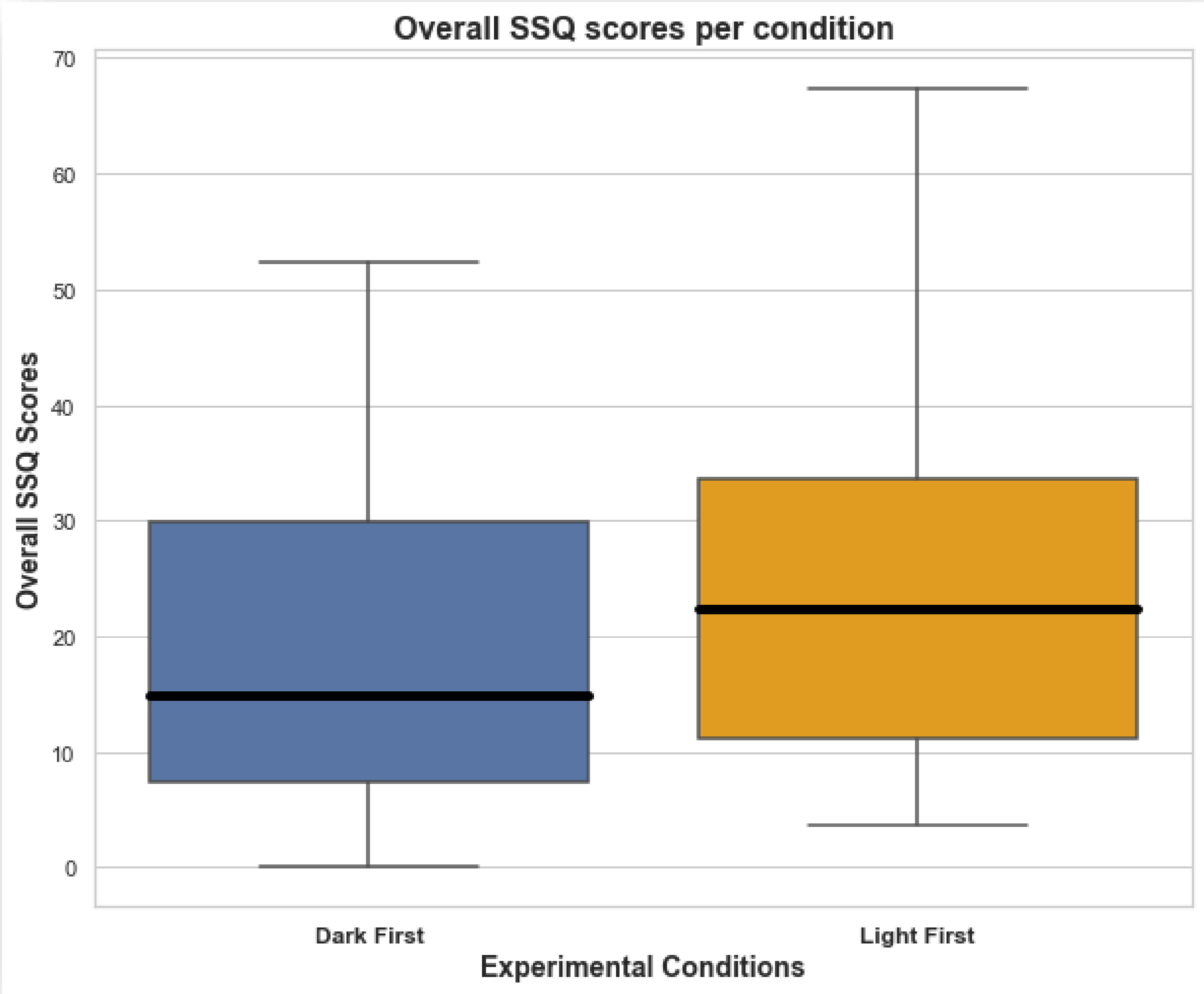

Figure 4.3 The boxplot of overall SSQ scores per condition.

Following our comparison between overall SSQ scores, we analysed the variation of velocities across successive streets, differentiated by each condition shown in Figure 4.4. The left side of the figure displays the streets under the "dark first" condition, and the right side displays the streets under the "light first" condition. The line within the box indicates the median velocity for each condition, and the average velocities are marked as white dots. Upon closely examining the figure, we observed that the "dark first" condition consistently showed higher velocities, particularly in the first three street stages. The Interquartile Range (IQR) for these streets, the range within which the central half of the velocities lie, is higher for the "dark first" condition. Due to the maximum possible velocity of 12, there is no higher value for participants to reach, therefore the ceiling effect is much more noticeable in the "dark first" condition.

Additionally, the lower quartile (the bottom edge of the box) for the "dark first" condition surpasses the median velocity (line within the box) of the "light first" condition. In the "dark first" condition, the median speeds on Streets 1, 2, 3, and 4 were 9.89, 11.93, 12.00, and 12.00, respectively, while in the 'light first' condition, the median velocities were lower, ranging 9.83, 10.54, 11.18, and 11.84, respectively.

This figure depicts an early advantage in terms of speed adaptation for the "dark first" condition. Here, the velocities for both conditions show closer similarities, as evidenced by the narrowing gap between the IQRs and median values. Our statistical analysis confirmed these visual findings. We performed the Mann-Whitney U test to assess the differences in velocities between the conditions. We found significant differences between conditions for the third (U-statistic = 214.0, p-value = 0.01, $p < 0.05$) and fourth (U-statistic = 201.5, p-value = 0.03, $p<0.05$) streets. These findings suggest that although participants in all groups adapted eventually, the participants in the "dark first" condition had a clear advantage at the beginning.

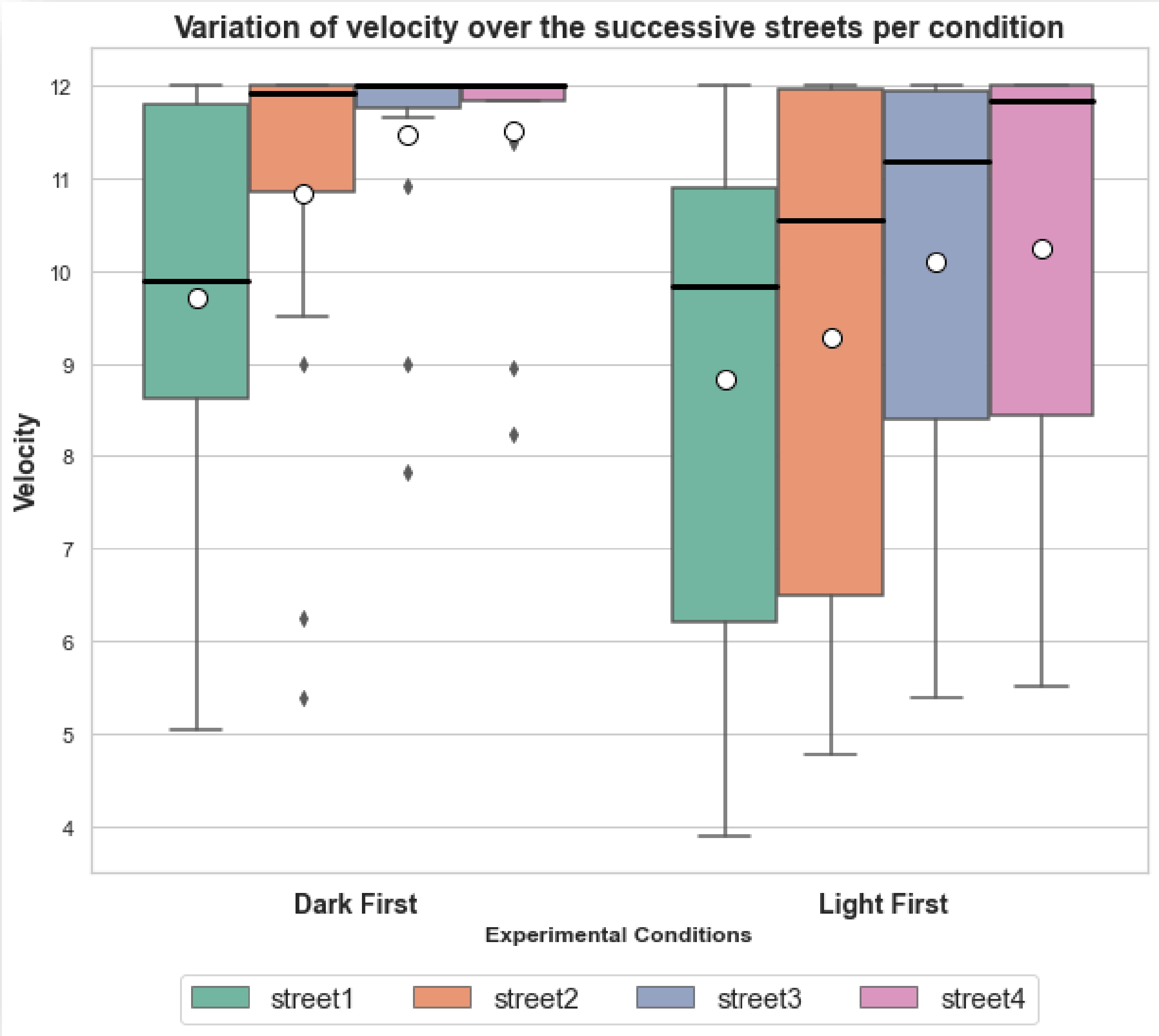

Figure 4.4 The boxplot of velocities across successive streets for each condition.

We also looked at how participants responded to different segments of the street, including if they had certain symptoms, which part of the street they liked to walk through, and whether they ever stopped walking while performing the task. Overall, in both conditions, we observed that participants did not stop at all(N=18) or stopped moving (N=14) in the light streets compared to dark streets (N=2) as well as suffered symptoms, particularly in the light part of the street (N=17) or both streets were the same(N=17) compared to symptoms caused by the dark part of the street (N=3). They did not, however, indicate a clear preference for the dark part of the street (N=9) compared to the light street (N=12) or both streets were the same(N=12). A Chi-square χ² test was performed to determine whether the experimental conditions had a significant influence on the reported variables including symptoms, preference and stop moving. The results did not demonstrate a significant association between the experimental conditions and participants' street preference (Chi-square χ^2 = 1.41, p-value = 0.494). However, there was a slight but not statistically significant trend towards an association between the experimental condition and experiencing sickness symptoms (Chi-square χ^2 = 5.79, p-value = 0.055). On the other hand, we found a statistically significant association between the experimental condition and whether participants stopped moving (Chi-square χ^2 = 8.13, p-value = 0.017). The count plot of stop moving variable was demonstrated in Figure 4.5.

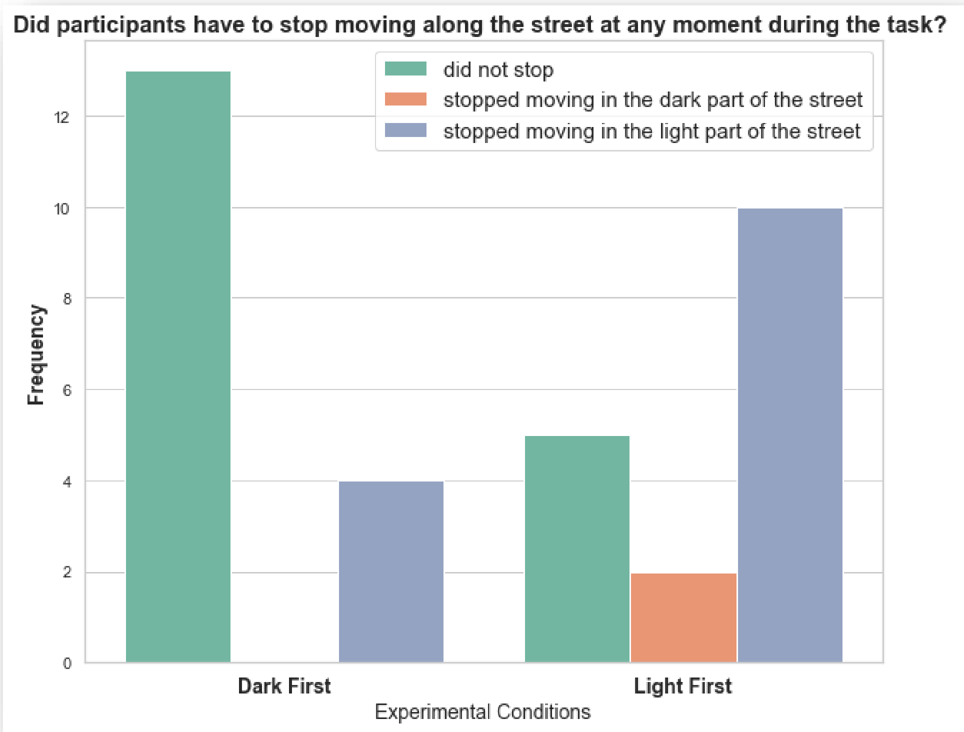

Figure 4.5 The boxplot of the frequency of "stop moving" variable during the task. *Participants' responses to stop moving during the task is demonstrated by the "dark first" and "light first" conditions.*

4.4 Experiment 1: Discussion

The main result of our first study emphasised the significance of the initial lighting condition on participants' speed of movement. In contrast to starting with a brighter street, when participants were exposed to a dark street at the beginning of the VR session, they tended to move at a faster velocity and exhibited fewer signs of simulator sickness. This finding highlighted how important the lighting of the environment can be to virtual reality experiences and might have wider ramifications for how VR settings are made.

The secondary finding that can be drawn from our study suggests that there could be an all-around connection between participants' speeds and the street's brightness, requiring further investigation into the underlying factors and mechanisms that influence this relationship. A possible mechanism that could explain this connection and the results of the follow-up experiment will be discussed together at section 4.7.

Our findings have a practical application in that we may be able to improve the usability of virtual reality by adjusting the initial lighting conditions in a virtual scene. In contrast to a virtual environment that maintains constant brightness throughout, participants might be able to move faster through the environment while having less simulator sickness by gently transitioning from a dark street to one with regular brightness, for example. To further investigate this possible implication and test whether these findings extend to various virtual settings, we ran a follow-up experiment explained in the next section.

4.5 Experiment 2: Materials and Methods

The second experiment served as a follow up to Experiment 1. We recruited in total of 36 new participants from the lab data base and assigned them to one of the two conditions. In the "dynamic light" condition, 18 participants moved through a street, which transitioned from a darker to a brighter street gradually. In the "static light" condition, 18 participants moved through a street that was always with bright lighting without having any change in the lighting parameter of the virtual environment through the VR session. The length of the streets and the patches were equal to the street environment developed for Experiment 1. Moreover, Experiment 2 employed the identical protocols, methods, and materials as in Experiment 1, including the participant recruitment, ethical guidelines, equipment and other procedures and materials. Experiment 2 also included the same post-questionnaire and response variables (Table 4.3), except for the participants' reports for different reactions in the "static light" condition, which were not included since participants in this condition only moved through a light street.

Table 4.3. Post-questionnaire after the VR exposure and participant responses per condition in Experiment 2

question	**response**	**static light condition**	**dynamic light condition**
SSQ Scores *Nausea(N)* *Oculomotor (O)* *Disorientation (D)* *Overall SSQ Score*	Mean ± SD	 12.7± 16.6 14.7 ± 15.7 22.4 ± 20.3 18.2 ± 15.6	 14.0 ± 18.5 19.1 ± 18.9 35.2 ± 34.8 24.4 ± 22.2
In which part did you feel the symptoms?	1 = light 2 = dark 0 = both the same	Non-applicable	7 3 7
Did you have to stop moving along the street at any moment during the task?	1 = stopped light part 2 = stopped dark part 0 = did not stop at all	Non-applicable	2 3 12
Which part of the street did you prefer to walk through?	1 = light 2 = dark 0 = both	Non-applicable	7 3 7
Velocity *Street 1* *Street 2* *Street 3* *Street 4*	Mean ± SD	 8.9 ± 2.8 10.5 ± 1.9 10.9 ± 1.7 11.17 ± 1.6	 10.5 ± 2.05 10.7 ± 1.9 11.12 ± 1.6 11.41 ± 1.3

4.6 Experiment 2: Results

Despite participants being evenly distributed based on the pre-questionnaire responses, our descriptive analysis on average time spent and an average speed for all participants revealed that one participant in the “dynamic light” condition was recognized as an outlier. This participant exhibited an extremely low speed during the experiment and due to this factor, the participant needed to be excluded from further analysis. Figure 4.6. displays the boxplot of the overall velocities for each condition, both with and without the outlier participant. For this reason, the experimental groups were assigned per condition for the final analysis included 17 participants in the “dynamic light” condition and 18 participants in the “static light” condition.

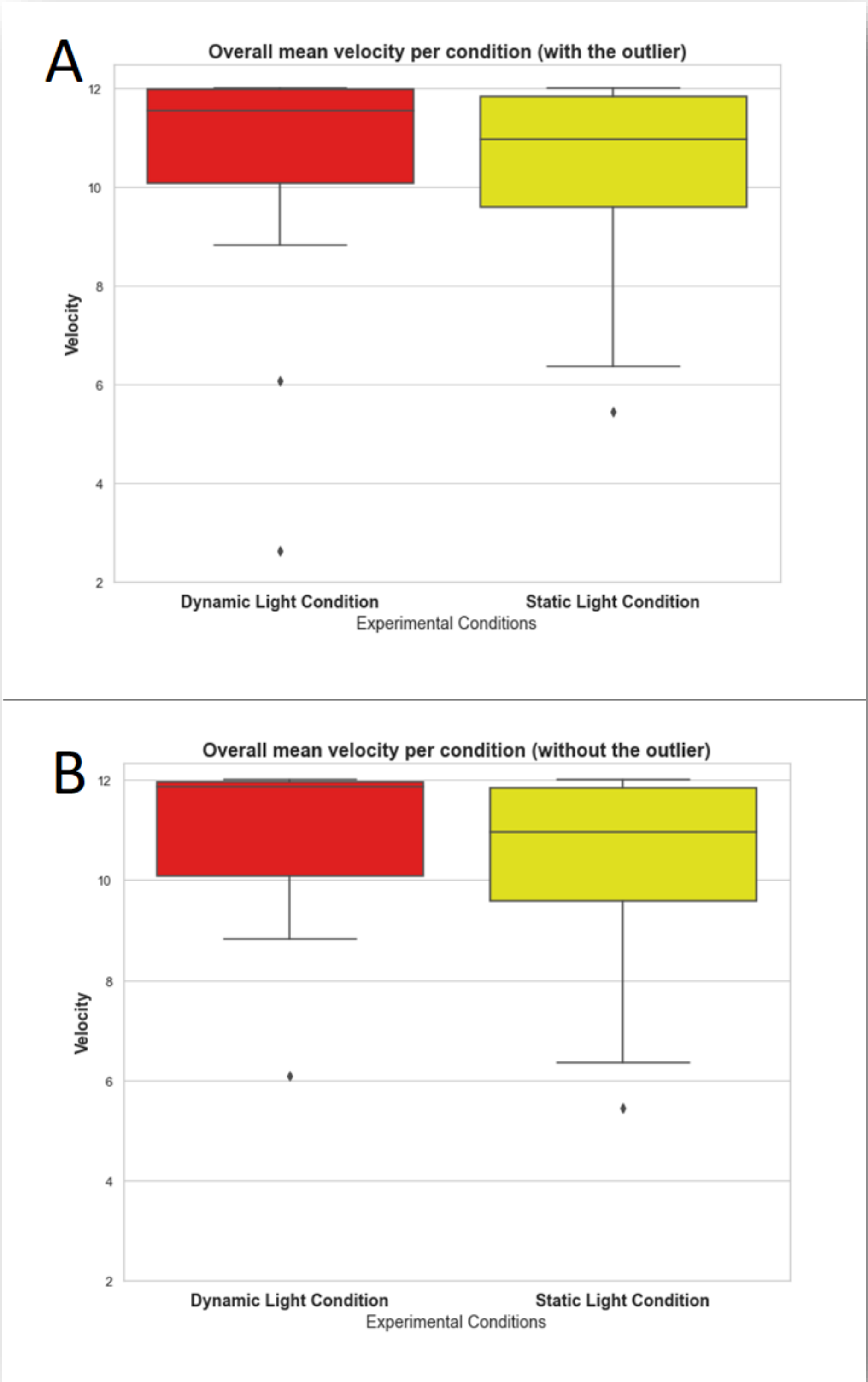

Figure 4.6 The boxplot of the overall velocities per condition. A) *The boxplot with the outlier participant.* ***B)*** *The boxplot without the outlier participant.*

After pre-processing and cleaning the data, we performed a Pearson correlation to understand the relationship between the overall SSQ scores, the components of the SSQ and the overall velocity during the experiment. We found a significant negative correlation between the total SSQ scores and the overall velocity (Pearson correlation = -0.45, p-value = 0.04, $p < 0.05$). The separate components of the SSQ indicated varying correlations with overall velocity. There was a moderate negative correlation with the Nausea (N) component that was statistically significant (Pearson correlation = -0.34, p-value = 0.043, $p < 0.05$). A strong negative correlation was revealed with the Oculomotor (O) component, which was also statistically significant (Pearson correlation = -0.51, p-value = 0.0018, $p < 0.05$). However, the Disorientation (D) component did not show a statistically significant correlation with overall velocity (Pearson correlation = -0.25, p-value = 0.13). We performed a Mann-Whitney U test to understand whether the SSQ scores significantly differed between the "dynamic light" and "static light" conditions. Following the SSQ analysis, we did not find any meaningful differences between the "dynamic light" and "static light" conditions for the total SSQ scores and its N, O, and D components.

Thereafter, we tested for the variations of the velocities for each condition over different patches of streets. After performing a Mann-Whitney U test, when comparing the "dynamic light" and "static light" conditions for the various patches of the street, we could not find any significant differences between conditions for the different patches of the street. However, when comparing velocity differences between conditions for Street 1 - the initial segment of the experiment, which started with darker lighting in the "dynamic light" condition and brighter light in the "static light" condition - the Mann-Whitney U test yielded a p-value of 0.0515 (U-statistic = 212), slightly above the standard 0.05 significance threshold. The boxplot of the variation of velocities over the different patches of the street between dynamic and static light conditions depicted in Figure 4.7.

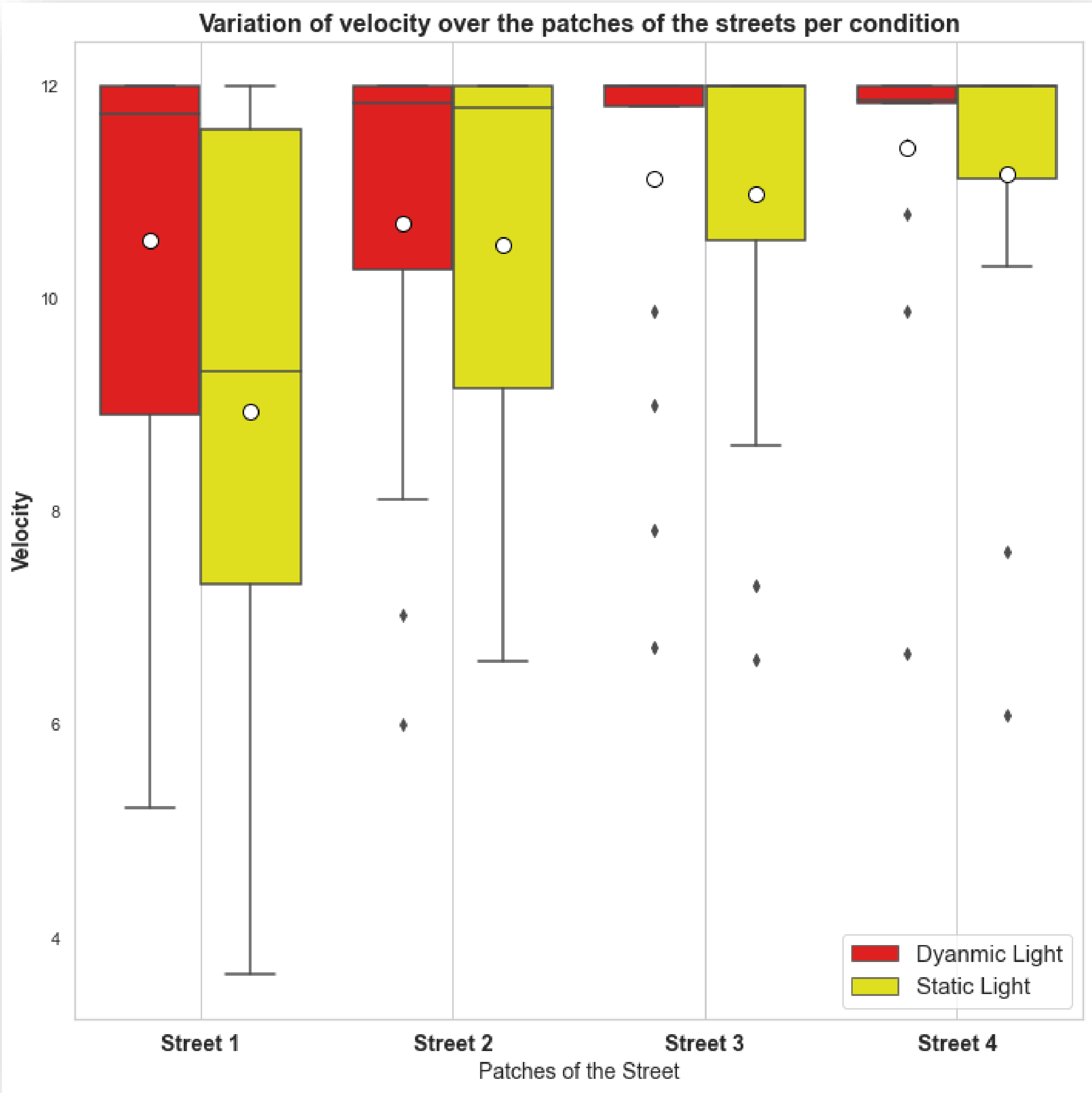

Figure 4.7 The boxplot of the variation of velocity over the successive streets per condition for Experiment 2.

In this experiment, participants' differing reactions to the lighting were examined only for the “dynamic light” condition, as those who were in the “static light” condition did not experience varying lighting changes. As demonstrated in Figure 4.8, participants reported that symptoms were either caused by the light part of the street (N=7) or both parts of the street were perceived similarly (N=7), compared to symptoms caused by the dark parts of the street

(N=3). However, participants preferred the light (N=8) or both lighting conditions equally (N=7), compared to the dark (N=2). Most participants did not stop at all (N=12) during the VR task, and those who stopped were distributed evenly either for the dark (N=3) or light (N=2) sections of the street.

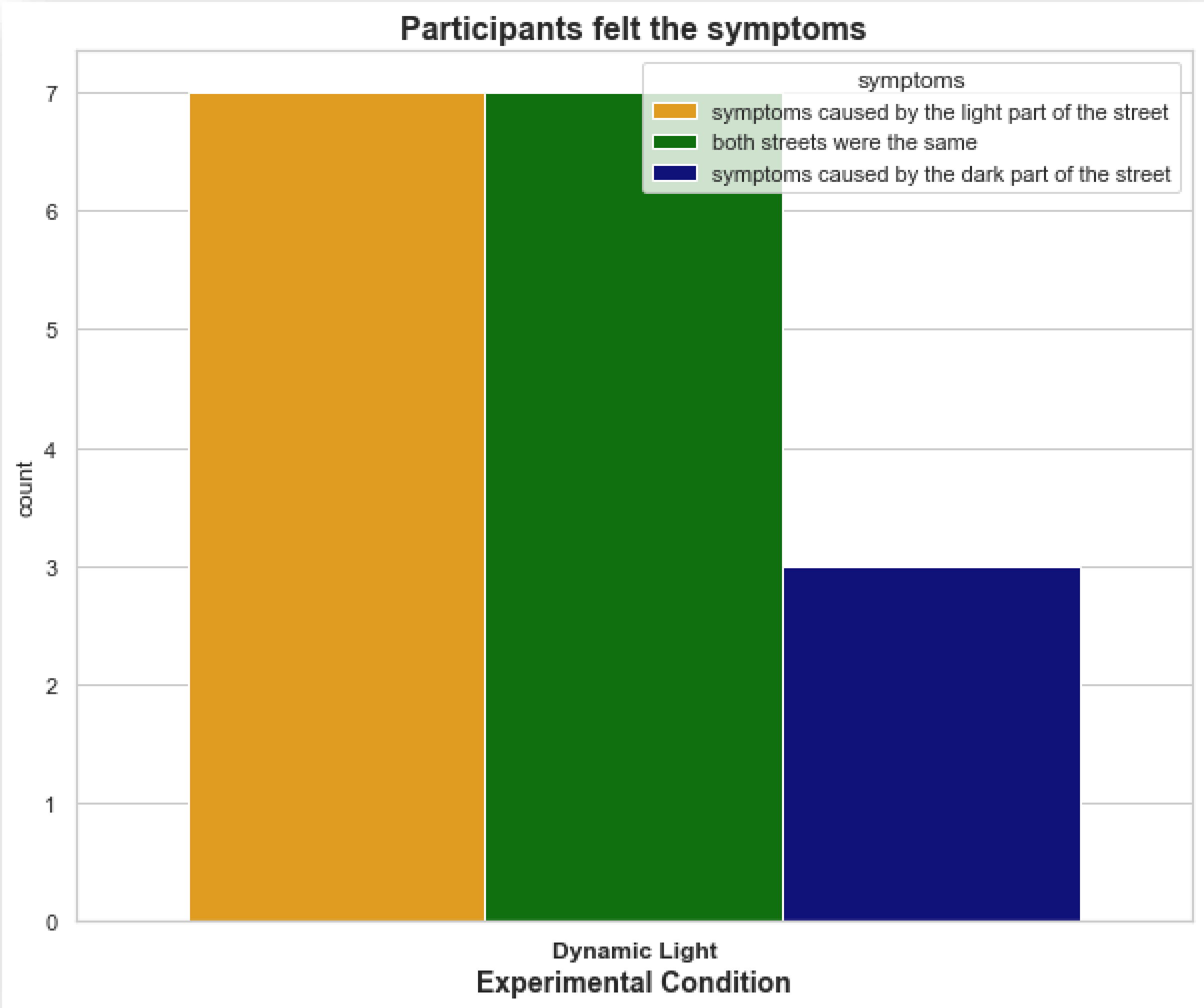

Figure 4.8 Participants' reports of symptoms for different lighting segments of the street in the dynamic light condition.

4.7 Experiment 2: Discussion

In this follow-up experiment, we utilised an objective marker for simulator sickness based on the velocity at which participants moved through the environment. The result from our study demonstrated that a dark environment that is integrated into the initial stage of the VR experience could have an influence on the velocity of participants. This experiment also confirmed that most of the symptoms were reported mainly on the light parts of the street.

The collective results of Experiment 1 and Experiment 2 indicate an overall advantage of a darker environment during the first VR exposure in reducing simulator sickness. These findings hold interesting implications for the usability of VR technology as implementing these findings into virtual environments could be crucial, especially for participants prone to motion sickness. Given that unpleasant symptoms of simulator sickness, such as drowsiness, dizziness, fatigue, and nausea (Kennedy & Frank, 1985), can make it difficult for people to enjoy virtual environments (Lin et al., 2002), adding darkness to the environment at the start of the VR experience can be advantageous for many participants of virtual environments. Making these changes to the visual sensory input coming from the virtual environment might further improve the overall experience because simulator sickness has been shown to adversely correlate with user experience scores (Somrak et al., 2019) and intention to adopt VR technology (Sagnier et al., 2020). Furthermore, as these symptoms could take hours to recover and persist for a long time, even after the VR experience concludes (Tanaka & Takagi, 2004; Moss & Muth, 2011), altering these environmental parameters could directly address and inhibit these issues.

The predictive coding approach proposes that the brain interprets sensory input as an empirical Bayesian device by making predictions based on past knowledge and expectations (Friston, 2002, 2003, 2005). This viewpoint also claims that discrepancies between predictions and actual input lead to prediction errors. When mismatches occur, prediction errors provide a mechanism to update the internal world model to enhance perception and learning through time (Rao & Ballard, 1999). Therefore, it can be argued that tailoring the environmental aspects of the VR environment to match one's expectations more closely could decrease the frequency of prediction errors. This argument is also consistent with the Neural Mismatch Model (Reason, 1978) of simulator sickness, which explains these unpleasant symptoms due to the sensory mismatch between past and present information caused by interpreting various sensory systems to perceive the external world differently. In addition, the EEG study of Nurnberger et al. (2019) revealed a causal relationship between higher mismatch levels and subjectively felt motion sickness in virtual reality.

For these reasons, we could argue that an initial dark VR setting may reduce these prediction errors through a decrease in salience and a decrease in perceptible resolution of the observation space, preventing individuals from experiencing the mismatch and subsequently reducing the occurrence of simulator sickness. In contrast, a brighter VR setting can produce more intense sensory stimulation, similar to a bright street, which could potentially contribute to the symptoms of simulator sickness. These arguments call for additional investigation through follow-up studies to support the findings.

Our study showed a promising approach for lowering simulator sickness and improving the usability of VR technology; however, it had certain limitations. For instance, we chose a specific speed that allowed participants to move without losing the PI and experiencing severe sickness. It is possible that the chosen speed was not sufficient to induce sickness in most participants, but this decision was made for safety reasons. Additionally, the maximum velocity point reached by participants during different segments of the street could potentially indicate a habituation effect. This phenomenon needs to be thoroughly investigated in future research. By addressing these limitations and conducting additional studies, a better understanding of the relationship between the lighting conditions of the VR environment and simulator sickness can ultimately shed new light on enhancing participant experiences in virtual environments.

5. Qigong Experiment

Change blindness (CB) refers to one's inability to perceive changes in their surroundings. This chapter will explore our second hypothesis: "*The gradual changes in the owned and seen virtual bodies can lead to "change blindness" in virtual reality. Therefore, due to the special status of the self-representation giving rise to embodiment, changes to participants' own virtual bodies would be more noticeable than changes to another virtual body*". We discussed the relevant literature about this phenomenon, potential cases of CB in virtual reality (VR), and the "embodiment in Chapter 2.

In this study, we aimed to investigate the occurrence of the CB in the VR, especially when gradual changes were made to an individual's own virtual body and that of another virtual character. Furthermore, we attempted to understand if there were any differences between the observed changes in one's own virtual body and the body of another character. We suggested that reduced CB in the owned virtual body could indicate self-representation in VR and explored how the relationship between embodiment and CB during gradual change might be used further to research the applicability of virtual reality for future work. Therefore, we argued that if the degree of change blindness is different between the own body representation and the other body, particularly if there were less likelihood of change blindness concerning their own body representation, this would be a significant indicator of virtual embodiment.

To answer our question to whether change blindness would apply to participant's embodied body and other body, we developed a virtual environment where participants began their experience in a virtual gym, practising Qigong exercises. The virtual bodies of the participants and the instructor's body underwent the same degree of gradual changes simultaneously. In general, the majority of participants did not perceive the changes in their own virtual body or the body of the instructor. However, the degree of CB was less for their own body than that of the instructor (Senel, Macia-Varela, Gallego, Jensen, Hornbæk, & Slater, 2023). Here, we will present the introduction, provide an overview of specific methods and materials, explain our results, debate and conclude our findings with a discussion.

5.1 Introduction

Individuals can sometimes fail to detect changes in their visual environment, even when those changes are explicit, such as a person they are conversing with undergoing a dramatic transformation (Simons & Levin, 1998). Despite the apparent obviousness of these alterations, this failure to detect changes often occurs among observers, people looking at a scene that (even dramatically) changes. Early change blindness studies suggested that internal (movement of the eyes or blinking) or external (change of the visual scene or real person interruption) visual disruptions, were necessary to trigger the phenomenon (Levin & Simons, 1997; Simons & Levin, 1998). Attention was also proposed as a primary factor for this failure (Rensink et al., 1997). However, Simons (2000) argued that attention could not be the sole reason for change blindness.

Moreover, research by Simons, Franconeri, and Reimer (2000) suggested that change blindness could manifest without any visual disruptions simply by introducing changes gradually. They further showed that change blindness (CB) could be more prevalent under gradual situations than those involving visual disruptions. These findings were further explored by a study of facial expressions conducted by David and colleagues (2006) to understand the relationship between gradual alterations and change blindness by applying changes to human facial expressions in a realistic setting (David et al., 2006). In their study, they altered the images of eight distinct scenarios by changing the colour of an object and modifying an actor's facial expression from neutral to emotional, with each of these scenes featuring three distinct actors. It was found that gradual change was difficult for observers to notice, making it three times less likely to be detected than in a condition where observers experienced a visual disruption. In addition to these findings on gradual changes, techniques based on change blindness have been utilised in VR to achieve various effects. These techniques include dynamically altering the virtual environment to allow participants to navigate a larger virtual space than the actual physical walking area (Suma et al., 2011), enabling a single physical object to represent multiple different virtual objects (Lohse et al., 2019), and conducting research on saliency, attention, and prediction (Martin et al., 2023).

Virtual embodiment, which is the process of replacing a person's actual body with a life-sized virtual body that is aligned and coincides with the actual body's spatial position and first-person perspective, is what gives the illusions of body ownership in immersive virtual reality (Kilteni et al., 2012; Kilteni et al., 2015). Therefore, to understand the relationship between change blindness and the embodiment in virtual environments and to determine any potential differences in the extent of change blindness between one’s body representation and another, we carried out the following experiment. We were particularly interested in determining whether there was a reduced likelihood of experiencing change blindness about one’s own body representation. The experiment was a Qigong training scenario in a virtual gym with two virtual bodies. The participants controlled one gender-matched virtual body, and the other virtual body, which was a virtual human character, interacted with the participant by giving instructions. The first virtual body was the gender-matched virtual body that participants embodied throughout the scenario, and approximately 45 degrees to their left, there was a second virtual body that represented the gender-matched virtual Qigong instructor. Participants viewed their own virtual bodies through a head-tracked head-mounted display with a wide field of view, both when looking down at themselves and into a virtual mirror placed directly in front of them. The instructor demonstrated a sequence of Qigong movements, and participants were asked to replicate those exercises. Specific instructions were given to the participants about when to look at the instructor and when to observe themselves in the mirror. Each participant held 6 degrees of freedom tracked controller in each hand, which enabled their virtual arms to move synchronously with their real arms.

5.2 Materials and Methods

5.2.1. Participants

We recruited a total of 40 participants from the lab database. Beyond the standard protocol for participant recruitment outlined in Chapter 3, our advertisement specifically mentioned that the VR experience would involve activities similar to those displayed in Figure 5.1. The advert with this picture mentioned that we were seeking individuals capable of performing these exercises in a virtual reality setting. This procedure was mainly adopted to solely include participants who can perform these physical exercises and without explicitly excluding people with disabilities.

Figure 5.1 Qigong study Advert picture for the exercises. *To recruit participants who can do physical movements without explicitly excluding people with disabilities, we used this advertisements picture during our advertisement.*

Participants were assigned to one of two versions of the application based on the gender they identified with. The “female version” featured a virtual body and an instructor body with traditionally feminine characteristics, while the “male version” displayed a virtual body and an instructor with traditionally masculine characteristics. Participants’ selection of the virtual bodies is shown in Figure 5.2. A total of 28 participants who spoke either Spanish (N=23) or English (N=5) with a mean age of 23.6 (SD ± 7.4) were allocated to the “female version”. This group consisted of 27 participants who identified as female, and one participant, despite identifying as non-binary, chose the virtual body with traditionally feminine characteristics. A total of 12 participants who spoke Spanish (N=8) or English (N=4) with a mean age of 28.1 (SD ± 8.4), all identified as male, were allocated to the “male version”. Participants were given an information sheet to read before participating in the experiment. They were informed orally and in writing that they could leave the study anytime without giving reasons. Participants were also requested to read and sign a consent form, which screened participants for being the age of 18, alcohol consumption, use of psychoactive medication, susceptibility to motion sickness, epilepsy diagnosis and cautioning for driving within three hours after the completion of the study. Following this experimental session, each participant was given 10 euros in gratitude for their time, and they were confidentially debriefed about the goal of the experiment.

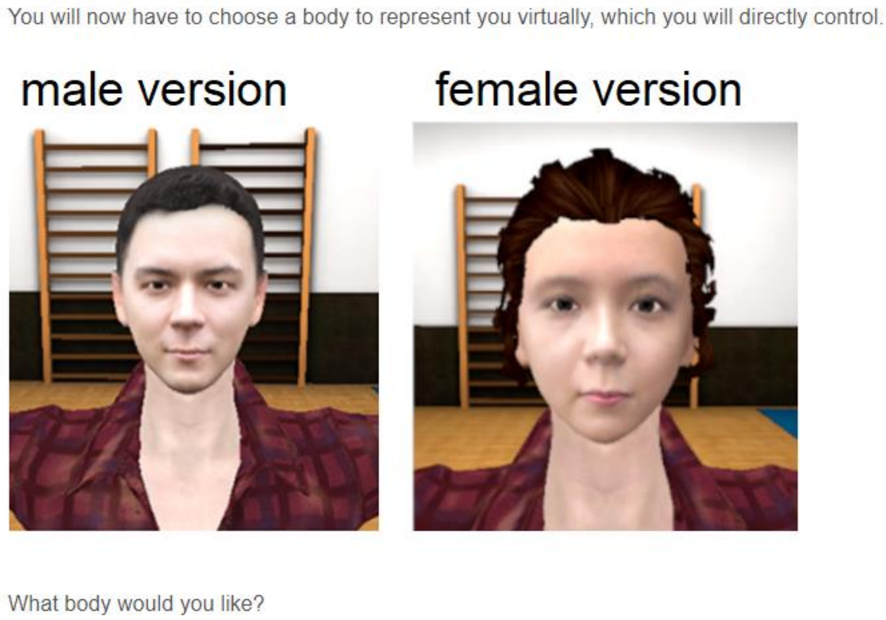

Figure 5.2 Participants' selection of their own virtual bodies

5.2.2. Experimental Design

We executed an experimental design with no specific factors introduced, solely using the "self body" and the "instructor body" as dependent variables to explore the variations in the occurrence of change blindness. The experimental scenario was identical for all participants, but the virtual bodies of the participant and the instructor varied depending on the gender with which the participant most strongly identified. The experiment did not involve random assignment or control groups. We investigated whether participants noticed the gradual alterations made to two virtual bodies depicted in the Qigong teaching scenario - a virtual body embodied by the participant and the other virtual body representing the instructor interacting with the participant. The experimental scenario for the Qigong is demonstrated in Figure 5.3.

Figure 5.3 The experimental scenario for the Qigong. A*) A participant embodied with a virtual body that has traditionally feminine characteristics in front of a virtual mirror and follows the movements of the instructor who is standing 45 degrees on the left.* ***B)*** *A participant with a virtual body that has traditionally male characteristics in front of a virtual mirror and follows the movements of the instructor who is standing 45 degrees on the left.* ***C****) A female participant looks down towards herself and sees her life-sized virtual body that substitutes her real body. Her feet were surrounded by weights to discourage the participant from moving her feet.* ***D)*** *A male participant directly looks at his virtual body's reflection in the mirror.*

The participants started the experiment in front of a virtual mirror embodied in a virtual body while the virtual instructor was placed 45 degrees left of the participants. The virtual instructor outlined some of the concepts of Qigong and performed Qigong exercises, while the participant was instructed to follow these movements demonstrated by the instructor. In addition, the virtual instructor gave instructions to the participants about the times that they should look in the mirror and the times that they should look at the instructor. Participants were instructed not to dislocate their legs from their starting position during the experiment. Participants' virtual feet were surrounded by weights. However, with Quest's controllers providing 6 degrees of freedom in each hand, participants could make movements synchronously reflected in the upper part of their virtual bodies. The virtual reality session lasted for 8 minutes. The faces of the participants' virtual bodies and the virtual instructors' virtual bodies underwent gradual changes during the experiment. These changes are displayed in Figure 5.4. The virtual bodies of the participants and the instructors were developed using Character Creator 3 software, with equal adjustments made to all face parameters. The adjusted dimensions included face heaviness (-25/+25), eye scale (-50/50), cheekbone scale (-50/50), nose scale (-100/100), mouth scale (-100/100), and jaw scale (-50/50). The Unity3D version 2020.2.6f1 was used for implementing the virtual gym environment. The time participants spent looking at their own bodies and the instructor's body was determined by the recordings of the head gaze directions during the experiment. This data was recorded as a 3-dimensional vector of the participant's head rotation every 0.5 seconds. The cut-off to determine whether the participant was looking at their own body or the instructor's body was defined as 245.5 degrees in the Y-dimension of the rotation vector. 221 degrees represented looking directly at the instructor's body, while 270 degrees represented looking directly at the participant's own body.

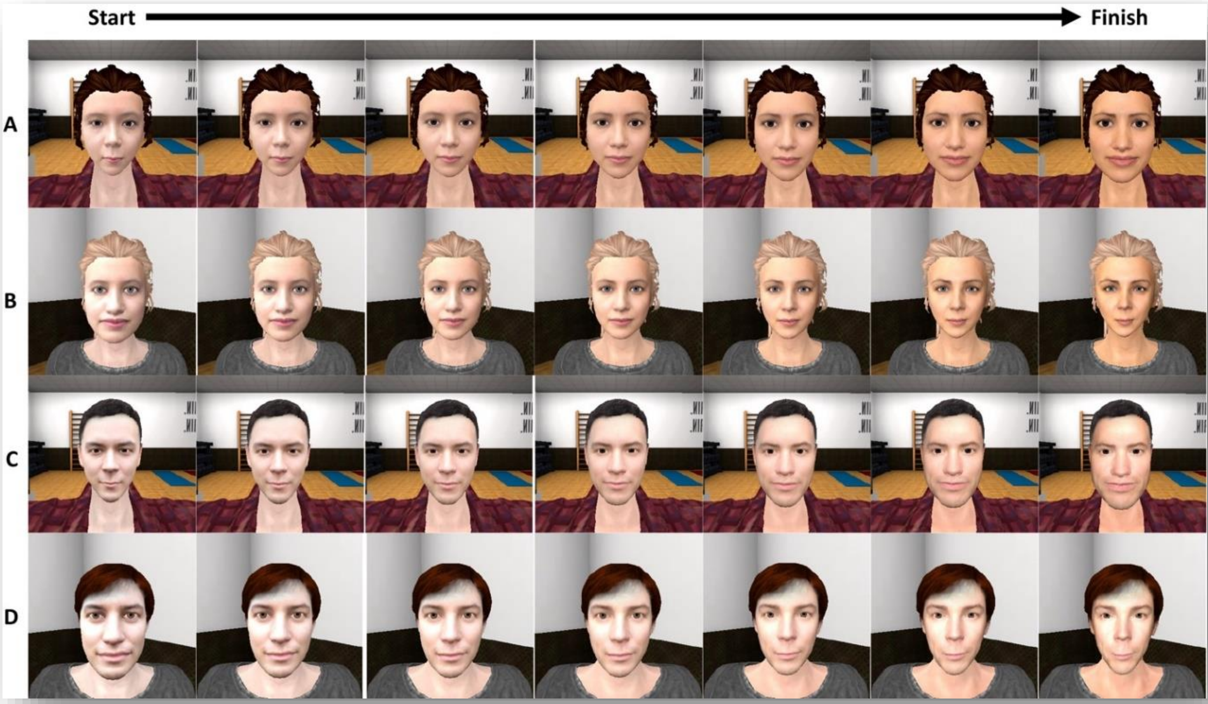

Figure 5.4 Evolution of the faces over time from left to right. A) *The virtual body of the participant who has traditional feminine characteristics.* ***B)*** *The instructor body who has traditional feminine characteristics.* ***C)*** *The virtual body of the participant who has traditionally masculine characteristics.* ***D)*** *The instructor body who has traditional masculine characteristics.*

5.2.3. Experimental Procedures

First, participants started completing a demographic information questionnaire with their participant ID on the Qualtrics platform. When the questionnaire stated, "Please, now notify the researcher, and we will carry out the virtual reality experience," we instructed them to engage in an 8-minute Qigong lesson in a virtual gym guided by a virtual instructor. We told participants that the virtual instructor would provide instructions on the exercises and movements during the experimental session, which they should adhere to. Subsequently, we familiarised participants with the Meta Quest 2 headset and its controllers that they would be using during the study. Next, we navigated them through the process of executing the application depending on their preferred gender as "male version" and "female version", as well as the preferred language from either Spanish or English, depending on their proficiency. The VR Qigong lesson consisted of an embodiment phase, an introduction, five Qigong exercises focusing on upper body movements, and an ending. The text we created for the VR scenario included the following instructions guided by the virtual instructor during the Qigong lesson.

“WELCOME: Hello. Welcome to this Qigong lesson. look around you. Now look in the mirror, do you see yourself? Raise your right arm, now raise the left one, look down towards your legs. Do not move your feet at all throughout this whole session. That is why we have placed those weight barriers.

INTRO: Now we are going to start the Qigong session. We will perform 5 exercises to help you achieve natural balance within yourself. I would like you to look at me while I explain the moves, but when you do the moves, look in the mirror and at yourself, and only watch me out of the corner of your eye. I will first perform the exercise myself while you look at me, and then I will tell you to repeat it while looking at the mirror. The first exercise is called Gathering Qi. Now, look at me.

GATHERING CHI: After you are ready, we are going to come up, and open our hands, outward. From this posture here, what we would like to do is, we are going to gather chi from heaven. As our hands reach up towards heaven, we want to inhale and gather chi from heaven. Now, look in the mirror. Press, towards the earth. As I come down, exhale. Gather chi, from the earth.

LIFTING THE SKY: This next exercise is called Lifting the sky. Now, look at me. Lower your hands down in front of you. Inhale while raising your hands, and turning your palms towards the sky. Hands above your head. And exhale, standing up. Stretch your hands up, reaching towards the sky. Inhale. Sinking by bending your knees. And, exhale, stretching your whole body. Now, look in the mirror.

PULL THE BONE: The next movement is called Pull the Bone. It’s very good for the lungs. Now, look at me. Inhale, as you move your hands towards you. And exhale, looking at your left hand moving further across to the left, as you sink your knees. You can stay in this position, and then return to the starting position. And do the same thing with the other side of your body. Now, look in the mirror.

SINGLE HAND: The next exercise is called Holding up a single hand. Now, look at me. For this, we inhale, put the left hand, above the shoulder, the palm looking up, and the right hand, looking down towards the right side of our ribs. Now, we stretch by taking the left hand up and the right hand down. You want to feel a complete spinal stretch. Now, we return to the starting position, and you do the same, but the other way around. Now we do the same with the left hand going up again, and to finish, with the right hand going up. And that’s the exercise. Now, look in the mirror.

LOOKING BACK: This last exercise is called Looking back like a cow gazing at the moon. Now, look at me. Start on this position. And when you exhale, slowly turn your spine, towards the left, turning the palms out. As if pushing, inhale, starting position. And exhale, turning towards the right. Do the same thing again, to the left. Now, look in the mirror.

ENDING: Now, look at me. We have now reached the end of the exercises Qigong can harmonize, strengthen, and have a healing effect on the functioning of all the internal organs and bodily systems. It increases the supply and flow of energy throughout the body. Can have a variety of rejuvenating effects and is believed to increase longevity. And it induces calm mental and emotional states. Now, look in the mirror. According to Chinese medicine, the energy relating to the body's internal organs flows around the extremities of the body – the hands and the feet. Thus, by stretching the arms and legs in specific movements, the health of the internal organs can be improved. Thanks a lot for your attention and have a good day.”

After participants completed the virtual reality session, they continued with the Qualtrics questionnaire. They were asked to assess the change blindness between the initial and final appearances of their own virtual bodies and the virtual body of the instructor by responding to whether they had noticed the change. These questions are shown in Figure 5.5. The answer "No, I did not notice this change" referred to change blindness.

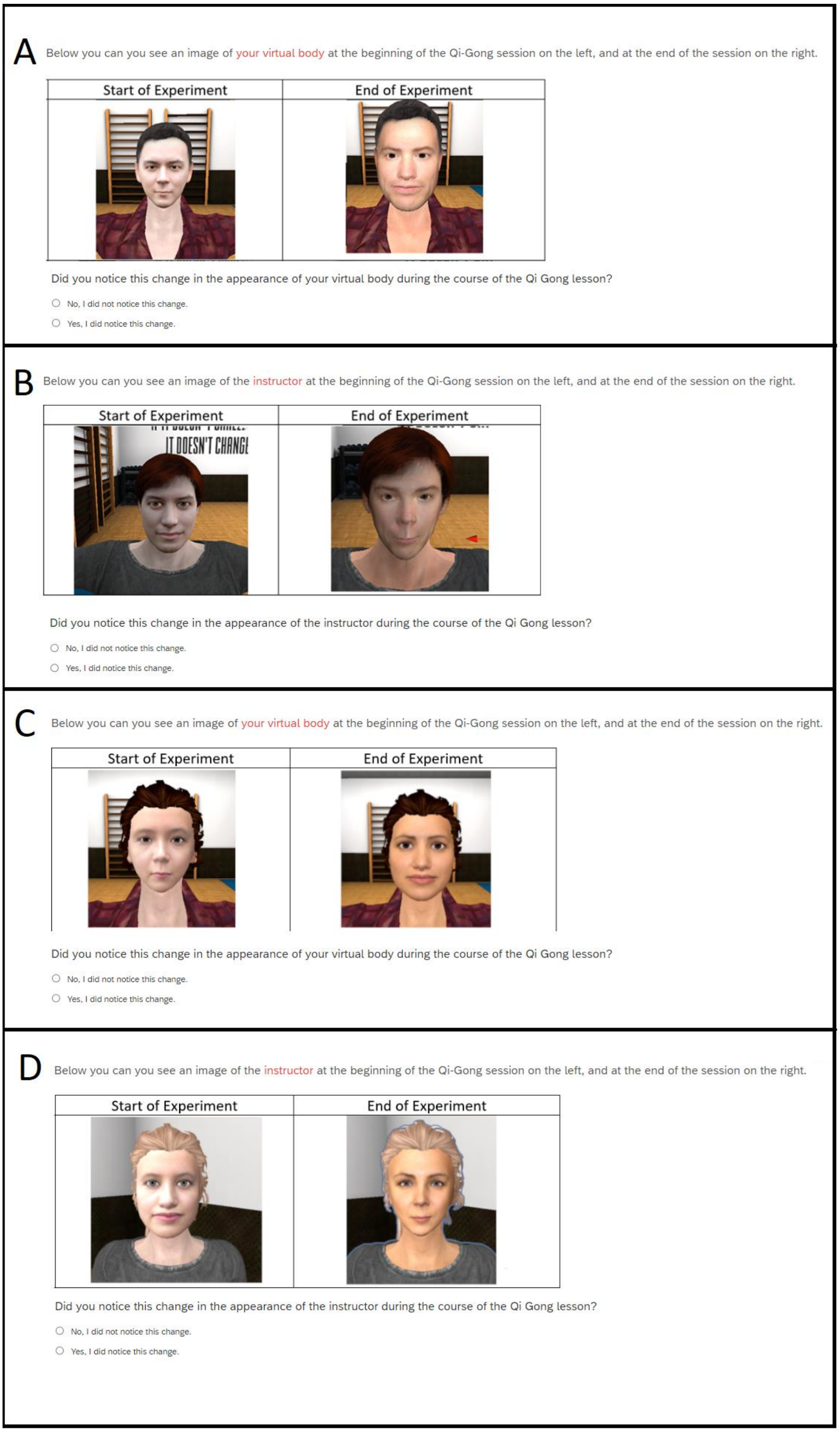

Figure 5.5 Change blindness questions. The questionnaire after the VR exposure included two questions as above – for the body of the participant and the body of the instructor. A)

Change blindness question for the participant's own virtual body for the "male version". ***B)*** *Change blindness question for the instructor's virtual body for the "male version".* ***C)*** *Change blindness question for the participant's own virtual body for the "female version".* ***D)*** *Change blindness question for the instructor's virtual body for the "female version".*

5.2.4. Response Variables

In this experiment, responses to change blindness questions (Figure 5.5) were evaluated as the main response variables. Participants in both the "male version" and the "female version" groups were asked whether they noticed the change in the appearance of their virtual body and the instructor's virtual body during the Qigong after the virtual reality exposure. The responses were binary options, including "No, I did not notice this change" and "Yes, I did notice this change". Additionally, responses from the pre-questionnaire (Table 5.1), including demographics information (age, gender, preferred experiment language, education, occupation), level of computer literacy, level of programming expertise, previous VR experience, videogame play time in the last year and last week were measured as independent variables to understand whether they influence the main response variables. Finally, the gaze directions and durations were measured to calculate the time participants looked towards their own bodies and the instructor's bodies. This data was collected to assess whether these proportions impacted the overall responses.

Table 5.1. Pre-questionnaire before the VR Qigong lesson and participant responses per group

question	**response**	**"male version"**	**"female version"**
What is your preferred experiment language?	English Spanish	4 8	5 23

What is your gender?	Male Female Non-binary	12 0 0	0 27 1
What is your age?	Mean ± SD	28.1 ± 8.49	23.6 ± 7.47
What is your occupation?	Student Employed part-time Employed full-time Self-employed Unemployed Retired	8 1 0 2 1 0	22 2 2 0 1 1
What is your level of education?	University studies Professional education Secondary education	8 3 1	23 3 2
How much have you experienced VR before? *1 = never* *7 = a great amount*	Median (IQR)	4(2)	4(3)
What is your level of knowledge of computer literacy? *1 = none* *7 = expert*	Median (IQR)	5(2)	4(2)
What is your level of knowledge of computer programming? *1 = none* *7 = expert*	Median (IQR)	3.5(3.5)	2.5(2)
How many times have you played video games in the past year?	0 times 1-5 times 6-10 times 11-15 times 16-20 times 21-25 times more than 25 times	0 1 3 1 1 0 6	2 9 5 4 2 0 6
How many hours have you played video games in the past week?	0 hours 1 hours 2-3 hours 3-5 hours 5-7 hours 7-9 hours more than 9 hours	1 4 3 0 1 0 3	10 12 4 1 0 1 0

The following section will present our results.

5.3 Results

5.3.1. Change blindness questionnaire results

To investigate whether gradual changes in the perceived and seen virtual bodies could lead to change blindness in virtual reality, we counted the number of participants who reported that they failed to notice changes in their own bodies and the instructor's body (Table 5.2). Out of 40 participants, 29 reported that they did not detect any change in their own virtual body, while 34 did not notice any change in the instructor's body. These numbers translate to an overall 72.5% of participants reporting they did not perceive a change in their own virtual body and 85% not observing any change in the instructor's body (Figure 5.6).

We performed Fisher's exact test to compare whether participants failed to notice the change in their own bodies versus the instructor's body. Our results demonstrated that participants failed to notice the change in the instructor body compared to their own (OR = 7.71, p-value = 0.03, $p < 0.05$). The odds ratio (OR) referred that the odds of participant noticing the change in their own body was 7.71 times greater than noticing the change in the instructor's body.

In addition, we employed the Chi-square test for our binary outcomes to determine whether participants failed to notice these changes more frequently than would be expected by chance. The results for the participant's own body revealed that the frequency of not noticing a change was significantly different from chance (Chi-square statistic $\chi^2 = 8.1$, p-value = 0.004, $p < 0.05$). Our analysis also indicated a significant result for not noticing a change in the instructor's body, which likewise differed from random expectations (Chi-square statistic $\chi^2 = 19.6$, p-value = 0.000009, $p < 0.05$).

Table 5.2. The number of participants who reported that they did not notice the change per group.

Condition	**N**	**Number who *did not report* the change (Change Blindness)**	**Number that reported the change**
Own body all	40	29	11
Own body "male version"	12	6	6
Own body "female version"	28	23	5
Instructor all	40	34	6
Instructor "male version"	12	9	3
Instructor "female version"	28	25	3

When we further analysed our findings per group, we discovered that the results varied depending on the group to which participants were allocated. These results were shown in Figure 5.6. For example, in the "male version", which consisted of participants identifying as male, only 50% reported not noticing the change in their own bodies. In comparison, 75% did not notice a change in the instructor's body. In contrast, not noticing the change was more prevalent in the "female version" condition, primarily consisting of participants identifying as female and one as non-binary. 82.1% of participants did not notice the change in their own bodies, and 89.3% failed to detect the change in the instructor's body.

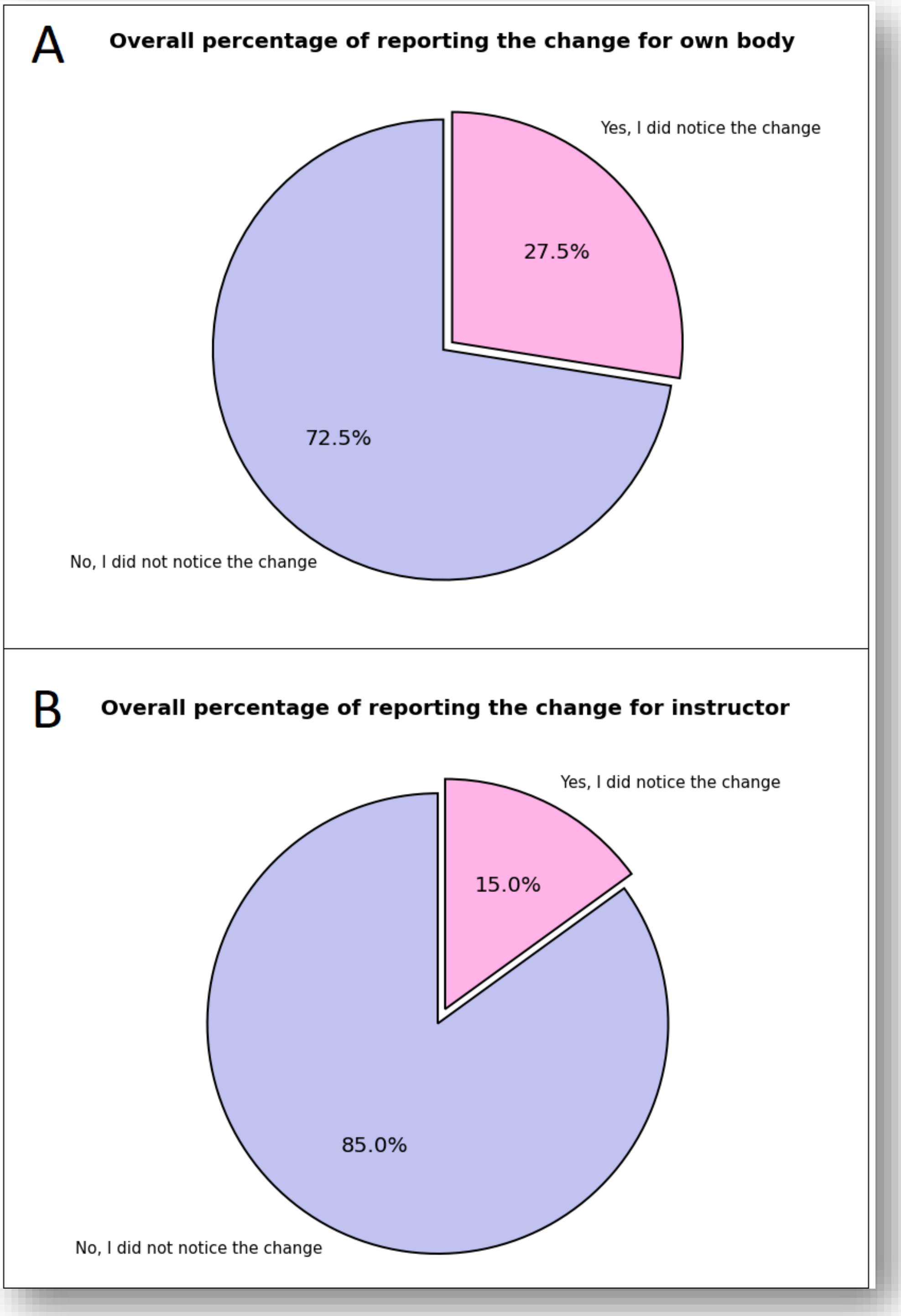

Figure 5.6 Overall percentage of reporting the change. A) *72.5% of participants reported that they did not notice the change in their own virtual body.* ***B)*** *85% of participants reported that they did not notice the change in the virtual body of the instructor.*

Our Chi-square test results for the "male version" group were insignificant, both for changes in the participant's body (Chi-square statistic $\chi^2 = 0$, p-value = 1) and the instructor's body (Chi-square statistic $\chi^2 = 3$, p-value = 0.08). However, the Chi-square test results for the "female version" group were significant for both the participant's own body (Chi-square statistic $\chi^2 = 11.57$, p-value = 0.0006, $p < 0.05$) and the instructor's body (Chi-square statistic = 17.28, p-value = 0.00003, $p<0.05$).

To understand these differences, we performed further analyses to evaluate the impact of demographic variables on our response variables, explicitly considering the age and the gender of the participants.

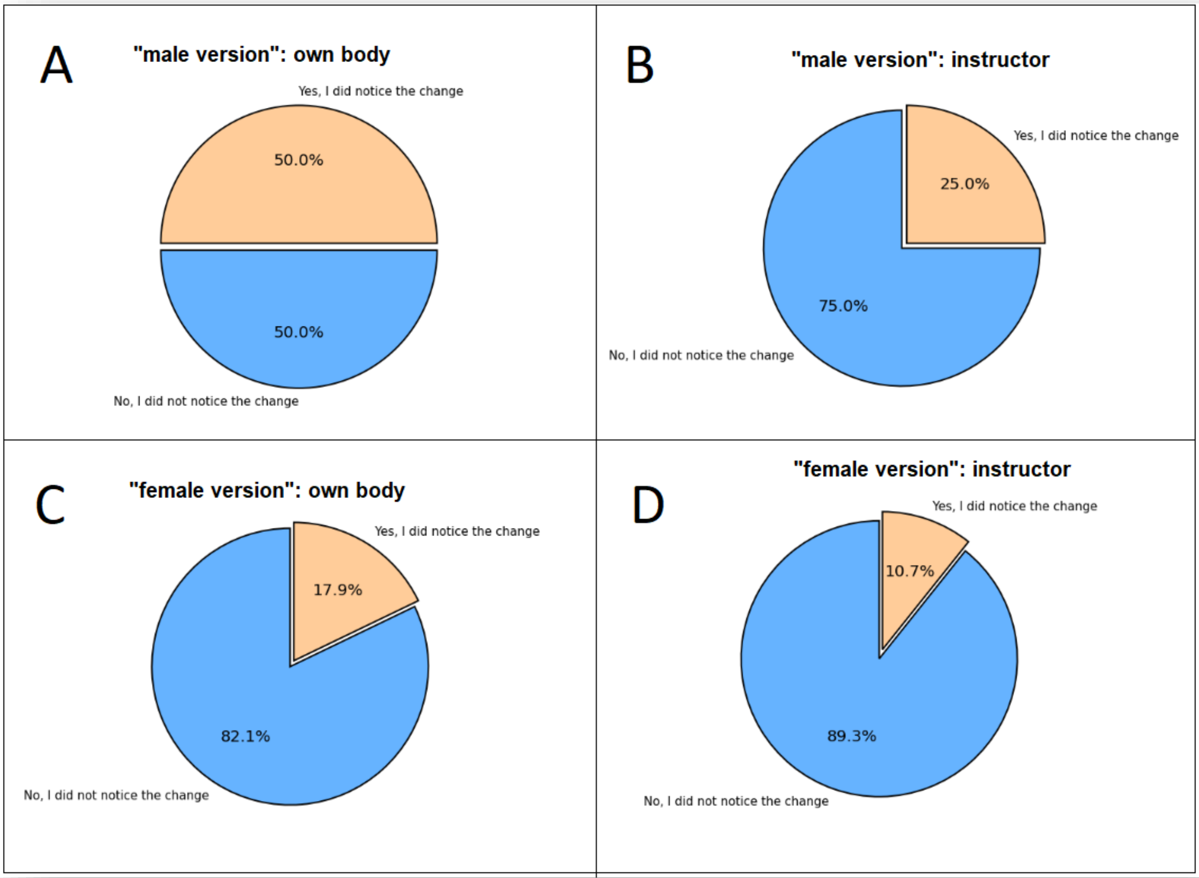

Figure 5.7 Percentage of reporting the change per group. A) *50% of participants in the "male version" group reported that they did not notice the change in their own virtual body.* ***B)*** *75%*

of participants in the "male version" group reported that they did not notice the change in the virtual body of the instructor. ***C)*** *82.1% of participants in the "female version" group reported that they did not notice the change in their own virtual body.* ***D)*** *89.3% of participants in the "female version" group reported that they did not notice the change in the virtual body of the instructor.*

5.3.2. The influence of demographic variables on change blindness

We performed a logistic regression using the Maximum Likelihood Estimation method to analyse the influence of demographic variables on the main response variables. The only demographic variable that revealed a significant relationship between the outcome variable "participants reporting that they did not notice the change in own body" was the gender variable (p=0.045) as shown in Figure 5.8. However, gender variable was not significant for the outcome variable "participants reporting that they did not notice the change in the instructor's body".

A

```
Optimization terminated successfully.
         Current function value: 0.536398
         Iterations 5
                           Logit Regression Results
==============================================================================
Dep. Variable:     change_virtual_body   No. Observations:                   40
Model:                           Logit   Df Residuals:                       38
Method:                            MLE   Df Model:                            1
Date:                 Thu, 25 May 2023   Pseudo R-squ.:                 0.08802
Time:                         16:04:28   Log-Likelihood:                -21.456
converged:                        True   LL-Null:                       -23.527
Covariance Type:             nonrobust   LLR p-value:                   0.04184
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const       1.458e-16      0.577   2.53e-16      1.000      -1.132       1.132
gender        -1.5261      0.759     -2.009      0.045      -3.015      -0.038
==============================================================================
```

B

```
Optimization terminated successfully.
         Current function value: 0.407050
         Iterations 6
                           Logit Regression Results
==============================================================================
Dep. Variable:       change_instructor   No. Observations:                   40
Model:                           Logit   Df Residuals:                       38
Method:                            MLE   Df Model:                            1
Date:                 Thu, 25 May 2023   Pseudo R-squ.:                 0.03704
Time:                         16:04:03   Log-Likelihood:                -16.282
converged:                        True   LL-Null:                       -16.908
Covariance Type:             nonrobust   LLR p-value:                    0.2630
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         -1.0986      0.667     -1.648      0.099      -2.405       0.208
gender        -1.0217      0.904     -1.130      0.259      -2.794       0.751
==============================================================================
```

Figure 5.8 Simple logistic regression result, the gender variable. A) *The output of the logistic regression analysis to determine the effect of gender on participants reporting noticing the change in own body (change_own_body). For the gender variable, being female is associated with a decrease in participants noticing the change in their own body (p=0.045, p < 0.05).* ***B)*** *The output of the logistic regression analysis to determine the effect of gender on participants reporting that they did not notice the change in the instructor's body (change_instructor). No significant results were found.*

5.3.3. The time spent looking at the participant’s own body vs the instructor’s body

The time participants spent looking at their own bodies and the instructor's body was quantified based on the head gaze direction records collected from the Meta Quest during the study. This information was captured every 0.5 seconds and the threshold of 245.5 degrees was used to distinguish between the participant observing their own body and the instructor. The gaze direction of 221 degrees implied that the participant was looking straight at the instructor's body, and the gaze direction of 270 degrees indicated that the participant was looking directly at their own body. The mean time participants spent was calculated for all groups collectively and for each group separately (Table 5.3). The overall mean for the amount of time participants spent looking at their own body (211 ± 58.6 SD) compared to the amount of time they spent looking at the virtual body of the instructor (213 ± 58.6) did not differ. Upon statistically evaluating the mean difference between these looking durations using a t-test, we found no significant differences (t-statistic = 0.13, p-value = 0.89).

On the other hand, when we calculated the average time for each group separately, we found that participants in the “male version” group spent more time looking at their own bodies (242.08 ± 41.9) than the instructor's body (182.9 ± 41.9). Moreover, when we performed a t-test, we found significant differences between the average time participants spent looking at their own bodies versus the time spent looking at the instructor's body (t-statistic = 2.44, p-value = 0.03). In contrast, within the “female version” group, the average time that participants spent looking at their own body (201.6 ± 61.1) versus the instructor's body (223.3 ± 61.1) was not significantly different (t-statistic = -0.93, p-value = 0.35).

Table 5.3. The average time participants spent looking at own body vs instructor per group.

Condition	N	Average time participants spent looking (Mean ± SD)
Own body all	40	213.7 ± 58.6
Own body "male version"	12	242.08 ± 41.9
Own body "female version"	28	201.6 ± 61.1
Instructor all	40	211.2 ± 58.6
Instructor "male version"	12	182.9 ± 41.9
Instructor "female version"	28	223.3 ± 61.1

5.4 Discussion

Our results suggested that change blindness (CB) can occur in virtual reality environments that use the gradual change paradigm with embodiment, and this occurrence can differ depending on the embodiment of a virtual body. Our findings revealed that the participants demonstrated more change blindness for the instructor body compared to their own body. We found that the overall occurrence of change blindness was high, standing at 85% for the virtual instructor and 73% for the participants' own virtual body. Our findings align with previous change blindness studies that compared gradual change conditions with disruption conditions in 2D images. For example, the study of Simons, Franconeri & Reimer (2000) demonstrated a higher occurrence of change blindness in the gradual change condition (69%) compared to the disruption condition (59%). Similarly, David, Laloyaux, Devue & Cleeremans (2006) found that only 15% of participants noticed changes in the gradual change condition applied to human facial expressions.

Furthermore, our results also highlighted gender differences between groups that participants were allocated based on the gender with which they most closely identify, except one participant who identified as non-binary and selected a virtual body with traditionally feminine characteristics. For instance, when participants reported that they did not notice the change, the change blindness for participants' own bodies was detected only for 50% of the participants in the "male version" group, which consisted of male participants, compared to 82.1% of participants in the "female version" group, which consisted of female participants and a non-binary participant. However, these differences were not recognised for the occurrence of change blindness in the instructor's body in both groups. %75 of the participants in the "male version" group and 89.3% in the "female version" group did not notice the change in the instructor. In line with these group differences in reporting the change, our logistic regression analysis showed that being female is associated with decreased noticing of the change in their own bodies. Additionally, while on average, participants spent a similar amount of time looking at their own bodies compared to the instructor, this result varied per group and, therefore, by gender. As shown in Table 5.3, male participants in the "male version" group spent more time looking at their own bodies than the instructor compared to the "female version" group, which did not demonstrate any significant differences between the average looking time at their own bodies versus the instructor.

Previous research accounted for these differences to be context specific. For example, a study by White & Caird (2010) revealed that women were more likely to experience change blindness while conversing with a male passenger in a driving simulator. These results were interpreted as potentially more related to the nature of the task than an inherent gender difference in susceptibility to change blindness. Similarly, our results might also be influenced by how different distractions are responded to. For example, the distraction was a conversation in the previous example while it was following Qigong exercises in our study.

Contrary to prior studies on change blindness, which primarily focused on observational tasks involving gradual changes, our study required participants to observe, listen to, and attempt to replicate exercises demonstrated by a virtual instructor. This difference in task nature might explain the observed gender differences. For instance, it has been documented that men outperform women in specific motor learning tasks, particularly in the context of throwing accuracy (Moreno-Briseño et al., 2010). This could potentially account for the gender differences we observed in our study.

Our results demonstrated that participants failed to notice the change in the instructor's body compared to their own. Accordingly, the overall likelihood of change blindness was lower for the participants' bodies than that of the instructor. The feeling of ownership over a body, the self-location and the first person's perspective was proposed as the core characteristics of bodily self-consciousness (Blanke, 2012). Multisensory integration of synchronous visuomotor (Sanchez-Vives et al., 2010) and visuotactile cues (Slater et al., 2008), as well as having a first-person perspective (Petkova & Ehrrson, 2008) in virtual reality can lead to body ownership illusion. As explained in Chapter 2, body ownership illusion and embodiment, which refers to the process of substituting a person's physical body with a life-sized virtual body that is aligned and matched with the actual body's spatial location and first-person perspective, has been shown to influence changes in attitudes, behaviour, and physiological responses (Maister et al., 2015; Peck et al., 2013; Banakou et al., 2016; Banakou et al., 2013; Matamala-Gomez et al., 2019; Bourdin et al., 2017; Barberia et al., 2018).

In the context of our Qigong experiment, participants' own body representations, seen from the first-person perspective and mirrored virtually, could be the most salient and meaningful feature within the virtual scene. Overall, the change blindness was lower for participants' own bodies, and the amount of time they spent looking at their own bodies was higher. As a result of the greater salience of the virtual body in the scenario, we suggest that this reduction in change blindness concerning the owned virtual body relative to the seen virtual body was a consequence produced by virtual embodiment based on multisensory integration. We argue that participants were more prone to detect changes in their self-representation due to their conspicuousness than in other scene elements, including other human bodies. Although the percentage of change blindness was higher for the participants' own bodies, it was still less than that of the instructor's body.

According to the predictive coding theory, prediction errors arise from discrepancies between anticipations based on past knowledge and expectations and the actual input. With its probabilistic nature of representing sensory stimuli, the brain minimises these prediction errors (Rao & Ballard, 1999; Friston, 2010). In the context of change blindness, it has been suggested that improved detection of changes may be associated with either a heightened emphasis on prediction error signals or the existence of robust visual predictions and both of these are linked to mechanisms of visual short-term memory and attention (Andermane et al., 2019). We propose that when changes occur gradually, they may remain below the sensory detection threshold, leading the brain to overlook the mismatch between the prediction and the actual input. This argument is also partially supported by the lower change blindness scores found in disruption studies compared to the gradual change studies. The main criticism against this argument would be the assumption that all changes should produce similar prediction errors.

This perspective aligns with the research presented by Burr & Cicchini, 2014, which posits that our perception is influenced by both current stimuli and past sensory experiences, where the brain effectively leverages recurring environmental patterns to reduce random fluctuations, resulting in more consistent visual experiences and a more dependable comprehension of our environment.

The gender differences may also be partially accounted for by the differing predictive mechanisms being triggered by different tasks, leading to the difference in attentional distributions. This explanation would align with the previous research suggesting that men have greater motor learning capabilities (Moreno-Briseno et al., 2010).

In conclusion, our study suggests that change blindness can occur in virtual reality differently for the embodied virtual body versus the other body, in this case, the instructor. The possibility of focusing more on the bodies rather than the faces can be argued for these results. Furthermore, our sample size was skewed, with fewer male participants compared to female participants. Therefore, future research should consider a larger and more balanced sample size, and including eye-tracking technology could help address these limitations.

6. Self-Dialogue with a Virtual Future Self Experiments

After the Qigong experiment presented in the previous chapter—which investigated the change blindness and its relation to embodiment—we further extend our knowledge on the applicability of virtual reality scenarios. Now, we delve into the practicability of therapeutic applications of virtual reality.

We designed two studies, both concerned with the “Self-Dialogue with a Virtual Future Self” experiments. These studies revolved around having a self-conversation by alternating between two virtual bodies in VR: one representing the participant and the other representing the counsellor. In the first study, participants had a self-conversation with themselves by being their own counsellors to address personal problems. We tested the impact of having different counsellor representations in this experiment. In the second study, we used the same self-conversation paradigm but explored its effectiveness for understanding and treating one’s own nicotine dependence.

This chapter will begin with an introduction to the self-conversation paradigm and the concept of future-self continuity. Later, we will continue with the specific materials, methods, and results for each study separately, followed by a discussion of the findings.

6.1 Introduction

Previous research on body ownership in virtual reality demonstrated that the embodiment of virtual bodies, especially when presented from the first-person’s perspective, can substantially change the participants’ perceptions, behaviours, and attitudes. As explained in Chapter 2, some examples of these changes include overestimation of the object sizes and faster reaction times for the assessment of oneself as having childlike characteristics as opposed to adult characteristics after adult participants were embodied in a virtual body of a child (Banakou et al., 2013), improved cognitive performance when participants experienced the virtual body of Einstein (Banakou, 2019), decreased implicit racial bias of Caucasian participants when they felt ownership over Black-race virtual bodies (Peck et al., 2013; Banakou et al., 2016) as well as recognition of fearful female faces when male offenders of domestic violence were being embodied in the body of the female victim (Seinfield et al., 2018). In addition, participants also experienced changes in their attitudes towards their personal problems when they conversed with themselves and became their own counsellors by swapping between their lookalike virtual bodies and the virtual body of a counsellor that looks like Sigmund Freud (Osimo et al., 2015; Slater et al., 2019).

Self-counselling enabled by virtual reality provides individuals with a virtual environment where they may interact with two virtual bodies, one representing their own virtual selves and the other representing the counsellor. This technique includes "body swapping", in which individuals switch between these virtual bodies while maintaining the conversation with two distinct viewpoints. The concept of self-counselling is based on two fundamental ideas: inner speech and Solomon's paradox.

In our daily lives, we all silently talk to ourselves. Engaging in such inner speech is a cognitive mechanism employed by individuals to both acquire and analyse self-related information (Morin & Everett, 1990). It is also a process that closely resembles our self-consciousness, indicating a special connection between our conscious thoughts and our knowledge of our existence. Additionally, this internal dialogue frequently mimics the sound and tone of our own spoken voice, providing a comfortable and dependable setting for self-analysis and reflection (Filik & Barber, 2011). Therefore, inner speech is a dynamic cognitive tool related to our experience.

We also tend to be better at offering counsel to others than ourselves. Solomon's paradox, which refers to the phenomenon where people exhibit greater ability for logical thinking while considering others' concerns rather than their own (Grossmann & Kross, 2014), has been used to characterise the odd duality in historical figure King Solomon's knowledge. Solomon was known for his deep knowledge, and his advice was highly sought after (Parker, 1992).

However, he did not seem to possess the same insight into his personal affairs, and his bad choices ultimately led to the fall of his kingdom. This contradiction strongly resembles the idea of inner speech and fundamentally expresses self-distance against self-immersion. Both concepts highlight the significance and power of perspective in self-awareness and judgement, indicating that our internal dialogue may be able to support us in overcoming the challenges provided by Solomon's paradox. As a result, VR self-counselling was investigated as a potential method to be a useful tool for embodying inner speech and Solomon's paradox with a self-conversation while exploring new approaches to self-understanding.

The VR self-conversation study conducted by Osimo et al. (2015) showed that participants reported higher levels of happiness and satisfaction when they moved synchronously and had ownership over a virtual counsellor's body that represented a different person, who was Sigmund Freud, rather than a virtual representation of themselves. The experiment aimed to investigate whether embodying Freud or another avatar identical to the participant would yield better results, and whether high body ownership of the Freud avatar (achieved through visual-motor synchrony) would be more beneficial than low ownership (visual-motor asynchrony). Researchers argued that participants could have struggled to find practical answers to their problems while embodied in a virtual representation of themselves. However, the experience of inhabiting a different body, such as Freud's, may have provided them access to problem-solving tools that were not previously available. This changed embodiment unlocked access to a newer perspective and the body that participants adopted, metaphorically symbolising another person and strongly linked with the psychological treatment, possibly reframing their outlook on personal issues. It was found that the best outcomes were achieved when participants were embodied as Freud with visual-motor synchrony.

Later, Slater et al. (2019) further investigated and validated the implications of VR self-counselling in their study. This study sought to determine whether body swapping was crucial, or if similar results could be attained simply by interacting with a pre-animated Freud avatar. For this reason, two groups were compared, participants who engaged in a conversation with a scripted Freud character versus participants who had a self-conversation mediated by body-swapping between Freud and lookalike avatars. The participants were immersed in a virtual environment through a head tracked wide FOV HMD, a first-person perspective, a life-sized virtual body, and real-time motion capture enhanced by visuomotor synchrony. When compared to the scripted condition, the self-conversation group resulted in an increased perception of change and help. As a result, body-swapping between two avatars while maintaining a self-conversation in a virtual reality setting emerged as a promising method for self-counselling, providing a unique way to use the power of virtual reality in personal problem-solving.

Moreover, these findings were strikingly similar to the principles of Solomon's paradox and the characteristics of inner speech, demonstrating a shared emphasis on the transformative power of self-distancing and perspective shifting in improving personal problem-solving and self-understanding. Embodying another person in VR could have provided participants with an alternative perspective through which they observed and confronted personal difficulties, like how inner speech affected their self-awareness. Furthermore, like Solomon's dilemma, this strategy allowed participants to self-distancing, which might have notably improved one's capacity to reason effectively about one's problems.

On the other hand, perceptions of one's current and future selves have been also demonstrated to be distinct (Pronin & Ross, 2006; Pronin et al., 2008). For example, unless attention is deliberately directed towards thoughts and feelings, broad attributions to the future self indicated to have an observer-like aspect often, meanwhile, current self-attributions exhibited actor-like characteristics (Pronin & Ross, 2006). Additionally, decision-making for the future self differed from decision-making for the current self, with the former resembling decision-making for another person. (Pronin et al., 2008).

Future self-continuity refers to the possible impact of sharing similarities between the present and future selves and perceiving the future self vividly and positively on intertemporal choice (Hershfield., 2011). Future self-continuity also proposes that when individuals perceive their future selves as strangers without a sense of continuity between their current and future selves, this might result in a lack of saving behaviour for the future self. A study verified this argument, which found a positive relationship between high self-continuity and future-saving activity (Ersner-Hershfield et al., 2009). The study of Hershfield et al. (2011) revealed that individuals who engaged with older versions of themselves in VR, as opposed to their non-aged virtual counterparts, had lower temporal discounting and higher contributions to their retirement savings.

In addition to monetary considerations, the future self-continuity concept was applied to various contexts, including ethical decision-making. High future self-continuity was associated with ethical judgements, while low future self-continuity was linked with unethical actions such as lying and cheating (Hershfield et al., 2012). Furthermore, developing a realistic perception of one's future self through VR engagement reduced incidences of delinquency and dishonesty (Van Gelder, Hershfield, & Nordgren, 2013). Furthermore, the idea of future self-continuity was substantially related to health behaviour. Rutchick et al. (2018) found that improving future self-continuity through a letter-writing activity to their future selves increased exercise behaviour and improved long-term health decisions. As a result, building a strong link between one's current and future selves was a powerful tool in encouraging healthy behaviours and decisions.

Following on from the literature related to future self-continuity, our studies detailed in this chapter explored the relationship between the VR self-counselling technique and the idea of future self-continuity. The first line of our research investigated the influence of embodying different counsellor representations, particularly the impact of having a future self-body on dealing with personal issues in a VR self-counselling setting. Secondly, we focused on different counsellor representations of future selves while addressing addiction issues, specifically nicotine dependence. We argued that observing oneself through the eyes of a future self-body as a counsellor might give a unique platform for introspection, allowing participants to visualise the effects of their current actions and behaviours on their future selves.

6.2 Experiment 1: Self-dialogue with a virtual future self about a personal problem

In this first study of this chapter, we examined our third hypothesis, "*Having a self-conversation about a personal problem by swapping between two virtual bodies, explaining the situation from a present-day lookalike body, and swapping bodies with a counsellor representation of a future self, will help participants to solve their personal problems*". The VR self-counselling study conducted by Slater et al., 2019, which employed the virtual body of Sigmund Freud as the counsellor's avatar, suggested that the counsellor's representation could be significant in the context of self-counselling. In particular, the use of Freud's virtual body, given his standing as a wise and renowned figure in psychotherapy, could be particularly meaningful in this process. Expanding upon this research trajectory, the present study brought new perspectives to the varying representations of the counsellor's virtual body during an embodied self-dialogue. Our study not only explored the implications of using temporally distinct self-avatars as counsellors, such as a Current Self, a virtual body resembling the participant's current appearance, and a Future Self, an aged version of the participant but also investigated the feasibility of utilising a gender-matched, General Self virtual body as an alternative to Sigmund Freud's virtual body. We anticipated that participants would report improved scores following an embodied self-dialogue with the counsellor's representations of the current and general bodies. However, we expected these improvements to be even more pronounced when the counsellor was represented by their future self-avatar.

6.2.1. Materials and Methods

6.2.1.1. Materials

In Experiments 1 and 2, the Virtual Reality (VR) session was conducted using a Meta Quest 1 headset, which offers a display resolution of 1600 × 1440 per eye, a refresh rate of 72 Hz, and weighs 470 g. This device has 6 degrees of freedom with rotational and positional tracking and uses comfortably designed controllers for hand movement tracking. The built-in speaker system was utilised during self-conversations.

ConVRSelf, a product developed by the spin-off company, Virtual Bodyworks, was utilised as the principal application and the VR environment facilitating the self-conversation. It was developed by using Unity 3D. The application incorporated a feature that modulates the pitch of the participant's original voice to a lower frequency following each body swap for the counsellor's body. The developed mode of the Meta Quest 1 was activated, and the ConVRSelf application was initiated from the Unknown Sources section of the Quest's applications menu with the experimenter's help.

Character Creator 3 (CC3) Software from Reallusion was used to create all virtual bodies (Figure 6.2) from the participant photos. The Headshot Plug-in was employed to generate the lookalike virtual bodies for participants for their own self virtual body and the virtual body of the counsellor in the Current Self condition. The Future Self condition virtual bodies were also built with the help of Headshot Plug-in by altering Ultimate Morphs and SkinGen modules to age the lookalike virtual body's morphs and skin textures. In addition, the counsellor's generic-looking, gender-matched virtual body for the General Self condition was also built using the CC3 software.

Before executing each virtual reality experiment session, the Quest headset and its controllers were disinfected using the CleanBox device, adhering to necessary safety protocols to eliminate potential contamination.

6.2.1.2. Participants

All participants in the pre-existing database of the lab were contacted via email that informed them about the duration of the experimental sessions, economic compensation and compensation, and factors that may disqualify them from participation, such as a history of epilepsy, a recent diagnosis of post-traumatic stress disorder, or active use of psychoactive medication. The participants who were interested in taking part in the study were given a participant ID and then pre-screened by questions including the age of the participants, the experimental language that they preferred to participate in, as well as the scoring for the World Health Organization (WHO)'s 5 Well-Being Index (WHO, 1998; Topp et al., 2015). The WHO-5 Well Being Index, was developed to measure mental well-being, was comprised of five items and had been translated and validated in various languages. In the Spanish adaptation, the index demonstrated good internal consistency (Cronbach's $\alpha = 0.86$) and discriminative validity (Lucas-Carrasco, 2012). The final score was calculated by multiplying the total raw score, which ranged from 0 to 25, by 4, with higher scores indicating higher well-being. After the initial screening, participants who scored below 13 on the WHO-5 Well-Being Index were excluded from recruitment for the experiment. This exclusion criterion was applied because the WHO-5 cut-off score of 13 or lower is typically recommended for identifying clinical depression, and we planned to recruit our participants from a healthy population.

After the initial screening, 51 participants were randomly assigned to one of three conditions with each condition comprising 17 participants. The conditions were as follows: Current Self (CS) with 11 females and 6 males, Future Self (FS) with 11 females and 6 males, and General Self (GS) with 9 females and 8 males. Regardless of condition, the average participant age was

25 years old. The language of the application and questionnaires during the study was evenly distributed, with each condition including 6 English speakers and 11 Spanish speakers.

Before participating in the first session of the study, all participants reviewed and provided their signatures on both the information sheet and the participant consent form. Participants were made aware verbally and through written communication that they could withdraw from the experiment at any time without providing a reason. All information and forms were available in both Spanish and English. The experimental protocols were also carefully adhered to the COVID-19 guidelines to ensure safety. Upon completion of the final session of the study, participants received an economic compensation of 20 Euros as an appreciation for the time they dedicated to the study.

6.2.1.3. Experimental Design

This study utilised a between-group experimental design. The experiment consisted of three conditions, each representing a different configuration of the counsellor's virtual body: the Current Self (CS) condition, the Future Self (FS) condition, and the General Self (GS) condition (Table 6.1). Under all conditions, three-dimensional (3D) virtual bodies representing the participant's own bodies and the bodies of the instructors were generated using the Character Creator software. These lookalike avatars were created from front-facing and full-body photographs that each participant provided (Figure 6.1).

Table 6.1. Comparison of counsellor's virtual body representation across experimental conditions: Current Self (CS), Future Self (FS), and General Self (GS) conditions.

Current Self (CS)	**Future Self (FS)**	**General Self (GS)**
The counsellor's virtual body is identical to the participant's own virtual body, which also resembles the real-life appearance of the participant.	The counsellor's virtual body is an age-rendered version of the participant's own virtual body.	The counsellor's virtual body is a generic-looking, gender-matched virtual body.

Figure 6.1 Sample photographs of the participant used for building a virtual body. A) *Front-facing headshot of the participant.* ***B)*** *Full-body photo of the participant from the front.* ***C)*** *Full-body photo of the participant from the side.*

The virtual bodies of each condition are shown in Figure 6.2. In the Current Self (CS) condition, the counsellor's virtual body mirrored the participant's own virtual body (Figure 6.2.B). Participants in the CS condition were informed that they would engage in a self-dialogue with themselves in virtual reality. For the Future Self (FS) condition, the counsellor's virtual body was the older version of the morphs and skins of the participant's lookalike virtual body, simulating a future version of themselves (Figure 6.2.C). Participants in the FS condition were informed that they would engage in a self-conversation with their projected future selves.

In contrast, the General Self (GS) condition employed a gender-matched avatar for the counsellor that neither resembled the participant nor their projected future self (Figure 6.2.D). Participants in this condition were told they would be conversing about their personal problems with a virtual body in front of them, representing another individual.

Figure 6.2 Sample visual representation of virtual bodies used in each experimental condition. *A) The original photo of the participant.* ***B)*** *Participant's own lookalike virtual body and the counsellor's body for the Current Self (CS) condition: The counsellor's virtual body was identical to the participant's own virtual body.* ***C)*** *Future Self (FS) condition: The counsellor's virtual body was an age-rendered version of the skin and morph parameters of the*

participant's own lookalike virtual body to project an older version of themselves. ***D)*** *General Self (GS) condition: Gender-matched, generic-looking counsellor virtual body that did not resemble either the participant or their future self.*

The study's design incorporated controlled comparison groups in parallel. The Future Self condition was implemented explicitly as an experimental condition to evaluate the impact of future self-continuity on virtual reality self-dialogue when addressing personal problems. On the other hand, both the Current Self and General Self conditions were evaluated as active controls, given the potential therapeutic benefits of self-conversation.

6.2.1.4. Experimental Procedures

The study was divided into three sessions, each separated by a week-long interval. The first and initial session was conducted online and took approximately 25 minutes. The second session, which included virtual reality and the questionnaires, lasted around 50 minutes. The third and final session of the experiment lasted roughly 25 minutes.

In the first session, participants started by reading and signing the information sheet and the participant consent form. Participants then filled out demographic questionnaires, the Future-Self Continuity Scale (Ernsner-Hershfield, 2009), and the Depression, Anxiety, and Stress – 21 Items (Lovibond & Lovibond, 1995; Bados et al., 2005). Subsequently, guided by semi-structured written interview questions, they identified a personal problem causing moderate stress levels in their lives. Following the interview, participants answered several psychological outcome measures assessing aspects, exploring importance, discomforts, help, significance, and change, such as the importance of the problem in their lives, the discomfort induced by the problem, the helpfulness of the intervention concerning the problem, the significance of the change they observed, and any differences in their actions, feelings, or thoughts compared to before the interview. They also answered some questions evaluating whether they gained knowledge, understanding, new ideas, control and perspective about their problem. This set of questions was adopted from a previous self-counselling study by

Slater et al. in 2019. The upcoming response variables section explains these general psychological outcome measures in detail. Participants completed the first session by providing us with their front-facing and full-body photographs, which were necessary for creating their 3D virtual bodies for the forthcoming virtual reality session.

A week following the first session, participants visited our VR laboratory for the second session, which incorporated the Virtual Reality (VR) experience that involved self-counselling. First, participants were briefed on the experimental procedures and informed about utilising the VR system with instruction videos. Later, they were reminded of the personal problem they had previously identified during the initial session. Additionally, participants were encouraged to have a self-dialogue in their native language and perform as many body swaps as they desired at their own pace, continuing until they felt that their conversation had reached its natural conclusion. We reassured participants of their privacy throughout the experiment, meaning they would be alone in the experimental room during the self-dialogue unless there were any technical issues. Participants were also informed that the experimenter would return to the experiment room once they had finalised the virtual reality session.

With the assistance of the experimenter, the VR system was initiated, and all participants began their experience in their own virtual bodies that were created to resemble their real-life physical appearances. The VR scenario began with an embodiment phase to help participants familiarise themselves with their own virtual bodies. Upon completing this phase, when participants were in their own virtual body, they described their previously defined personal problem to the virtual body in front of them, representing the counsellor. After the problem explanation, participants also completed embodiment exercises that helped them to familiarise themselves with the counsellor's body. Later, they listened to their own problem and responded to their personal problem. The perspectives from both their own virtual body and the counsellor's virtual body are depicted in Figure 6.3.

Overall, participants were free to switch back and forth between their own virtual body and the virtual body of the counsellor as often as they wanted, with no limits on the number of body swaps. After the VR self-dialogue, participants responded to the post-VR experience questions by answering an open-ended question about their VR experience and additional questions regarding body recognition, body ownership, and agency. They were also asked to estimate the age of the counsellor's body and the number of body swaps they thought they had performed. Additionally, they responded to psychological outcome measures, the Future-Self Continuity Scale (FSCS), and the Depression, Anxiety, and Stress – 21 Items (DASS-21) questionnaires.

A week after the second session, participants returned to our laboratory for the final session of the study, which included the questionnaires from the previous session by only excluding the post-VR experience questionnaire. The questionnaires included the Future Self Continuity Scale and DASS-21 and psychological outcome questions regarding the impact of the previous VR experience on their personal problem and their current perspectives on the issue after having had this experience. Upon completing the final session, participants received a total economic compensation of 20 euros.

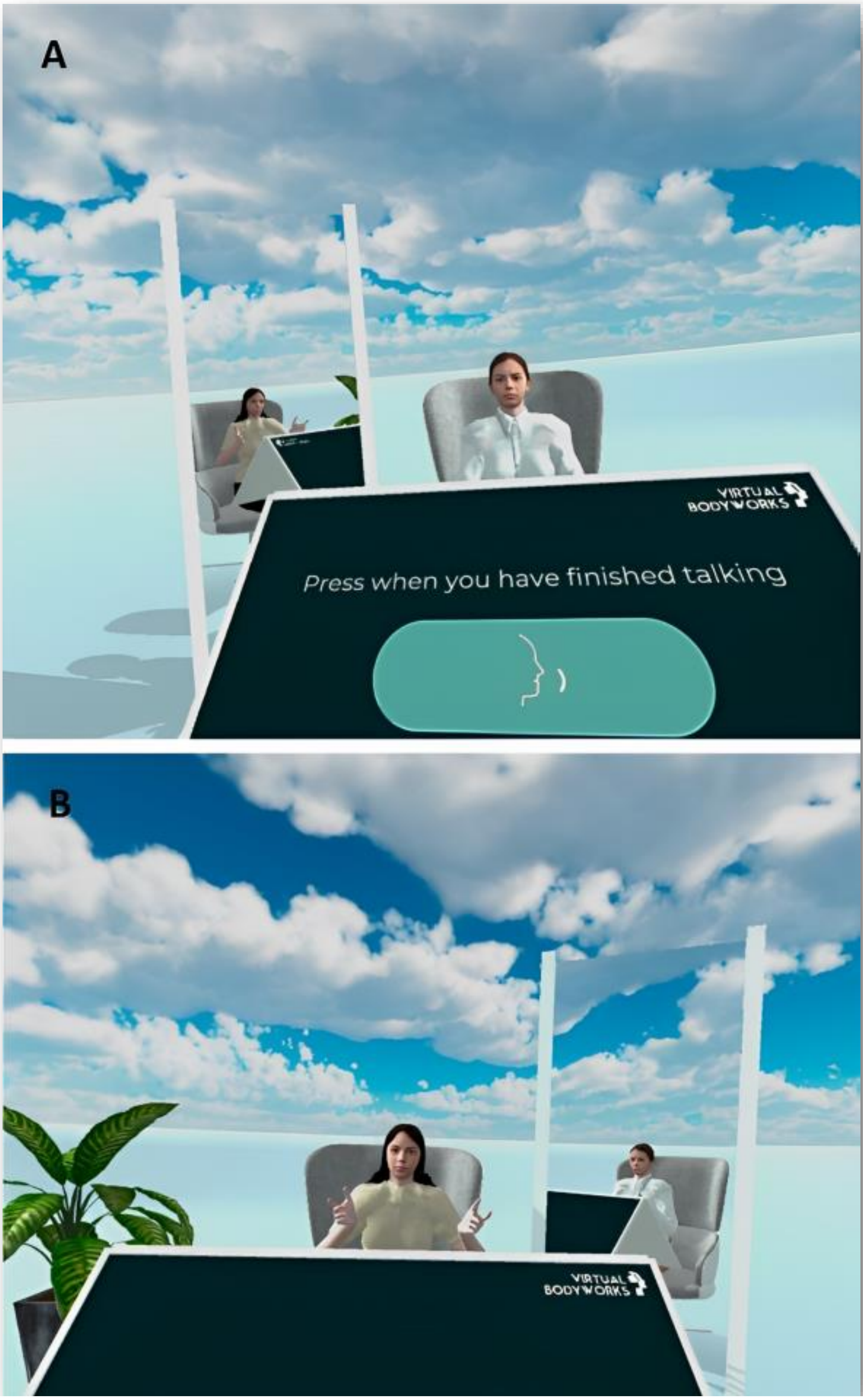

Figure 6.3 Perspective of the virtual bodies during the VR session. A) *Perspective of the participant's own virtual body.* ***B)*** *Perspective of the counsellor's virtual body in the FS condition.*

6.2.1.5. Response Variables

This study incorporated a wide range of response variables. Some of the response variables included VR response measures that captured participants' subjective experiences of body ownership and agency throughout their VR experience for both their own virtual bodies and the virtual body of the counsellor to signify how deeply they identified with their virtual bodies and perceived control over their actions.

Participants were informed that they would alternate between two virtual bodies. They would start the experience with a body looking like themselves, and we referred to this body as the "Self Body". There would be another seated avatar in front of them, with whom they would swap bodies, and we referred to this body as the "Other Body". After the VR session, participants were instructed to rate the following statements about these virtual bodies on a scale from -3 to 3, where -3 meant the least agreement and 3 the most agreement (Table 6.2). Participants were also asked to report their estimation of the age of the counsellor's virtual body, which referred to the *otherage* variable.

Table 6.2. VR response measures. The questions were presented on a -3 to 3 scale where -3 indicated the minimum agreement while 3 indicated the maximum agreement. Otherage variable was the predicted age of the counsellor.

variable	**question**
selfrecognise	Did you recognise yourself in the Self Body when you looked in the mirror?
selfdown	When I was in the Self Body: I felt that the virtual body that I saw looking down towards myself was my own body.
selfagency	When I was in the Self Body: I felt that the movements of the virtual body were caused by my own movements.
otherdown	When I was in the Other Body: I felt that the virtual body that I saw looking down towards myself was my own body.
othermirror	When I was in the Other Body: I felt that the virtual body that I saw when I looked into the mirror was my own body.
otheragency	When I was in the Other Body: I felt that the movements of the virtual body were caused by my own movements.
otherage	How old do you think your "Other Body" is?

Moreover, participants' self-continuity with their future selves was evaluated as response variables in every session to explore the aspects of similarity, connectedness, care, and likeness (Table 6.3). Participants scored their continuity on a scale from 1 to 7 where 1 indicated less continuity while 7 indicated more continuity).

Table 6.3. Future Self Continuity Scale. It was used to investigate the relationship between participants' current selves and future selves.

variable	**question**
similar	How similar do you feel to a future self ten years from now?
connected	How connected do you feel to a future self ten years from now?
care	How much do you care about your future self ten years from now?
like	How much do you like your future self ten years from now?

The responses to the general psychological variables (Table 6.4) were also collected during all sessions to assess participants' perspectives on their identified personal problems regarding the aspects including knowledge, understanding, generation of new ideas, control, and shifts in perspective as well as the impact of personal problems concerning importance, discomfort, help received, significance of the possible changes made, and any different feelings experienced. These response variables were integrated to understand the participants' perception of their problems and whether the impact of these problems on their lives could offer critical insights into the effectiveness of the VR intervention.

Table 6.4.General psychological variables. These responses were assessed in all sessions to understand participants' perceptions of their personal problems and their impact on their lives.

variable	**question**
Perspective	
knowledge	I feel that now I have more knowledge about my problem.
understand	I think that, after this intervention, I am able to better understand my problem.
newideas	I think I can have new ideas on how to solve my problem.

control	I feel that I control my problem better.
newperspective	This dialogue helped me to have a new perspective on my problem.
Impact	
importance	What is the level of importance of the problem in your current life? 0=Not at all 1=Slightly 2=Moderately 3=Very 4=Extremely
discomfort	What is the level of discomfort induced by the problem in your current life? 0=It does not disturb or affect me 1=It disturbs or affects me slightly 2=It moderately disturbs or affects me 3=It disturbs or affects me much 4=It disturbs and incapacitates me greatly
help	How much did the intervention help you as regards to the problem? 0=Not sure 1=Made things a lot worse 2=Made things somewhat worse 3=Made no difference 4=Made things somewhat better 5=Made things a lot better
change	How important or significant to you personally do you consider this change to be? 0=Nothing important 1=A bit important 2=Moderately important 3=Very important 4=Extremely important
different	Are you doing, feeling, or thinking differently from the way you did before? 1=yes 0=no

Furthermore, clinical measures of depression, anxiety, and stress (DASS -21 Items) were incorporated in each session to determine the overall psychological health of our participants, as well as the possible effect of the VR experience on these dimensions (Table 6.5).

Table 6.5. DASS 21 Items. These responses were used as clinical measures of depression, anxiety, and stress during all sessions.

variable	meaning	interpretation
DASS_Depression	Depression (dysphoria, hopelessness, devaluation of life, self-deprecation, lack of interest / involvement, anhedonia and inertia.	Normal: 0-9 Mild: 10-13 Moderate: 14-20 Severe: 21-27 Extremely Severe: 28+
DASS_Anxiety	Anxiety (autonomic arousal, skeletal muscle effects, situational anxiety, and subjective experience of anxious affect.	Normal: 0-7 Mild: 8-9 Moderate: 10-14 Severe: 15-19 Extremely Severe: 20+
DASS_ Stress	Stress (levels of chronic nonspecific arousal, difficulty relaxing, nervous arousal, and being easily upset / agitated, irritable / over-reactive and impatient.	Normal: 0-14 Mild: 15-18 Moderate: 19-25 Severe: 26-33 Extremely Severe: 34+

Lastly, we considered both participant-reported and actual recorded swap times between the participants' own bodies and the counsellor's body as response variables. Participants also responded to a question about their experience of body swapping. This was rated on an agreement scale from -3 (least agreement) to 3 (most agreement). The rating for body-swapping was: "Every time I changed the avatar and observed the situation from the perspective of the second avatar, I understood my problem better." Table 6.6 demonstrates body swapping variables.

Table 6.6. Body-swapping variables. Reported swap times, VR recording of swap times and better understanding of the problem after each body-swap.

variable	meaning
swaptime	How many times did you swap bodies? 1 = 1-2 times 2 = 3-5 times 3 = 5-7 times 4 = 8 times or more
vr_swap	Number of actual swaps recorded in the VR session
better_understand_after_swap	Every time I changed the avatar and observed the situation from the perspective of the second avatar, I understood my problem better. ('-3 means the least agreement and 3 the most agreement')

Our findings were introduced in the following section. The results section comprises only the findings obtained with the Frequentist statistical methodologies. An in-depth analysis that includes both Bayesian techniques and sentiment analysis of the participants' responses to problem definition and the open-ended questions about their thoughts, opinions, and comments after the VR will be detailed in the forthcoming journal publication of this study, which is currently under preparation.

6.2.2. Results

6.2.2.1. Demographic variables

In the first session of the experiment, we gathered basic demographic information from our participants. The questions included participants' age, gender, preferred language for the experiment, educational background, occupation, computer literacy level, programming expertise level, previous VR experience, and videogame playtime in the last year and week. The participants' responses to the demographic questions are demonstrated in Table 6.7.

Table 6.7. Basic demographic questions and participant responses per condition in the first session of the experiment.

question	response	Current Self	Future Self	General Self
What is your preferred experiment language?	English Spanish	6 11	6 11	6 11
What is your gender?	Male Female Non-binary	6 11 0	6 11 0	8 9 0
What is your age?	Mean ± SD	25.47 ± 6.52	25.41 ± 5.75	25.94 ± 6.09
What is your occupation?	Student Employed part-time Employed full-time Self-employed Unemployed Retired	11 3 3 0 0 0	13 0 2 0 2 0	10 2 2 0 3 0
What is your level of education?	University studies Professional education Secondary education	13 3 1	17 0 0	13 3 1
How much have you experienced VR before? *1 = never* *7 = a great amount*	Median (IQR)	3(3)	3(2)	2(1)
What is your level of knowledge of computer literacy? *1 = none* *7 = expert*	Median (IQR)	5(2)	5(1)	5(1)
What is your level of knowledge of computer programming? *1 = none* *7 = expert*	Median (IQR)	2(2)	3(2)	2(3)

How many times have you played video games in the past year?	0 times 1-5 times 6-10 times 11-15 times 16-20 times 21-25 times more than 25 times	1 6 5 2 0 0 0	2 5 4 2 2 1 1	2 2 1 1 1 0 10
How many hours have you played video games in the past week?	0 hours 1 hours 2-3 hours 3-5 hours 5-7 hours 7-9 hours more than 9 hours	9 4 1 2 0 0 1	9 4 3 0 1 0 0	4 4 3 2 1 1 2

According to the demographic information responses we obtained from participants, it was observed that there were variations between conditions, specifically in two demographic variables: the frequency of video game play over the past year and the hours spent on video games in the past week. For this reason, we checked for the variance across different conditions for all demographic variables. Our one-way ANOVA results indicated a significant difference between conditions in the frequency of video game play over the past year (f-value: 4.84, p-value: 0.012, $p<0.05$) and the hours spent playing video games in the past week (f-value: 3.28, p-value: 0.04, $p<0.05$) were significant. On the other hand, the other demographic variables showed no significant differences between conditions.

The distribution of these two video game play variables varied across all conditions, with participants in the General Self condition reporting a higher frequency and more hours spent on video game play (Figure 6.4). However, when we performed a logistic regression analysis using the Maximum Likelihood Estimation to understand the impact of demographic variables on the main response variables, we could not find any significant influence of these variables.

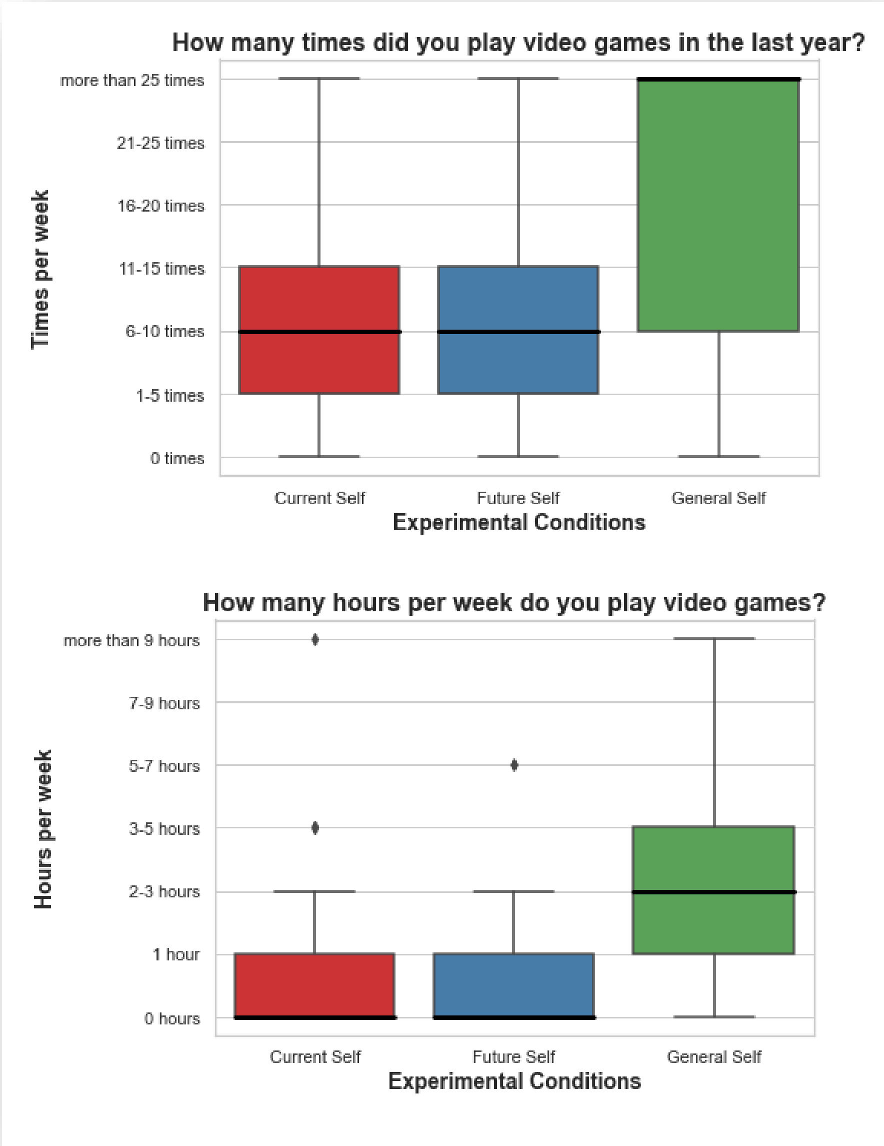

Figure 6.4 Video game demographic variables.

6.2.2.2. VR response measures

We visualised participants' responses obtained from the VR response questions about body recognition, ownership, and agency scores as box plots in Figure 6. 5. We observed that all median scores and the majority of the interquartile ranges were above 0. These results suggested that participants experienced a strong sense of body ownership and agency, aligning with findings from previous studies (Osimo et al., 2015; Slater et al., 2019).

Participants also indicated high self-recognition scores for their own virtual bodies. Therefore, upon comparison, we did not find significant differences in body recognition, ownership, and agency across the experimental conditions.

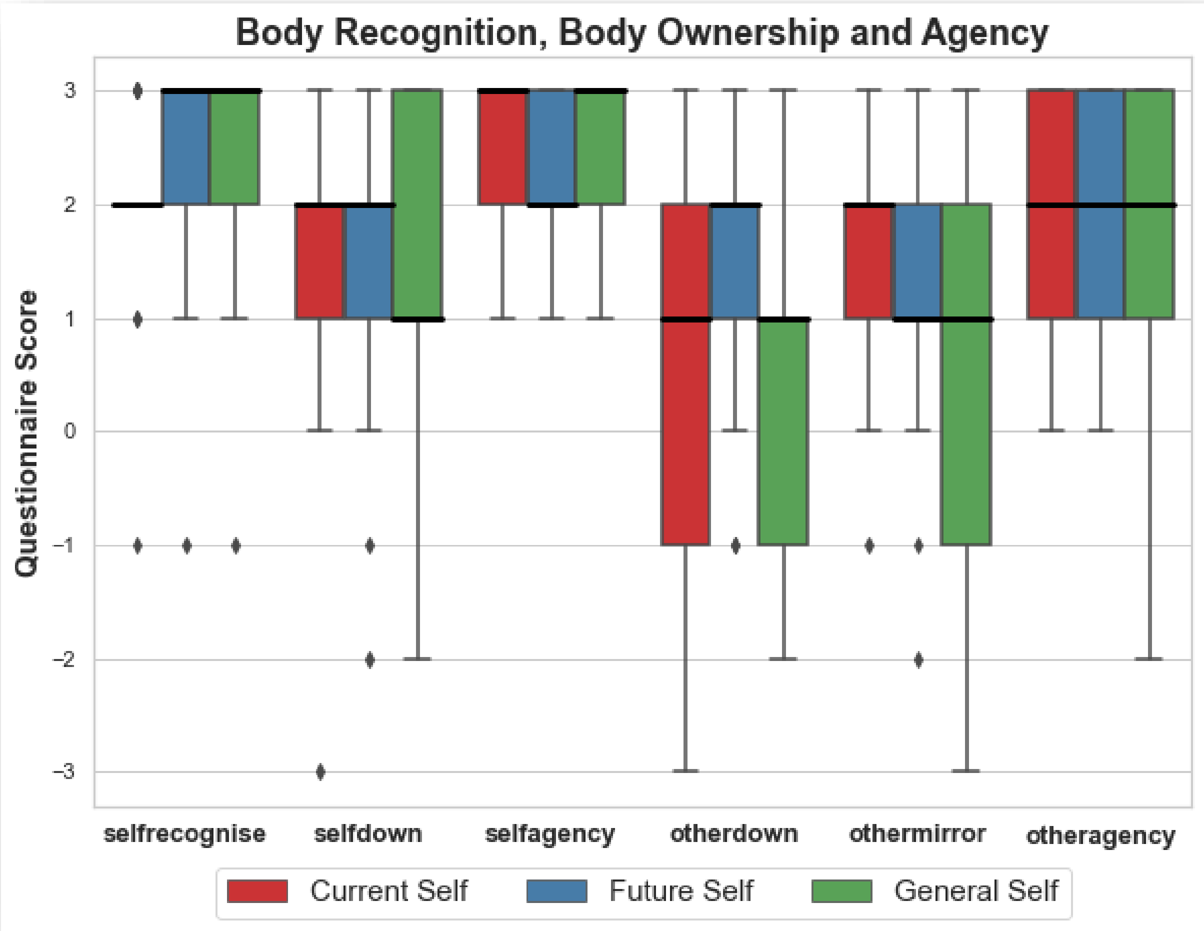

Figure 6.5 VR response measures. *Body recognition, body ownership and agency between experimental conditions.*

The mean age estimations of the counsellor's virtual body across conditions are presented in Table 6.8. The boxplot for mean age scores is also demonstrated in Figure 6.6. In all conditions, the actual mean age of the participants was 25 years old. However, in the "Current Self" condition, participants perceived their counsellor bodies, which were designed to look like them, to be slightly older, with an estimated mean age of 29 years old rather than their actual mean age of 25 years old. This represented a minor overestimation. In contrast, participants in the Future Self condition estimated the age of their counsellor bodies, which were designed to look like an old version of themselves as 41 years old. This estimation for the future self was higher, by about 15 years, than their actual age, aligning with our expectations. Finally, the mean of the estimated age of the counsellor body in the General Self condition was 32 years old, which was 7 years older than the actual mean age of the participants.

Table 6.8.The estimation of the average age of the counsellor's virtual body per condition.

Condition	**Mean ± SD of the estimated age of the counsellor body**
Current Self	29.17 ± 6.61
Future Self	41.35 ± 10.73
General Self	32.23 ± 5.37

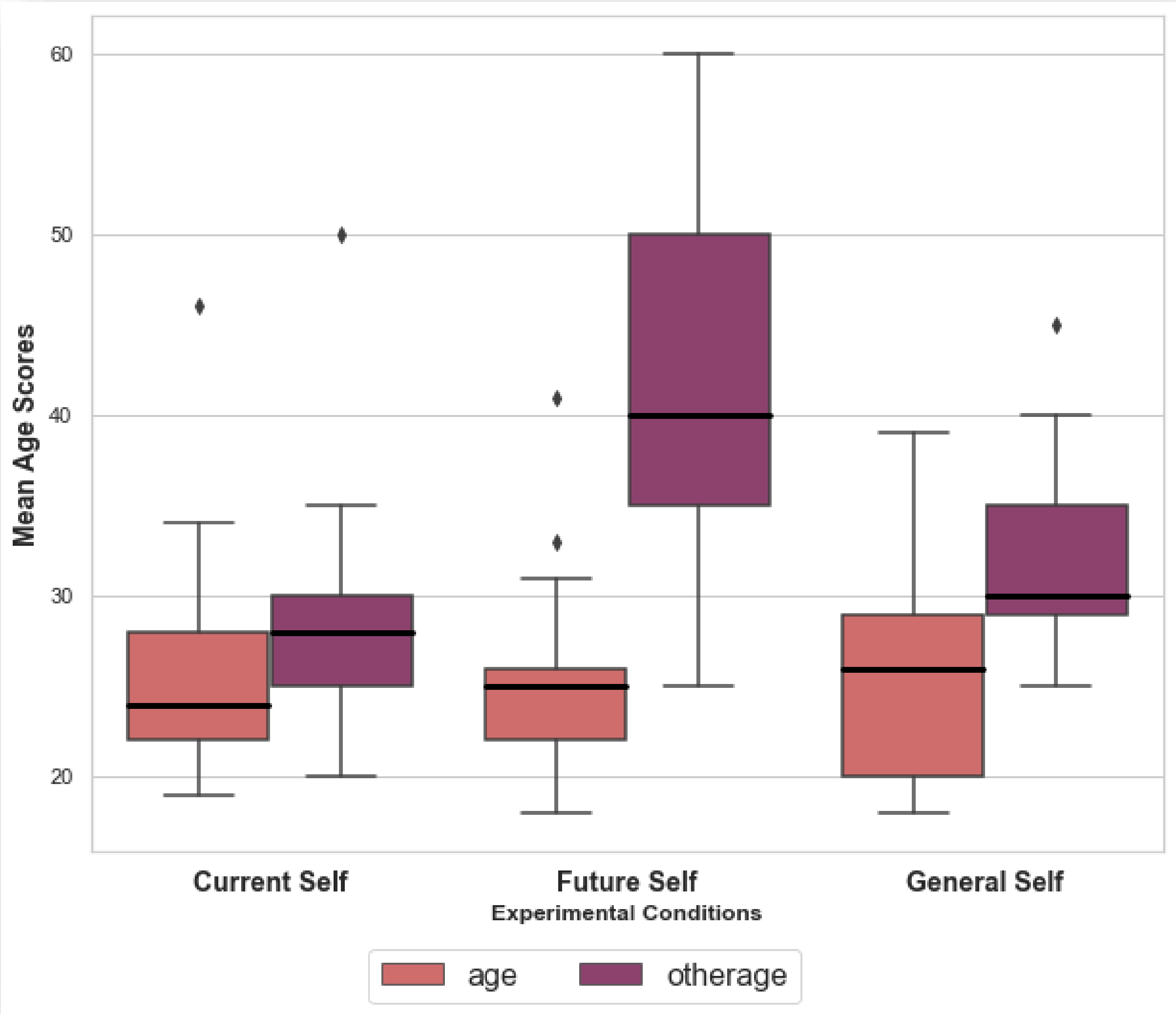

Figure 6.6 The mean of the actual age of the participants and the average estimated age of the counsellor body per condition. *Age variable represents the actual age of the participants while other age variable represents the predicted age of the counsellor body.*

6.2.2.3. Future Self-Continuity

The Future Self-Continuity Scale was utilised to understand the relationship between participants and their future selves across different sessions and conditions. We conducted a series of Wilcoxon signed-rank tests to investigate the changes over time within each experimental condition. For each condition (Current Self, Future Self, General Self), we compared participant responses at three different time points: “one week before VR”, “after VR”, and “one week after VR”. The comparisons were conducted pairwise, i.e., “one week before VR” vs “after VR”, “one week before VR” vs “one week after VR”, and “after VR” vs “one week after VR”. As illustrated in Figure 6.7, there were observable tendencies in how similar participants felt about their future selves across the sessions. Although a downward trend was noticeable after the VR session for the Current Self condition, an upward trend for the Future Self condition following the VR session and an upward trend was observed one week after the VR session for the General Self condition, the results from the Wilcoxon signed-rank test performed did not yield any significant differences between the sessions for any of the experimental conditions.

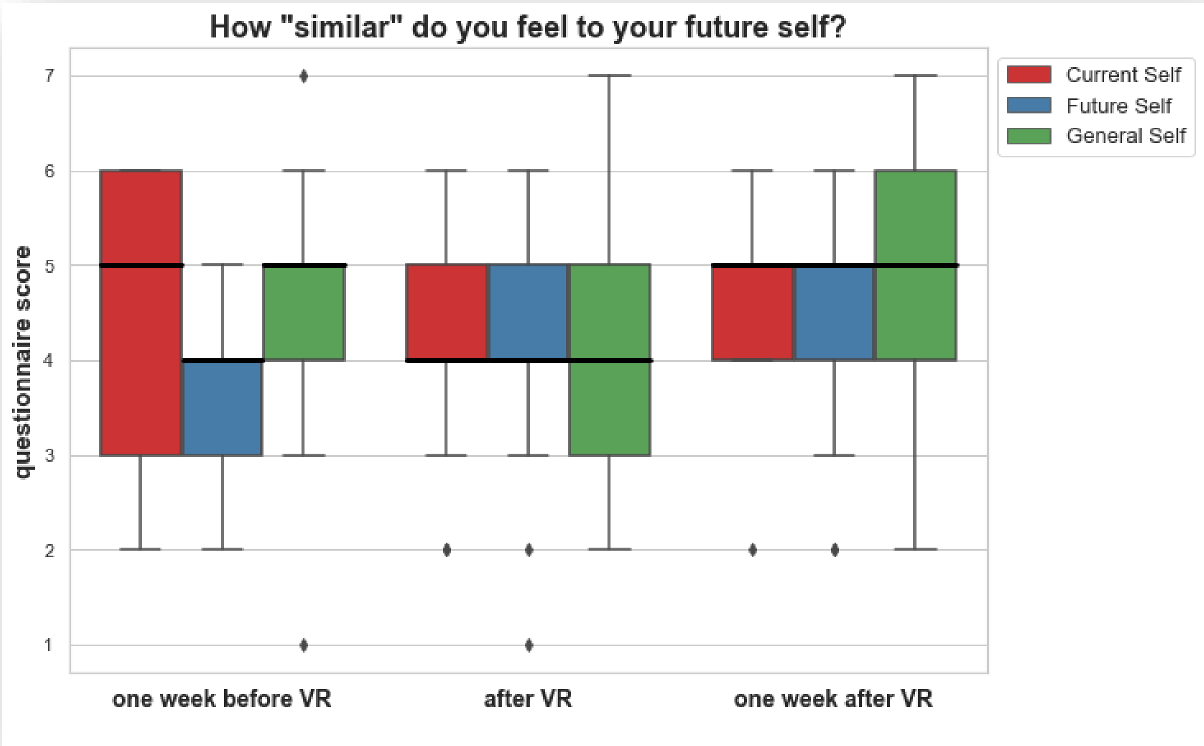

Figure 6.7 Future Self-Continuity “Similarity” by session and condition.

The connectedness participants felt with their future selves is depicted in Figure 6.8. In the Future Self condition, even though participants were observed to feel a heightened connection with their future selves following the VR session, this feeling decreased to initial levels after one-week post-session. However, overall, The Wilcoxon signed-rank test revealed no statistically significant differences between sessions in any of the experimental conditions.

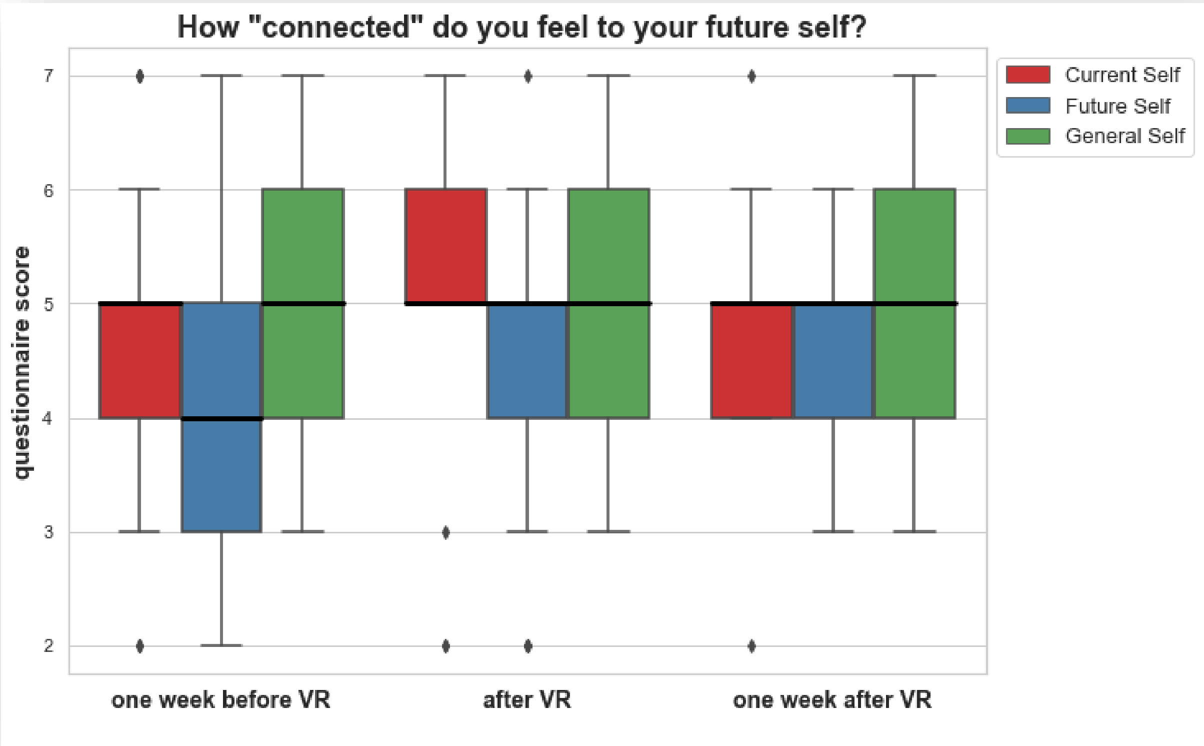

Figure 6.8. Future Self-Continuity "Connectedness" by session and condition.

Furthermore, in terms of care shown after the VR session, participants in the Current Self and Future Self conditions appeared to exhibit more care for their future selves than those in the General Self condition, as illustrated in Figure 6.9. For the Future Self condition, a Wilcoxon signed-rank test revealed a significant increase in care one week after the VR session compared to one week before (W-statistic = 5.0, p-value = 0.03). Similarly, in the Current Self condition, there was a significant increase in care levels immediately after the VR as compared to one week before the VR (W-statistic = 12.0, p-value = 0.02). These results suggested that the VR session influenced the participants' care for their future selves in both conditions.

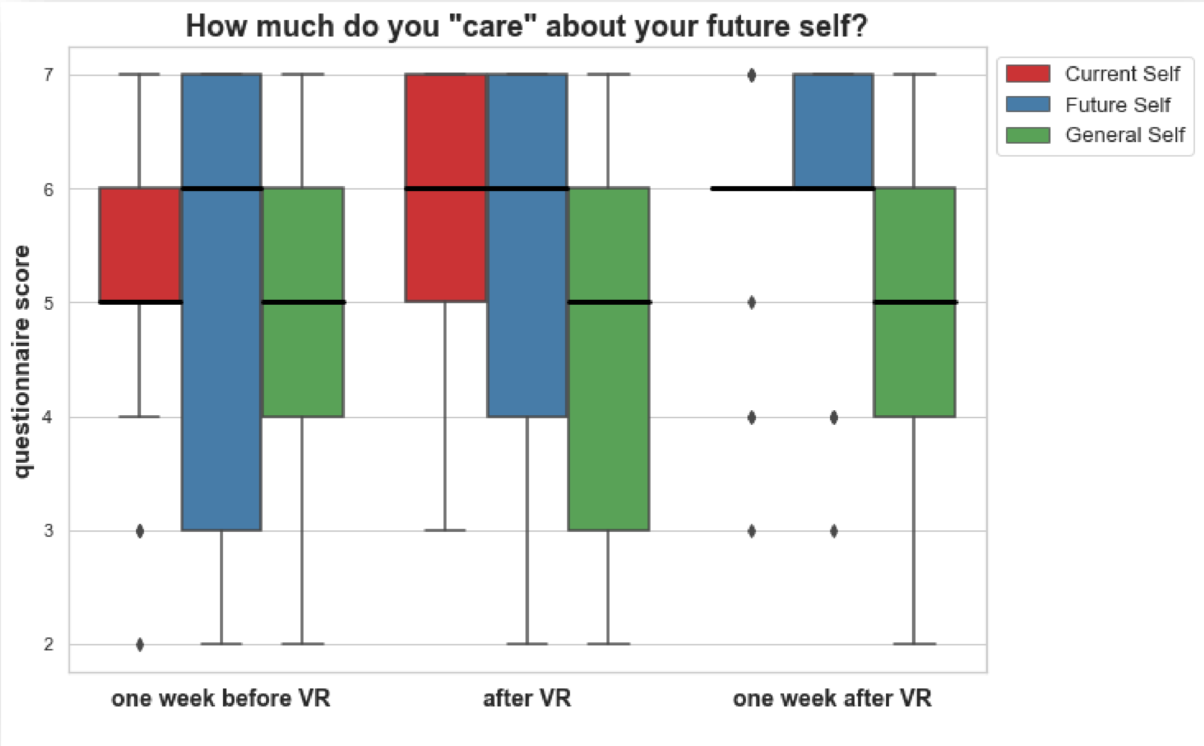

Figure 6.9. Future Self-Continuity "Care" by session and condition.

Lastly, as depicted in Figure 6.10, the degree to which participants liked their future selves, the "like" variable decreased for the Future Self condition following the VR session. The Wilcoxon signed-rank test results also indicated statistically significant differences between sessions for the Future Self condition (W-statistic = 7.0, p-value = 0.03).

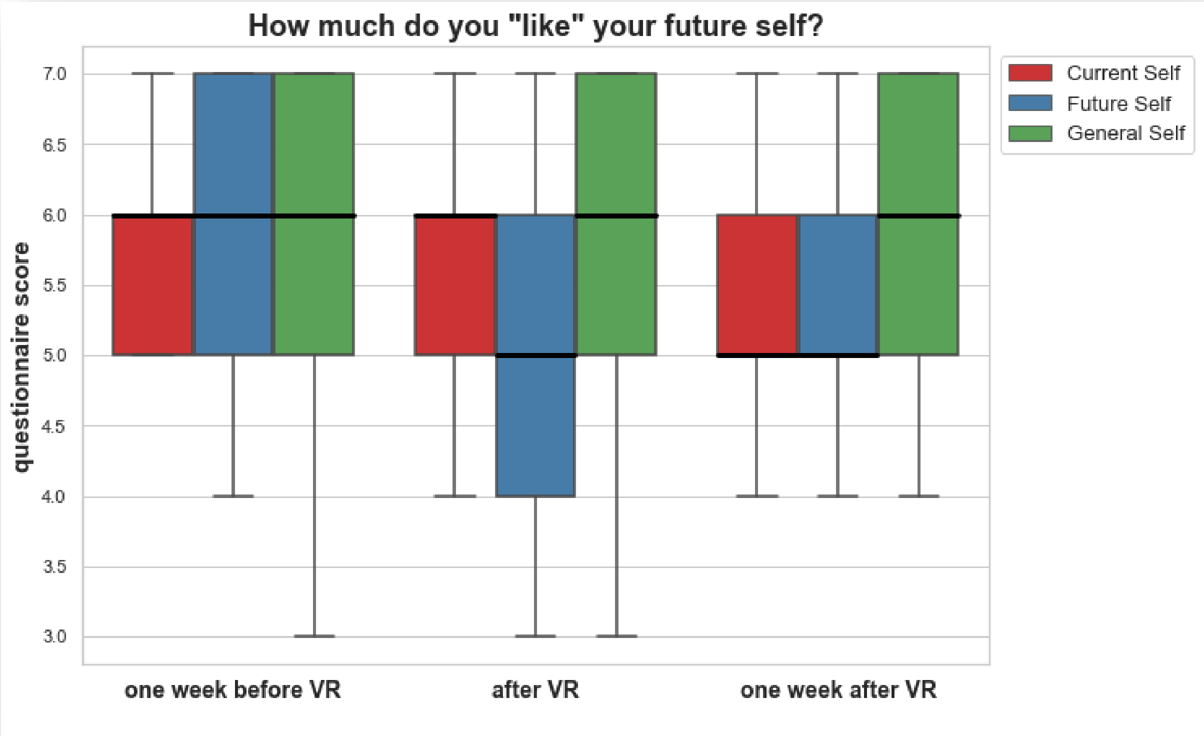

Figure 6.10. Future Self-Continuity "Like" by session and condition.

Accordingly, significant differences between sessions were only observed for the "care" and the "like" variables in the Current Self and Future Self conditions. For the Current Self condition, the difference was significant only for "care", while in the Future Self condition, significant differences were noted for both "care" and "like" variables.

6.2.2.4. General Psychological Variables

In all sessions, we evaluated a set of general psychological variables categorised into two groups: "Perspective" and "Impact". The "Perspective" category included knowledge, understanding, new ideas, control, and new perspective. In addition, the "Impact" category comprised variables like importance, discomfort, help, change, and difference. Participants responded to these variables at three specific points: in the first session after defining the problem, in the second session immediately following the VR experience and one week after the VR experience. We conducted a Wilcoxon signed-rank test for each condition to compare these variables between experimental sessions for each condition.

For the “knowledge” variable (Figure 6.11), our results revealed significant differences across the sessions for the Current Self and General Self conditions.

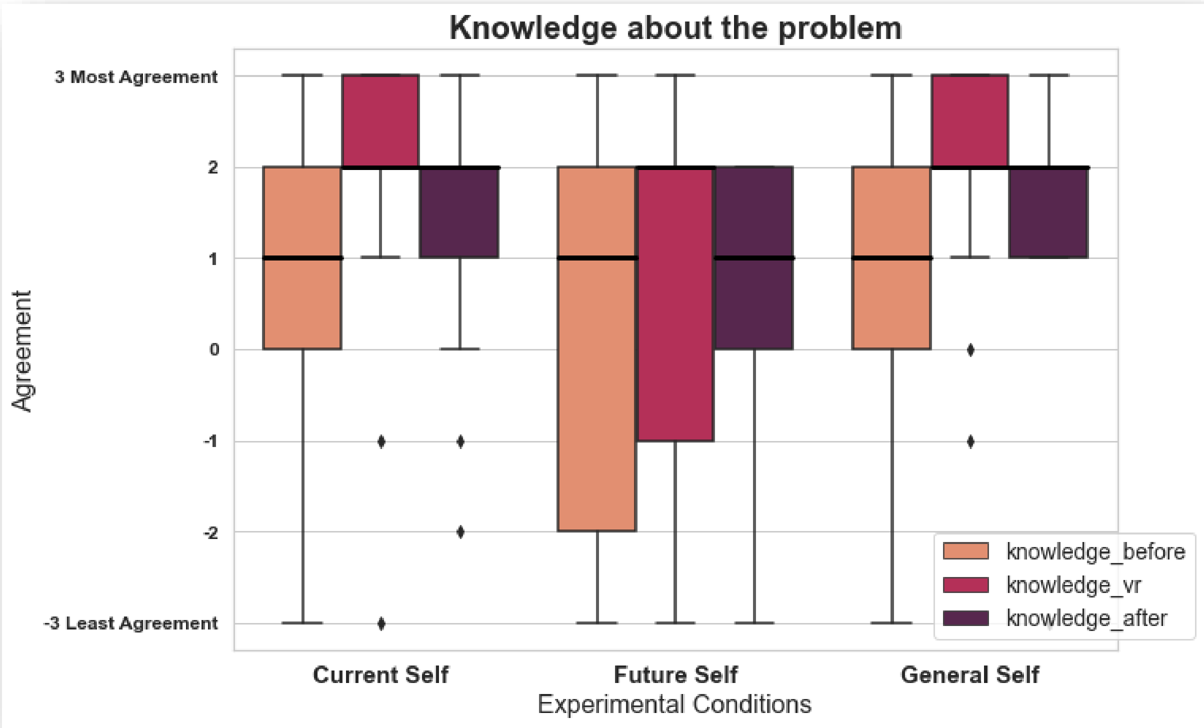

Figure 6.11. The "knowledge" variable across experimental sessions per condition.

Specifically, for the Current Self condition, a significant shift in knowledge was observed between one week before VR and after VR (W-statistic = 10.0, p-value = 0.01), and also between one week before VR and one week after VR (W-statistic = 11.0, p-value = 0.04). However, no significant difference was observed between after VR and one week after VR (W-statistic = 19.5, p-value = 0.41). For the General Self condition, there was also a significant difference in knowledge between one week before VR and right after VR (W-statistic = 13.5, p-value = 0.01), as well as between one week before VR and one week after VR (W-statistic =

11.0, p-value = 0.02). Similar to the Current Self condition, no significant difference was found for the sessions between right after VR and one week after VR (W-statistic = 11.0, p-value = 0.30). In contrast, no significant differences were observed for the Future Self condition across any of the sessions: between one week before VR and the session right after VR (W-statistic = 16.5, p-value = 0.058), between one week before VR and one week after VR (W-statistic = 7.0, p-value = 0.057), and between the session right after VR and one week after VR (W-statistic = 17.5, p-value = 0.94). These results suggested that participants in the Current Self and General Self conditions gained a greater knowledge of their personal problems following the VR experience. However, the Future Self condition did not reveal a significant change.

Like the "knowledge" variable, our Wilcoxon signed-rank test analysis of the responses to the "understand" variable highlighted significant variations between sessions for the Current Self and General Self conditions (Figure 6.12).

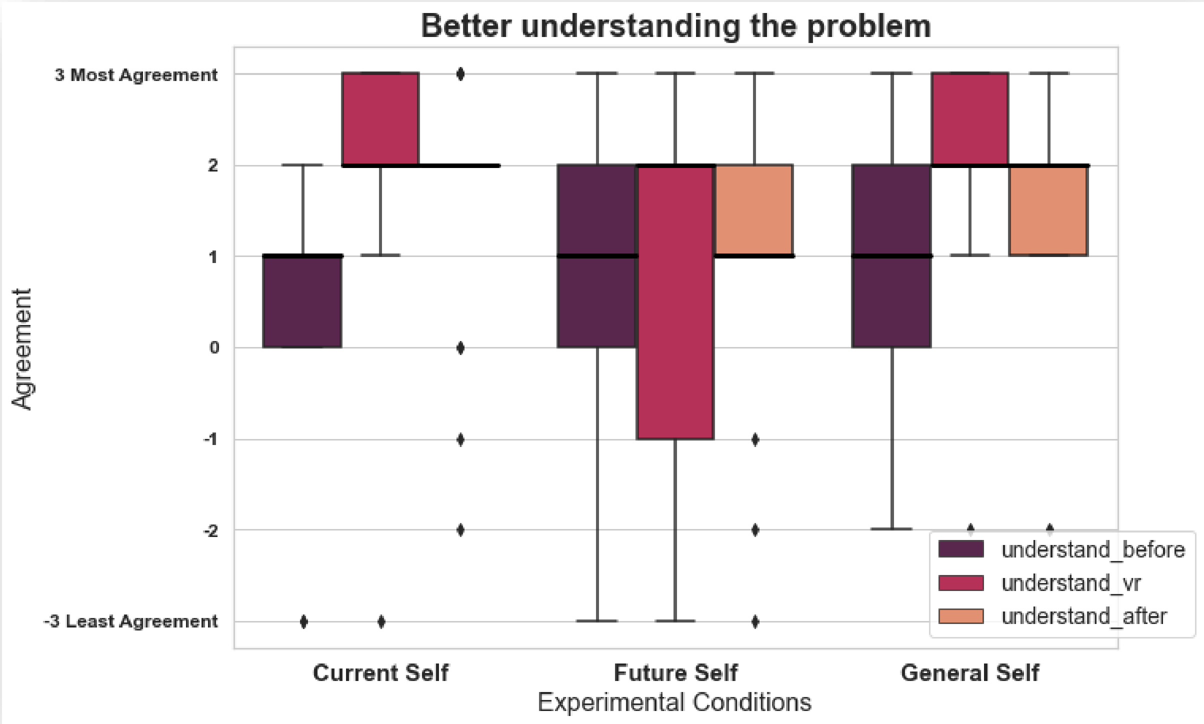

Figure 6.12. The "understand" variable across experimental sessions per condition.

In the Current Self condition, we observed a significant increase in understanding between the session one week before VR and the session right after VR (W-statistic = 0.0, p-value = 0.001), and also between the session one week before VR and the session one week after VR (W-statistic = 25.5, p-value = 0.04). However, there was no significant difference in understanding between the session right after VR and the session one week after VR (W-statistic = 16.5, p-value = 0.24). In the General Self condition, there were also significant differences in understanding between the session one week before VR and the session right after VR (W-statistic = 5.0, p-value = 0.006), and between the session one week before VR and the session one week after VR (W-statistic = 5.0, p-value = 0.005). No significant difference was noted between the session right after VR and the session one week after VR (W-statistic = 9.0, p-value = 0.08). However, for the Future Self condition, no statistical differences were found across all sessions: between the session one week before VR and the session right after VR (W-statistic = 33.0, p-value = 0.20), between the session one week before VR and the session one week after VR (W-statistic = 13.5, p-value = 0.13), and between the session right after VR and the session one week after VR (W-statistic = 17.5, p-value = 0.94269).

Following the analysis, the results demonstrated that the differences between the session one week before VR and the session right after VR, as well as between the session one week before VR and the session one week after VR, were significant for both the Current Self and General Self conditions. This result indicated a substantial improvement in the participants' understanding of personal problems in both the Current Self and General Self conditions post-VR experience.

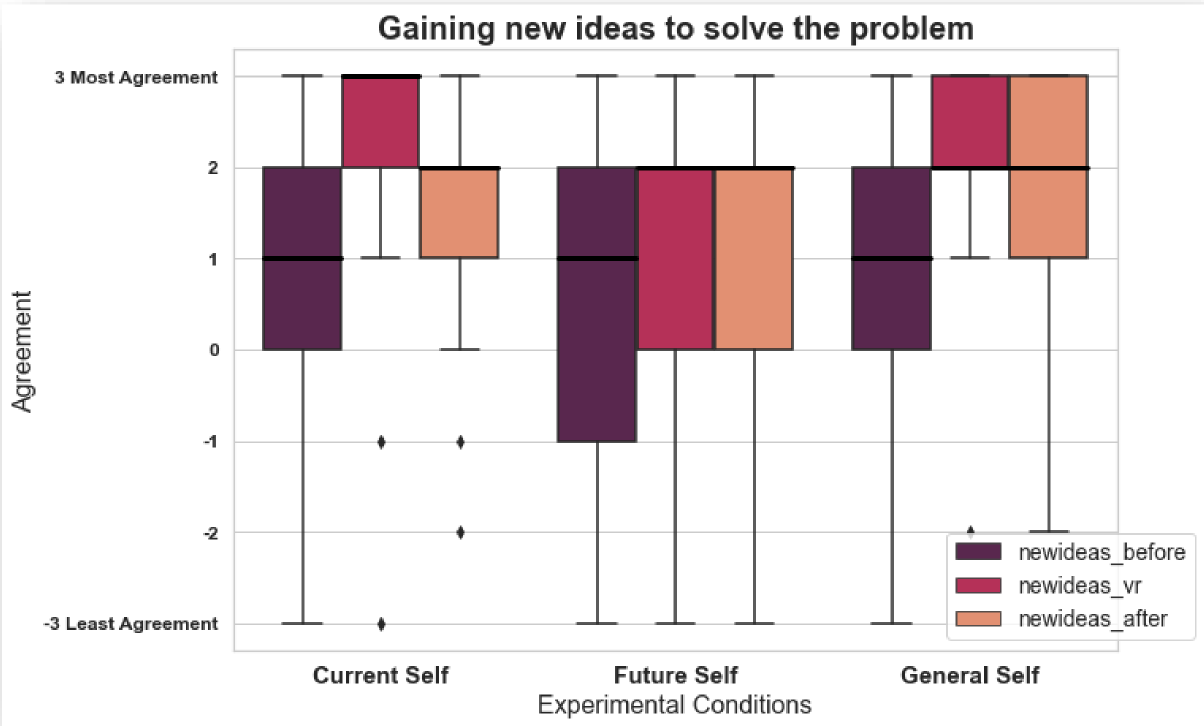

Figure 6.13. The "newideas" variable across experimental sessions per condition.

Similarly, the “newideas” variable was significant also showed significant differences between sessions for both the Current Self and General Self conditions (Figure 6.13). For the Current

Self condition, the significant results for the new ideas were noted between the one week before VR and after VR sessions (W-statistic = 9.5, p-value = 0.01). Significant differences were observed in the General Self condition between the one week before VR and after VR sessions (W-statistic = 12.0, p-value = 0.01) and between the one week before VR and after VR sessions (W-statistic = 12.0, p-value = 0.03). On the other hand, the Future Self condition did not reveal substantial changes. Although there was a significant difference between one week before VR and one week after VR sessions (W-statistic = 13.5, p-value = 0.03), no significant difference was observed between the one week before VR and after VR sessions (W-statistic = 14.0, p-value = 0.08).

These results indicated that the VR self-counselling session was effective in developing new problem-solving ideas for the Current Self and General Self conditions, and the effect was less prominent for the Future Self condition.

The “control” variable was significantly different between sessions for the Current Self and General Self conditions. Significant differences were observed in the Current Self condition between one week before VR and after VR sessions (W-statistic = 5.0, p-value = 0.002) and between one week before VR and after VR sessions (W-statistic = 14.5, p-value = 0.01). Similarly, the General Self condition demonstrated substantial shifts between one week before VR and after VR sessions (W-statistic = 17.0, p-value = 0.02) and between one week before VR and one week after VR sessions (W-statistic = 8.0, p-value = 0.01). Meanwhile, the Future Self condition did not show significant differences between one week before VR and after VR sessions (W-statistic = 29.0, p-value = 0.07). However, an important shift was observed between one week before VR and after VR sessions (W-statistic = 13.5, p-value = 0.01218).

These findings indicate that participants, particularly in the Current Self and General Self conditions, gained control over their problems following the VR session. The Future Self condition showed some improvement, although the results were not as pronounced (Figure 6.14).

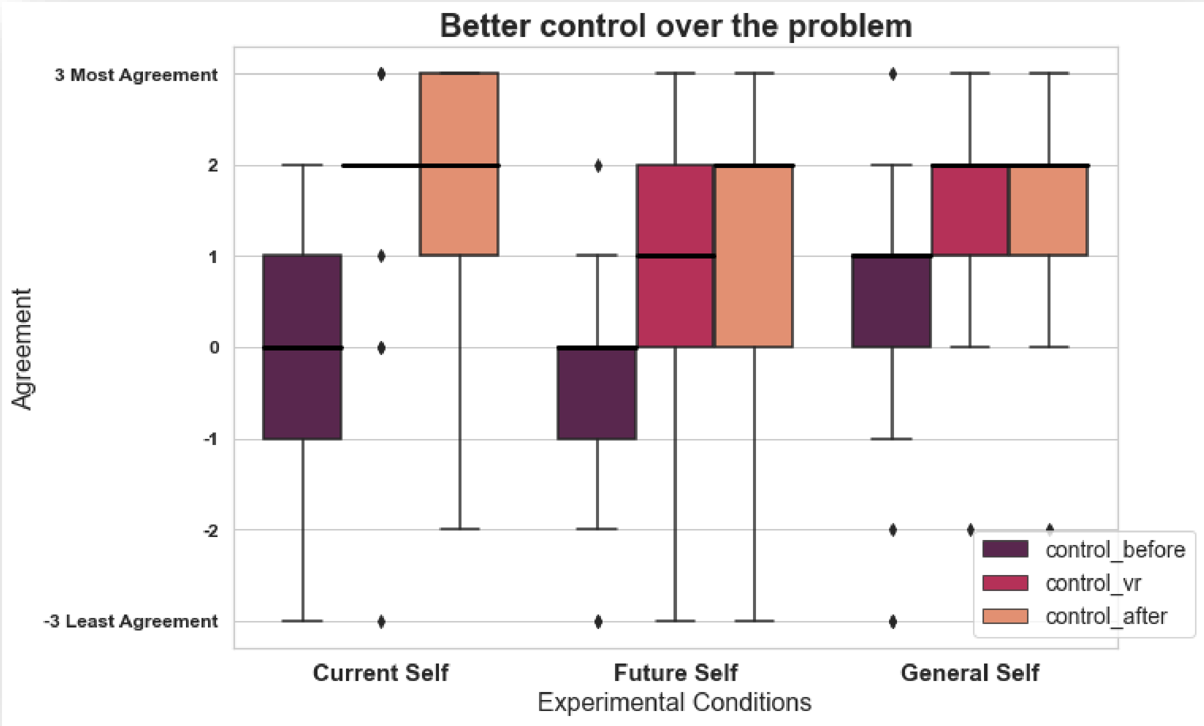

Figure 6.14. The "control" variable across experimental sessions per condition.

Finally, for the "newperspective" variable, all conditions indicated significant differences across sessions. For the Current Self condition, substantial shifts were noted both between one week before VR and after VR sessions (W-statistic = 6.0, p-value = 0.001) and one week before VR and one week after VR sessions (W-statistic = 18.5, p-value = 0.01). The General Self condition mirrored this pattern, with significant changes observed between one week before VR and after VR sessions (W-statistic = 14.0, p-value = 0.01) and one week before VR and one week after VR sessions (W-statistic = 18.5, p-value = 0.01). In the Future Self condition, a significant shift was detected between one week before VR and after VR sessions (W-statistic = 3.0, p-value = 0.004), and an even more substantial change was observed between one week before VR and one week after VR sessions (W-statistic = 0.0, p-value = 0.001). These findings underscore that all participant groups developed a new perspective on their personal problems following the VR self-counselling session (Figure 6.15).

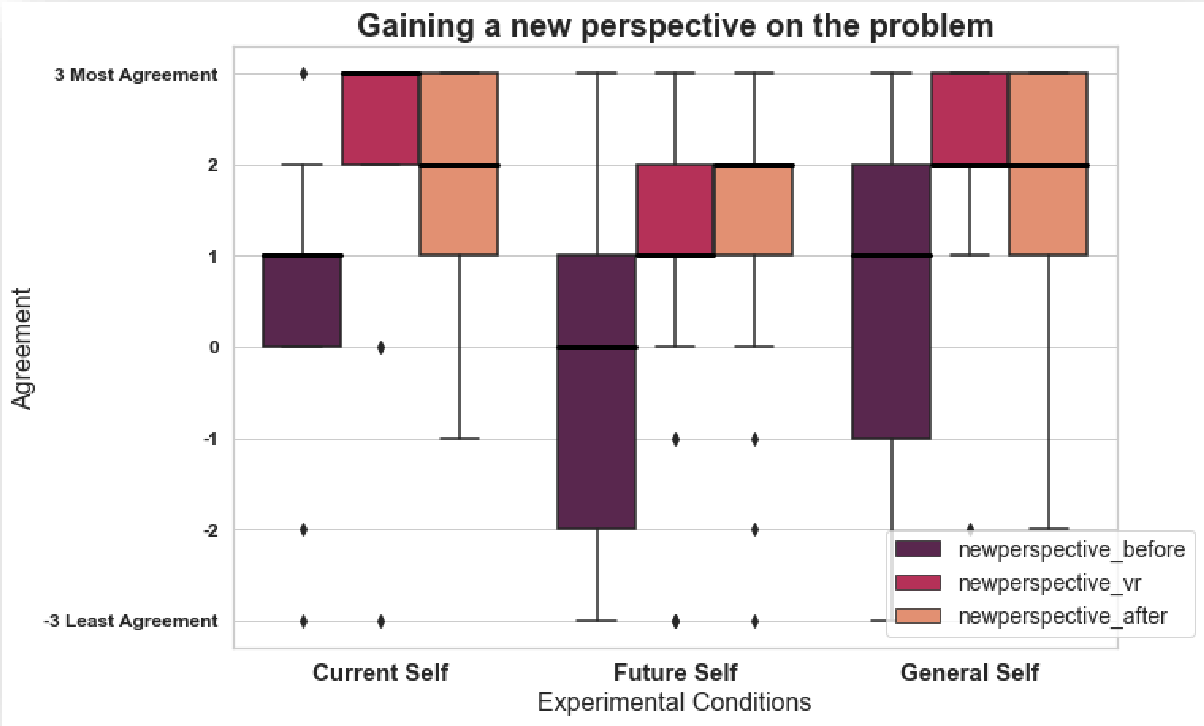

Figure 6.15. The "newperspective" variable across experimental sessions per condition.

The overall findings from the perspective variables suggested that self-counselling in VR significantly influenced participants' perspectives on the Current Self and General Self conditions. However, even though some differences were observed, the results for the Future Self condition were not as pronounced compared to other conditions.

Following these outcomes, we analysed the impact outcomes obtained from the general psychological variables. Like the perspective outcomes, we performed the Wilcoxon signed-rank test to determine if there were significant differences across sessions.

For the "importance" variable, which measured the level of importance participants placed on the personal problem in their lives, only for the General Self condition, a significant difference was observed between one week before VR and second after VR sessions (W-statistic = 5.5, p-value = 0.01). This finding implied that the perceived importance of the problem usually remained consistent throughout the study regardless of the session or condition.

However, for the “discomfort” variable, which assessed the level of discomfort induced by the problem in participants’ lives, the Wilcoxon signed-rank test revealed significant results both for the Current Self (W-statistic = 11.0, p-value = 0.03) and General Self (W-statistic = 0.0, p-value = 0.04) conditions between after VR and one week after VR sessions, referring a decreased discomfort after the VR session. The “change” variable, measuring the impact of how significant they consider the change to be, exhibited a significant difference only for the General Self condition across experimental sessions. The difference was observed between one week before VR and after VR sessions (W-statistic = 7.0, p-value = 0.03) and after VR and one week after VR (W-statistic = 3.0, p-value = 0.03) sessions. However, no significant difference was observed between one week before VR and one week after VR sessions (W-statistic = 17.0, p-value = 0.8).

On the other hand, for the “help “variable, estimating the perceived helpfulness of the intervention regarding the problem (the boxplot illustrated in Figure 6.16), the Wilcoxon Signed-Rank tests showed significant differences for all experimental conditions.

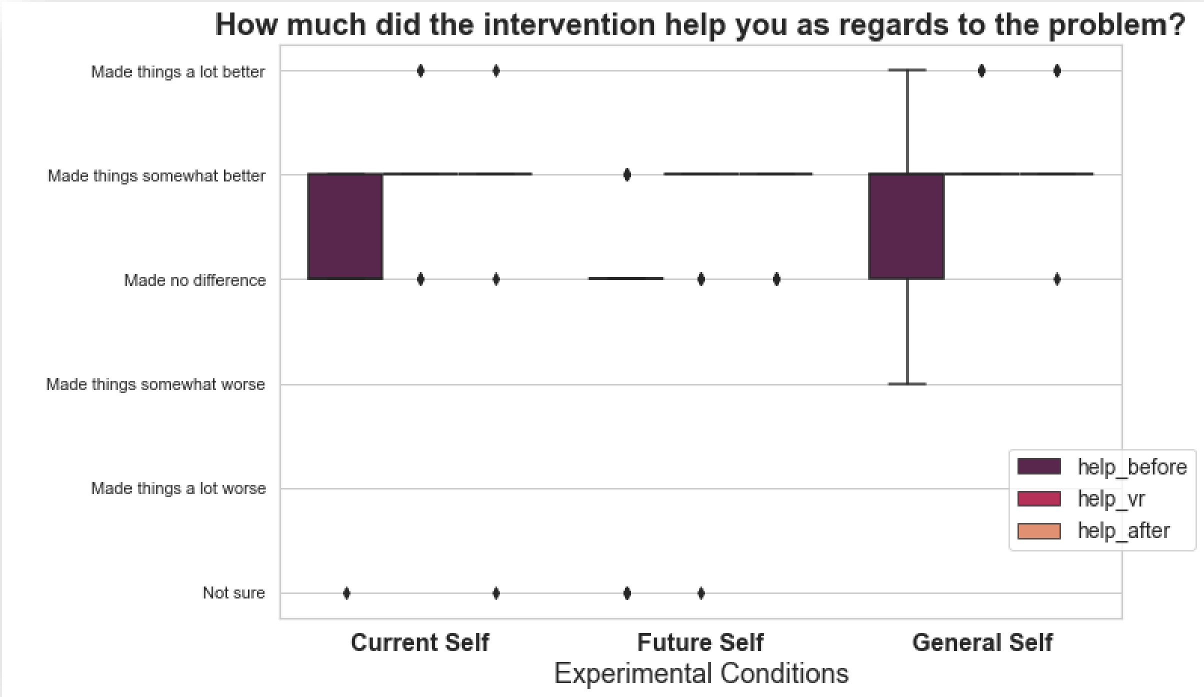

Figure 6.16. The "help" variable across experimental sessions per condition.

In the Current Self condition, a significant difference was observed between one week before VR and after VR sessions (W-statistic = 0.0, p-value = 0.005). In addition, significant differences were shown for the Future Self condition between one week before VR and after VR sessions (W-statistic = 7.5, p-value = 0.02) and between one week before VR and one week after VR sessions (W-statistic = 0.0, p-value = 0.004). However, no significant change was detected between after VR and one week after VR sessions. Likewise, for the General Self condition, there were significant shifts both between one week before VR and after VR sessions (W-statistic = 0.0, p-value = 0.008) and between one week before VR and one week after VR sessions (W-statistic = 0.0, p-value = 0.006). In contrast, the change between after VR and one week after VR sessions remained insignificant.

Overall, these outcomes suggested that the VR self-counselling was effective in helping participants across all conditions.

Additionally, the “different” variable, referring to whether participants do, feel, or think differently from the way they did before (displayed in Figure 6.17), demonstrated significant session differences for all conditions. The Current Self (H = 12.9, p-value = 0.001), Future Self (H = 6.93, p-value = 0.03) and General Self conditions (H = 12.6, p-value = 0.001) all revealed significant differences between one week before VR and after VR sessions as well as between one week before VR and one week after VR sessions. These findings implied that independent of the condition, participants did, felt and thought differently about their problems from the way they did before following the VR self-counselling sessions.

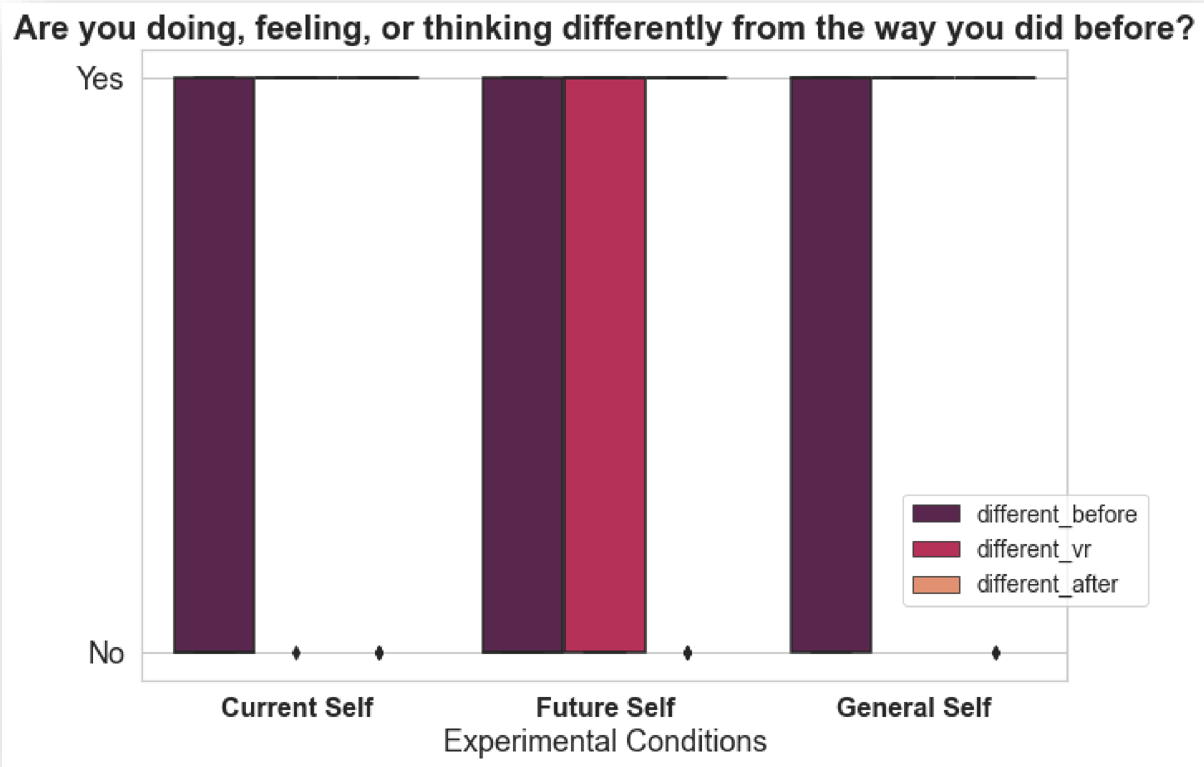

Figure 6.17.The "different" variable across experimental sessions per condition.

The overall results from the impact variables demonstrated that the importance and discomfort remained stable across sessions; however, the VR self-counselling significantly impacted participants’ perception of the help received and their general feelings towards their problem. The help and different outcomes were especially pronounced in all conditions.

The change also varied for the Current Self condition. The findings contributed to the growing body of evidence supporting the use of VR in therapeutic and self-help contexts.

6.2.2.4. Clinical Measures

We collected participants' responses about the general well-being of the participants in the first session using the WHO-5 Well-Being Index and later the depression, anxiety and stress during all sessions by using Depression, Anxiety, Stress Scale 21 Items (DASS-21). These variables were used to assess and understand the psychological well-being of our participants and to gain insights into the levels of changes in depression, anxiety and stress experienced by our participants. Table 6.9 displays the average scores for each condition, which revealed that participants in each experimental group attained raw scores greater than 13 on the WHO-5 Well-Being Index, suggesting that they belong to a healthy population in terms of well-being. When we analysed each participant individually, we found that three participants - one from the Current Self condition, one from the Future Self condition, and one from the General Self condition - scored below 13, with scores of 11, 11, and 12, respectively. Despite this difference, there was no significant variation in participants' general well-being across conditions, as one-way ANOVA results indicated no significant difference (f-value = 0.5, p-value = 0.609).

Table 6.9. The mean scores obtained from the WHO-5 Well-Being Index indicated per condition.

condition	**Mean $\pm$ SD of WHO-5 Well-Being Index scores**
Current Self	17.17 $\pm$ 2.45
Future Self	17.35 $\pm$ 3.06
General Self	18.11 $\pm$ 3.17

Table 6.10 presents the overall raw DASS-21 scores across sessions for each condition. The mean scores suggest that participants in the General Self condition had lower DASS scores overall than those in the Current and Future Self conditions. However, the Kruskal-Wallis test results indicate no significant variation in the first session scores across the experimental conditions (H = 2.76, p-value= 0.25). The boxplot in Figure 6.18 also shows the overall raw

scores between sessions per condition. For the depression (H = 4.97, p-value= 0.08), anxiety (H = 4.28, p-value= 0.11), and stress (H = 1.09, p-value= 0.57) subscales of the DASS-21 items, we also could not find any significant differences per condition between the first sessions. In addition, in all conditions, participants' scores for each subscale were in the normal range, as demonstrated in Table 6.11.

Table 6.10. The mean scores obtain from the DASS-21 per condition.

Condition	**Mean ± SD of DASS Session 1 (dass_before)**	**Mean ± SD of DASS Session 2 (dass_vr)**	**Mean ± SD of DASS Session 3 (dass_after)**
Current Self	20.47 ± 16.56	21.52 ± 17.29	21.05 ± 20.76
Future Self	22.00 ± 15.36	24.11 ± 21.98	22.47 ± 22.37
General Self	13.64 ± 10.84	13.41 ± 11.91	7.29 ± 5.82

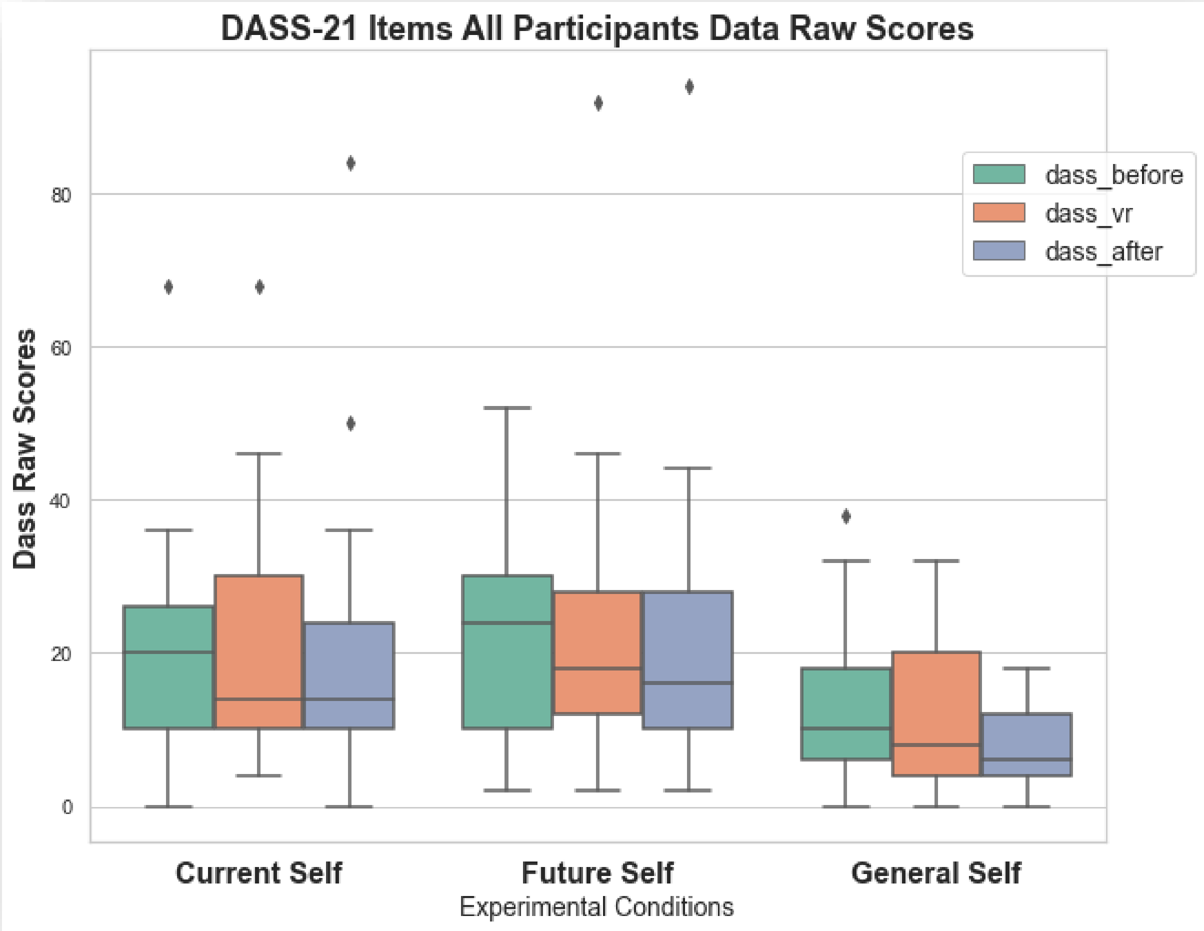

Figure 6.18. The boxplot of the overall DASS-21 Items Scores between experimental conditions.

Table 6.11. The mean scores of the depression, anxiety, and stress scores per condition.

Condition	**depression (mean ± SD)**	**anxiety (mean ± SD)**	**stress (mean ± SD)**
Current Self	6.35 ± 5.66	4.35 ± 4.91	9.76 ± 7.77
Future Self	5.29 ± 6.24	5.88 ± 5.58	10.82 ± 6.96
General Self	2.70 ± 3.23	2.47 ± 2.96	8.47 ± 6.83

6.2.2.4. Body Swapping

As part of our response variables, we assessed both the participant-reported and actual recorded swap times between the participants' own bodies and the bodies of the counsellors.

The scores obtained from these variables are demonstrated in Table 6.12. The findings demonstrated that reported swap times were slightly lower than the actual swap times. While participants in the GS condition swapped bodies more frequently than those in the CS and FS conditions, ANOVA results indicated that this difference was not statistically significant.

Table 6.12. The mean scores obtained from the reported and actual body swaps indicated per condition.

Condition	**Average reported VR Swap**	**Mean ± SD of actual VR Swap**
Current Self	Between 3-5 and 5-7 times	8.7 ± 3.8
Future Self	Between 3-5 and 5-7 times	9.17 ± 4.27
General Self	5-7 times	11.2 ± 6.49

Following the VR experience, participants were questioned about their experiences with body-swapping interactions. Specifically, we aimed to confirm that when they switched their virtual body and viewed the situation from the second avatar's perspective, their understanding of their own problem improved. For this, participants were asked to express their agreement on a scale from -3 (least agreement) to 3 (most agreement), and their responses were displayed in Figure 6.19.

The median scores above 0 suggest an improved understanding of the problem facilitated by VR body swapping across all conditions. In addition, the results derived from the Kruskal-Wallis H test, which compared the differences across experimental conditions for better understanding through VR body swapping, demonstrated a statistically significant difference between the experimental groups with the H-statistic value of 6.69 and a p-value of 0.03.

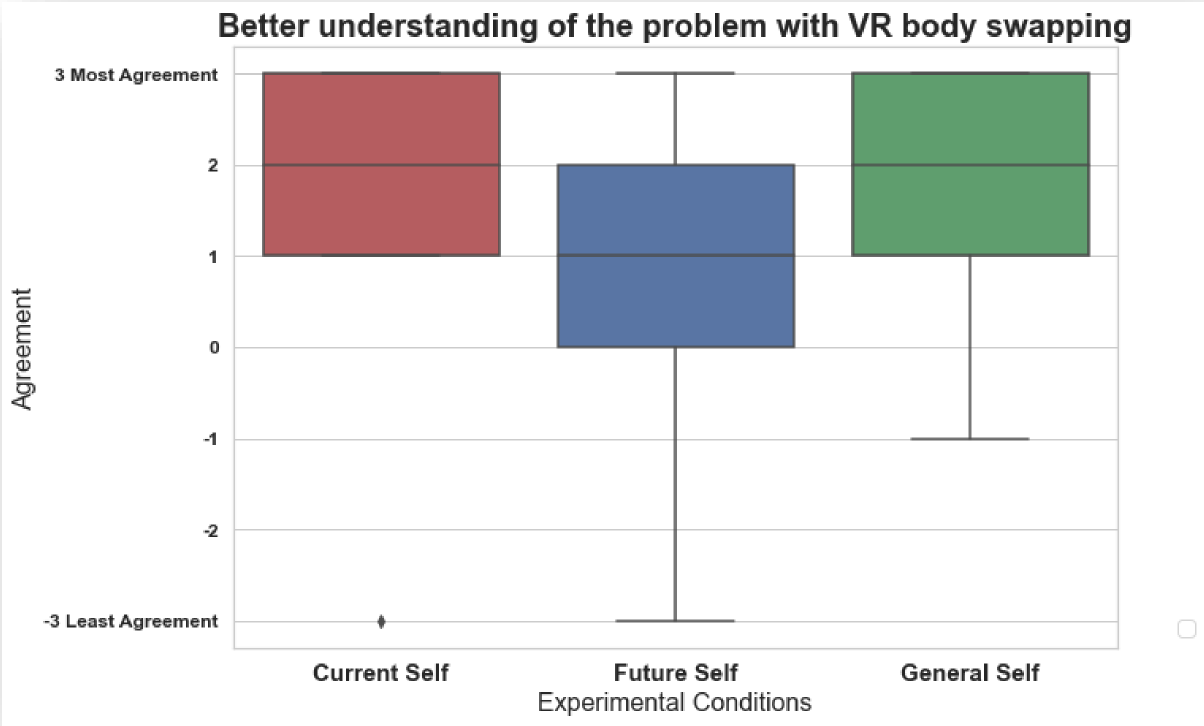

Figure 6.19. Better understanding of the problem with VR body-swapping.

6.2.3. Discussion

The present experiment aimed to investigate the impact of employing different counsellor body representations in the context of VR self-counselling by especially addressing personal problems that generate moderate levels of stress in the lives of participants. We compared virtual counsellor body representations across three distinct conditions: the Current Self (CS) condition, which included a lookalike, real-life mirroring depiction of participants; the Future Self (FS) condition, which encompassed an age-projected, older version of participants; and the General Self (GS) condition, which represented a generic, gender-matched representation of a counsellor.

The findings derived from the VR response measures suggest that, across all conditions, participants could identify their lookalike virtual bodies and feel a sense of body ownership and agency over their virtual bodies, both in their own virtual bodies' representation and the virtual body of the counsellor. In the FS condition, participants perceived their future selves as approximately 15 years older than their actual ages. Interestingly, in the CS condition, they also assessed their counsellor bodies as being, on average, four years older than their actual ages. This approximation might be attributed to participants wearing different clothes for their bodies than the counsellor. Casual clothing was assigned to their own bodies, while the counsellor was dressed formally in a white shirt. This contrast in clothing could have led to such an unexpected perception of the counsellor's body in the Current Self condition. Previous research on self-counselling (Slater et al., 2019) has emphasised the role of clothing as a marker of self-identification. Therefore, although the physical appearance of both bodies was identical, this might be the driving factor behind the observed results. Conversely, the General Self counsellor was evaluated as, on average, seven years older than the participants and was perceived as a distinctly different person who appeared older.

The results from the general psychological variables revealed that the GS and the CS conditions led to more promising outcomes in comparison with the FS condition. Prior studies have posited that increased similarity, connectedness, care, and liking for one's future self, coupled with a vivid and positive perception of it, can decrease temporal discounting (Hershfield, 2011). Based on the previous research on future self-continuity, we expected to observe improved outcomes in the FS condition, predicting that this would promote greater future self-continuity and better psychological results. We expected participants to resolve their personal problems more effectively and exhibit enhanced results after swapping bodies with the age-rendered versions of their virtual bodies acting as counsellors. Nevertheless, we did not observe any significant shifts between the experimental sessions on the Future Self Continuity Scale for any of the conditions, except the increased care for the FS condition. Moreover, our findings indicated that the like for the FS condition decreased for participants after the VR intervention and overall FS condition was less successful in achieving the desired outcomes than the GS and CS conditions.

As a part of the general psychological variables, the "perspective" variables contained elements of acquiring knowledge, enhancing understanding, generating new ideas, feeling control, and obtaining a new perspective concerning the personal problem identified by the participants and the changes occurring in these elements between sessions. In both the CS and GS conditions, participants gained knowledge and an enhanced understanding of their problems following the VR experience, gained new ideas and felt more control over them. However, these effects were not observed in the FS condition. All conditions, including the CS, FS and GS, indicated significant differences across sessions for the new perspective variable, referring that self-conversation helped everyone to gain a new perspective on their problem, irrelevant to the condition. As a result, the overall findings derived from the "perspective" variables suggested that self-counselling in VR significantly influenced participants' perspectives, primarily in the GS and CS conditions. Nonetheless, they did not show significant results for the FS condition.

In addition, the general psychological variables related to "impact" concerned aspects such as the level of importance and discomfort caused by the problem, the extent to which the intervention was helpful, how significant participants personally expected this change to be, and whether participants did and felt different compared to their previous mindset. The importance and discomfort aspects remained insignificant across all conditions between sessions, except the GS condition. At the same time, the help and different variables proved significant for all conditions, with a more prominent effect on the CS and GS conditions. Additionally, the change variable was solely significant for the GS condition.

Conversely, the clinical measures related to depression, anxiety, and stress (DASS-21 Items) did not exhibit significant changes between sessions or across conditions. Even though the medians of the scores appeared to differ across conditions, with the GS condition exhibiting lower scores, this difference was not statistically significant either for the overall scores or the depression, anxiety, and stress subscales of the DASS-21 items.

According to our analysis, these findings suggested that enhancing future self-continuity may not be essential within the VR self-conversation framework. Although earlier studies demonstrated improved health and exercise behaviour following an enhancement of future self-continuity with a 20-year projection period (Ruthnick, 2018), our findings present a converse effect, implying that this condition is not beneficial as a counsellor representation for solving a personal problem. One possible explanation for these less favourable outcomes and diminished liking of the FS condition could be participants' perceived disconnection from their future selves. The portrayal of future selves in a very distant manner, as if they were separate entities (Pronin et al., 2008; Pronin and Ross; 2009), may contribute to these results, though this contradicts previous research where the projection was 20 years, and the effect was still present. Ageism might also provide another potential explanation for the negative outcomes, with younger participants perhaps unconsciously employing it as a defence mechanism against death anxiety during self-conversation (Bodner, 2009). Overall, it can be the case that the counsellor's virtual body does not need to depict an older, wise figure, akin to the participant's future self or even Sigmund Freud, and a general-looking counsellor body could be sufficient. Future studies of self-counselling should focus on contrasting general-looking counsellor bodies with the counsellor body of Sigmund Freud to further investigate these findings.

Regarding the CS condition, the increased future self-continuity scores and age approximation might suggest that participants regarded the counsellor's representation as a distant-future self-representation. Past research has revealed varying approaches to the near future (several days to a week) and distant future (several months to years) selves regarding feasibility and desirability in decision-making (Liberman et al., 1998), confidence in predicting future outcomes (Nussbaum et al., 2006), self-conceptions and identities (Wakslak et al., 2008), and the expression of values in behavioural intentions (Eyal et al., 2009) can differ. These temporal distinctions in approaching the near and distant future were also shown to be mirrored by distinct neural characteristics in anticipating emotional events (D'Argembeau et al., 2008) and self-appraisals (Luo et al., 2013). Therefore, the improved results for the counsellor's virtual body in the CS condition compared to the FS condition might be argued as the potential formation of a future self-continuity mechanism in the CS condition. This result of potentially perceiving a lookalike counsellor body as a near-future self may also shed light on why a previous self-counselling study (Osimo et al., 2015), which reported better outcomes with Sigmund Freud's virtual body as the counsellor, while not observing similar results with a virtual body that resembled the participants' appearance. In contrast, our study revealed that even though the generic-looking counsellor body in the GS condition was better, it still highlighted improved outcomes when using a lookalike body as the counsellor in the CS condition.

When we interpret these results with the lens of predictive coding, we can gain an even more nuanced understanding of the participant responses across the conditions. The observed preference for the General Self (GS) condition can be explained by the participant possibly encountering fewer prediction errors with the GS avatar due to its generic nature, reducing the model complexity of the brain's predictive model compared to the Future Self (FS) and Current Self (CS) conditions. This inclination to reduce model complexity for increased generalization and decreased redundancy (Hobson & Friston, 2012) may account for the better outcome in the GS condition.

Furthermore, the lack of significant shifts in the Future Self Continuity Scale across the different conditions may be explained by perceptual attenuation (Cardoso-Leite et al., 2010). Attenuation refers to the process by which the brain's forward models predict the sensory impacts of our actions, enabling humans to distinguish changes in their environment from those that they themselves cause, thereby potentially enhancing their ability to detect environmental changes. Perceptual attenuation might suggest that in the FS condition, the participants may have effectively predicted away the impact of the FS avatars actions. This adaptation could explain the indifferent reactions to the older avatar representation compared to the other conditions.

Moreover, the GS condition's success, despite its generic representation gives a unique insight into the workings of the predictive brain. The condition's non-specific nature might have introduced less prediction error, as it represents a simpler model, leaving more cognitive resources to the self-counselling task. This supports our previous interpretation that the contrast in clothing between the participant and the counsellor could have shaped perceptions by modulating the complexity of the predictive model.

When we combine this with the findings about the CS condition, it could be argued that the brain's predictive processes were more accurate due to the representation's similarity to the participant's current self, leading to smaller prediction errors and better outcomes. This would explain why the CS condition led to more favourable outcomes than the FS condition and hints that self-similarity might play an important role during the virtual self-counselling paradigm. The results suggest that the future self-counselling interventions might benefit from finding ways to further minimizing the prediction errors between the counsellor and the current perception of oneself to increase efficiency of the intervention.

In the following section, we will present our findings that explore a similar VR self-counselling framework in addiction research. Specifically, we will discuss a self-counselling study concerning nicotine dependence, draw comparisons with the personal problem-solving self-counselling study, explain methodological differences, introduce the results, and deliver a discussion. Towards the end of this chapter, finally, we will provide a general discussion of both studies surrounding VR self-counselling.

6.3 Experiment 2: Self-dialogue with a virtual future self about nicotine dependence

This section will present our study, which focuses on utilising virtual reality (VR) self-counselling to address nicotine dependence. The details of our research proposal were previously published in our short paper titled "Conversation with your future self about nicotine dependence" (Senel & Slater, 2020). Furthermore, we presented our preliminary findings, which specifically involved our population as hospital employees from Hospital Clinic Barcelona, through a scientific poster titled "Self-dialogue with Virtual Future Self about Nicotine Dependence: Preliminary Results" (Senel, Swidrak, Bario-Gimenez, Lopez-Pelayo, Mondon, Spanlang & Slater, 2022) at the University of Barcelona's Multibrain Congress.

Tobacco use continues to pose a significant health problem, causing eight million deaths yearly (WHO, 2023). In Spain, 24% of the population indicated smoking in 2020, while 22%

reported daily smoking (AECC, 2021). The age groups with the highest proportion of smokers include individuals between 25 and 35 years old, closely followed by the age group of people between 45 to 54 years old (AECC, 2021). The Spanish Ministry of Health, Public Health Commission, states that smoking remains the primary cause of morbidity and mortality in Spain, with an estimated average of 51,870 deaths yearly (Comisión de Salud Pública, 2019). Previous studies have also shown that smoking hospital employees underestimate the health risks associated with smoking and have significantly different perceptions of smoking as a risk factor compared to non-smokers (Willing & Ladelund, 2004).

Additionally, incorporating training in tobacco cessation, using a shared software system and providing free access to pharmacological treatments as part of the Catalan Network of Smoke-free Hospitals has demonstrated the feasibility and success of smoking cessation programs (Martinez et al., 2012). A systematic review of smoking cessation methods suggests that Nicotine Replacement Therapy, Champix, and training for quitting smoking are the most recommended approaches for smoking cessation (Heydari et al., 2014). However, in another review, adverse events regarding these therapies were reported by young persons who are receiving pharmacotherapies (Stanton & Grimshaw, 2013).

One of the barriers to quitting smoking lies in the difficulty individuals face in recognising the long-term detrimental effects of smoking (Murphy-Hoefer et al., 2004). Since the harm caused by smoking accumulates gradually over time, the risks involved are often overlooked and underestimated (Arnett, 2000; Masiero et al., 2015). This inclination to devalue future outcomes compared to immediate rewards is called delay discounting or temporal discounting.

When individuals are presented with choices involving monetary gains over different timeframes, they tend to discount the value of gains that are further in the future. This discounting effect is particularly pronounced regarding health outcomes (Chapman, 1996; Chapman & Elstein, 1995), indicating a general tendency to underestimate the importance of long-term health-related decisions. Studies have also demonstrated that smokers exhibit higher levels of temporal discounting than non-smokers (Kollins, 2003; Bickel et al., 2008). However, this effect has been shown to reverse as the number of cigarettes smoked decreases (Yi et al., 2008). Furthermore, research has indicated that engaging in positive envisioning of personal future events, known as episodic future thinking, can reduce cigarette smoking and temporal discounting (Stein et al., 2016).

Our perception of our potential future selves, including our hopes, fears, goals, and threats, significantly impacts our current self-image and serves as an incentive for our future behaviour (Markus &Nurius, 1986). For instance, the results of a longitudinal study in which the data was obtained 23 years apart indicated that those individuals who demonstrated positive self-perceptions of ageing lived, on average, 7.5 years longer compared to those who did not have positive perceptions of ageing (Levi et al., 2002).

For these reasons, our current study examined the influence of various virtual bodies representing future selves on nicotine dependence. Virtual reality (VR) has proven to be a valuable tool for understanding, assessing, and treating mental disorders, including addictions (Freeman et al., 2017). While cue-exposure therapy is the most commonly used VR technique for therapeutic purposes in nicotine dependence and alcohol use disorders (Lee et al., 2003; Lee et al., 2004; Moon et al., 2009), which involves repeated exposure to substance-related cues to diminish the association between those cues and subjective craving as well as physiological responses (Heather & Bradley, 1990; Heather & Greeley, 1990), the impact of VR self-counselling on smoking cessation has not been previously investigated.

Furthermore, in a previous study, the future self-continuity approach was found to be less effective than the gender-matched generic-looking counsellor condition. However, a study regarding health outcomes by integrating a future self-continuity approach demonstrated that future self-continuity could increase exercise and health behaviours (Rutchick et al., 2018). Also, research on episodic future thinking, a way of prospection, indicated that it reduces delay discounting and the number of cigarettes smoked (Stein et al., 2016). Considering the focus of our current study on health-related outcomes rather than daily life problems, it was anticipated that different self-representations would have a more substantial impact. Therefore, we proposed that using the future self-continuity approach in virtual reality for addiction remains under-researched but promising.

The primary objective of this study was to investigate our fourth and final hypothesis, which was: "*Having a self-conversation about nicotine dependence by swapping between two virtual bodies, explaining the situation from a present-day lookalike body, and swapping bodies with a counsellor representation of different future selves, will help participants to decrease their behavioural and physical nicotine dependence scores*".

Based on our study design and the hypothesis, we anticipated several outcomes. Firstly, participants who engaged in a self-dialogue with their future selves, specifically in the Future Self Non-Smoking or Future Self Smoking conditions compared to the Current Self condition, were expected to exhibit a reduction in their Stages of Change related to smoking. Secondly, we expected that participants in the Future Self Non-Smoking or Future Self Smoking conditions would experience a decrease in their levels of physical nicotine dependence, as assessed by measures such as the Fagerström Test for Nicotine Dependence (Heatherton et al., 1991), Timeline Followback (TFB) Method Assessment for smoking (Robinson et al., 2014), and biochemical verification (Benowitz et al., 2020). Additionally, we anticipated a decrease in levels of behavioural dependence, as measured by the Glover-Nilsson Smoking Behavioural Questionnaire (Glover et al., 2005), for participants in future self conditions. Moreover, we predicted an increase in future-self continuity for the participants in the future self conditions, which would result in reducing physical nicotine dependence. Comparatively, we expected that the Future Self Non-Smoking condition would positively impact participants' physical and behavioural dependence scores and their Stages of Change related to smoking compared to the Future Self Smoking condition. Furthermore, significant differences were anticipated between the groups at different assessment points for variables, including impact and perspective. Lastly, we expected the most significant change in the Stages of Change related to smoking to be observed among participants who previously had a low level of physical dependence across all conditions.

6.3.1. Materials and Methods

As explained in Experiment 1, we also used the same materials for Experiment 2. These materials included the Meta Quest 1 headset with its controllers, the ConVRSelf application developed by Virtual Bodyworks, the Character Creator 3 (CC3) software from Reallusion for creating virtual bodies. The necessary safety protocols for disinfecting the Meta Quest 1 headset and controllers were also followed.

6.3.1.1. Participants

In this study, we initially recruited 20 participants who worked at the Hospital Clinic Barcelona for the experiment (N=17 F, 3 M, mean Age: 39, Median Years of Smoking: 10+). Participants received 20 euros as a gratitude for their time to participate in our study. However, due to challenges with recruitment limited to hospital workers, we expanded the study to the general public and offered 60 euros to thank participants for their time. We extended the study and recruited 13 more participants to a total of 33 participants (N=25 F, 8 M, mean age: 34.78, median years of smoking: 10+ years).

The inclusion criteria for participants included being between 18-60 years old, being cigarette smokers, having smoked at least 100 cigarettes in their lifetime, and falling into the pre-contemplation, contemplation, or preparation stages of smoking based on the Stages of Change measure.

Exclusion criteria were also implemented, including having epilepsy or post-traumatic stress disorder, taking psychoactive medication (such as antidepressants, anxiolytics, antipsychotics, certain muscle relaxants, and antiepileptic drugs), consuming alcohol within 6 hours prior to the experiment, engaging in driving or operating dangerous machinery immediately after the VR experience, having an ongoing COVID-19 infection, and scoring lower than 13 on the WHO-5 Well Being Index. Participants scoring lower than 13 on the index were referred to their local healthcare system for further counselling.

All collected data were stored separately from participants' personal information to ensure confidentiality and privacy.

6.3.1.2. Experimental Design

A between-group experimental design was employed for this study to randomly assign participants to one of three different conditions: Future Self Non-Smoking, Future Self Smoking, and Current Self (Table 6.13). The study was designed as a controlled study with parallel comparison groups, including the Future Self Non-Smoking and Future Self Smoking conditions as the experimental conditions, to test the effectiveness of the future-self continuity approach. In contrast, the Current Self condition served as the control condition. We expected participants to show changes in their smoking habits, even under the Current Self condition, so this condition was evaluated as an active control.

Table 6.13. Summary of the experimental conditions.

Experimental Condition	**Virtual counsellor and instructions**
Current Self	Participants were informed that the virtual counsellor sitting in front of them in the virtual environment represent their own current selves.
Future Self Non-Smoking	Participants were informed that the virtual counsellor sitting in front of them in the virtual environment would be that of a future self who had quit smoking 20 years priorly. The virtual counsellor represented a computer graphics rendering of a possible healthy-looking future self.
Future Self Smoking	Participants were informed that the virtual counsellor sitting in front of them in the virtual environment would be that of a future self who never quit smoking. The virtual counsellor represented a computer graphics rendering of a possible unhealthy-looking future self.

Depending on the randomly assigned condition, participants went through one of the three conditions (Figure 6.20). In the Current Self (CS) Condition, participants engaged in self-dialogue with a virtual counsellor who closely resembled their current self. They discussed their current smoking habits, their feelings about smoking, and the reasons for their continued smoking behaviour. In addition, in the Future Self Non-Smoking (FSNS) Condition, participants interacted with a virtual counsellor who represented their future self, having successfully quit smoking 20 years prior. Through virtual embodiment exercises and interactions, participants asked their future self-counsellor questions about their smoking cessation journey, how they felt about quitting, and the strategies they used to remain smoke-free over the years. Lastly, participants in the Future Self Smoking (FSS) Condition, had a self-conversation with a virtual counsellor who represented their future self and had never quit smoking. Similar virtual conversations took place, but the focus shifted to discussing the effects of smoking on their health, the financial impact of smoking over the past 20 years, and the impact of smoking on their relationships.

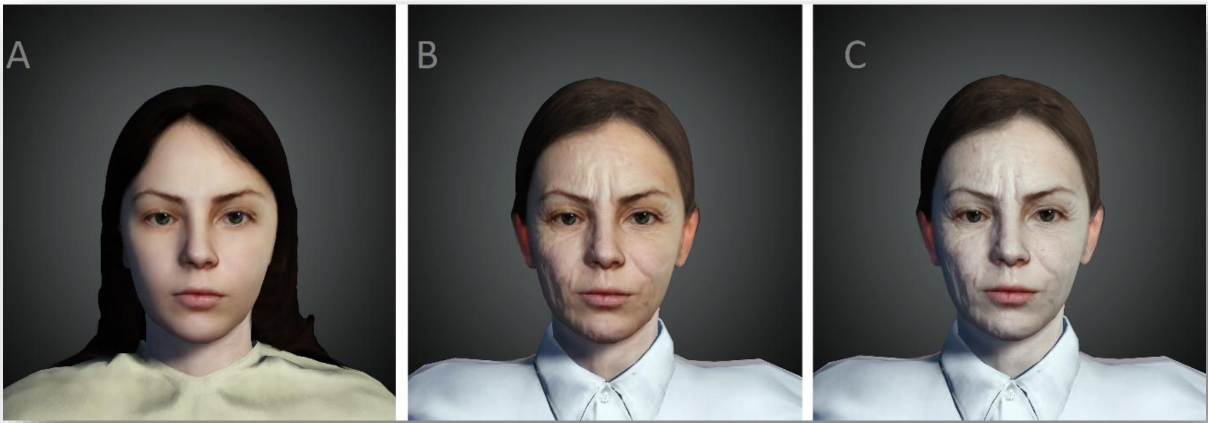

Figure 6.20.Experimental Conditions. A) *Current Self* ***B)*** *Future Self Non-Smoking* ***C)*** *Future Self Smoking*

The appearance of the Future Self Non-Smoking (FSNS) and Future Self Smoking (FSS) conditions did not show important differences; the only distinction was the skin texture of the future self body, with the FSS condition displaying a sicker appearance compared to the

FSNS condition. The reason behind this design was to investigate the difference between these conditions not based on the appearance but rather on the instructions given to participants regarding the version of their future self with whom they would engage in self-dialogue. In the FSNS condition, participants interacted with a future self who had successfully quit smoking, while in the FSS condition, participants engaged with a future self who continued to smoke. This approach allowed us to focus on the conceptual differences between the conditions rather than relying solely on appearance. By investigating these three different conditions, the study aimed to gain insights into the impact of future self-representations through virtual counsellors on smoking-related outcomes and behavioural change.

6.3.1.3. Experimental Procedures

The experiment took place at two locations: the Instituto de Investigaciones Biomédicas August Pi i Sunyer (IDIBAPS), Hospital Clinic Barcelona, and Event Lab, Universitat de Barcelona. Participants were assigned an identifier (ID) number, and all subsequent data were stored based on this ID, ensuring that no document contained both the participants' ID number and their name.

The experiment consisted of four sessions, with the first session lasting approximately 15 minutes, the second session lasting about 50 minutes, and the third and fourth sessions each lasting around 25 minutes. All sessions, except the fourth session, were scheduled one week apart from each other. The second session, which was the VR session, occurred one week after the first session, and the third session took place one week after the second session. The fourth session, which served as a follow-up session, happened one month after the VR session.

Like Experiment 1, participants were assigned anonymous ID numbers, and interested participants underwent assessments before participating in the WHO-5 Well-Being Index (WHO, 1998; Topp et al., 2015), which measured their general well-being. Participants who obtained a raw score higher than 13 on the WHO-5 Well-Being Index and expressed their willingness to participate in the study proceeded to complete a demographic information questionnaire and the Future Self Continuity Scale (Ernsner-Hershfield, 2009). Concerning smoking dependence, participants were administered the Stages of Change questionnaire (Prochaska, 1993) to assess their readiness to change their smoking behaviour. Additionally, a semi-structured interview was conducted to gather information about their smoking habits and to facilitate the creation of a problem definition regarding nicotine dependence. After the problem definition, like in Experiment 1, perspective variables were used to measure the impact of this interview. This approach allowed for a deeper understanding of participants' smoking behaviours and their motivation to make changes.

Participants who scored a raw score below 13 were not recruited for the following session. They were advised to seek better counselling options through their local healthcare service, and relevant contact information was provided. In the first session, participants were also requested to provide front-facing and full-body images of themselves, which were necessary to create their 3D virtual bodies, following a similar procedure as in Experiment 1.

A week later, participants came to the laboratory for the second session, which involved the Virtual Reality (VR) experience. Before this session, the ConVRSelf application with personalised virtual bodies generated with the CC3 and Unity software had been prepared for the Meta Quest Headset. Participants were requested to fill out several assessments related to nicotine dependence. The Fagerström Test for Nicotine Dependence (Heatherton et al., 1991) and the Timeline Followback (TFB) Method Assessment (Robinson et al., 2014) were utilised to evaluate physical nicotine dependence. In addition, the Glover Nilsson Smoking Behavioural Questionnaire (Glover et al., 2005) was administered to measure behavioural dependence on smoking. These measures provided valuable insights into the participants' physical and behavioural dependence levels on nicotine.

After completing these questionnaires, we provided a detailed explanation of each step involved in the VR procedure and presented participants with an overview of how the VR system operated, including instruction videos.

Once participants were ready, the VR session began. In the virtual room scene, participants observed their virtual bodies, which closely resembled their real-life appearance, as they sat in a chair from a first-person perspective. Additionally, they could see another virtual body representing the assigned condition positioned in front of them. Subsequently, participants engaged in embodiment exercises, performing simple movements as instructed by the application.

Based on their randomly assigned conditions (Future Self Non-Smoking, Future Self Smoking, and Current Self), participants initiated a self-conversation with the virtual counsellor body corresponding to their assigned condition. They began the conversation by posing a question related to nicotine dependence to the counsellor in front of them, which was determined during the first session following the semi-structured interview.

Following the question, the body-swapping process was initiated, allowing participants to experience the virtual counsellor's body associated with their assigned condition. From the perspective of the counsellor body, participants provided free responses to the question. The body-swapping process continued as long as participants felt it was necessary.

Upon completing the self-dialogue, participants concluded the session by quitting the application and concluding the experiment. The procedure in the virtual reality session is illustrated in Figure 6.21. After the VR session, participants were asked to write a short paragraph about their experience. Next, they completed questionnaires and scales, including VR response questions, perspective, impact variables, FSCS, and the System Usability Scale (Brooke, 1996; Peres et al., 2013). These assessments included their subjective experiences, continuity with future selves, and usability scoring of the software.

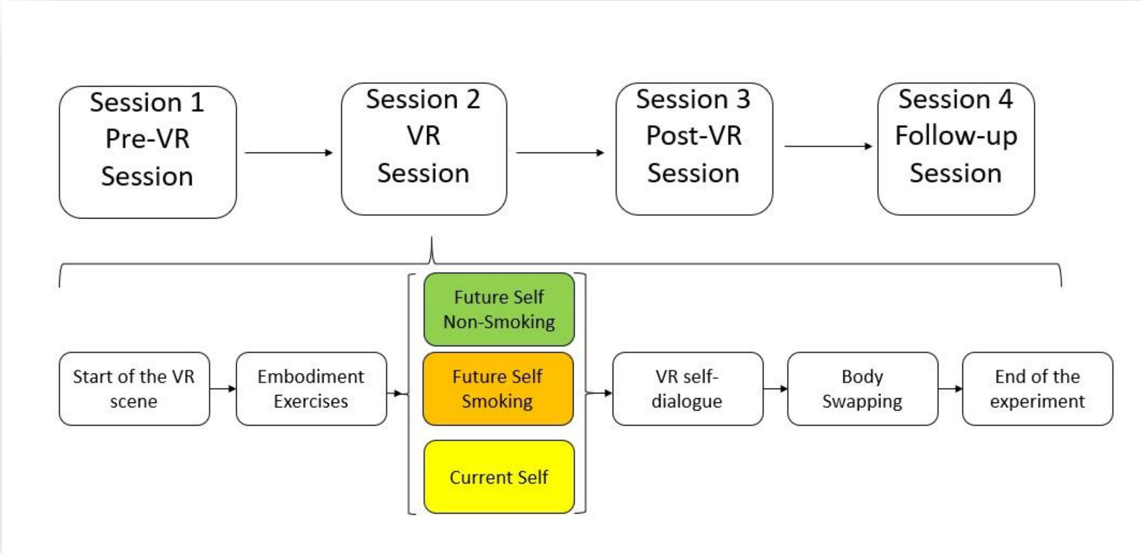

Figure 6.21. Procedure in virtual reality. *During the virtual reality (VR) session, participants were in the virtual room where they saw their own virtual body and a virtual body representing their assigned condition. They engage in embodiment exercises, performing simple movements while observing their virtual body in a mirror. They were randomly assigned to one of three conditions (Future Self Non-Smoking, Future Self Smoking, or Current Self). They initiated the self-conversation by asking the pre-defined question about nicotine dependence to the virtual counsellor in front of them. They then experience a body-swapping process, and from the counsellor's perspective, they listen to their own question and provide a free-form response. This body-swapping interaction can continue as long as desired. At the end of the session, participants exit the application, concluding the experiment.*

One week after the second session, the third session took place, and the participants were asked to complete the Future Self Continuity Scale, Stages of Change, Glover-Nilsson Smoking Behavioural Questionnaire, Fagerström Test for Nicotine Dependence, Perspective, and Impact questions again. They were also given open-ended questions to answer. One month after the third session, the fourth session was conducted as a follow-up session. The questionnaires administered during the fourth session were the same as those in the third session. During sessions 2, 3, and 4, exhaled carbon monoxide results were obtained from participants for biomarker verification to measure the levels of the change using the piCO™ Smokerlyzer® device (Bedfont Scientific Ltd, UK, https://www.bedfont.com/pico). This device is specifically designed to assess carbon monoxide levels in breath samples, providing an indication of changes in carbon monoxide levels between sessions. Table 6.14 explains the specific measurements, questionnaires, and scales administered during each session.

Table 6.14. Summary of the measurements, questionnaires, and scales per session.

Session 1: **Pre-VR session**	**Session 2:** **VR session**	**Session 3:** **Post-VR session**	**Session 4:** **Follow-up session**
- Information sheet (Day 1) - Consent form - Front-facing and full-body pictures - Demographics questionnaire - WHO-5 Well Being Index - Future Self Continuity Scale - Stages of Change - Semi structured interview about smoking habit - Problem definition - Impact questions	- Information Sheet (Day 2) - Biomarker verification - Fagerström Test for Nicotine Dependence - Timeline Followback (TFB) Method Assessment - Glover-Nilsson Smoking Behavioural Questionnaire - Virtual Reality (VR) -Short paragraph about the VR experience - VR response questions - Impact questions - Perspective questions	- Biomarker Verification - Stages of Change - Future Self Continuity Scale - Fagerström Test for Nicotine Dependence Timeline Followback (TFB) Method Assessment - Glover-Nilsson Smoking Behavioural Questionnaire - Impact questions - Perspective questions - Open-ended questions about the past week	-Biomarker Verification -Stages of Change - Future Self Continuity Scale - Fagerström Test for Nicotine Dependence Timeline Followback (TFB) Method Assessment - Glover-Nilsson Smoking Behavioural Questionnaire - Impact questions - Perspective questions - Open-ended questions about the past month

In the following section, we will present the response variables and provide details about the measurements administered in this study.

6.3.1.4. Response Variables

Experiment 2 included some of the response variables utilised in Experiment 1 and additional variables related to nicotine dependence. The common response variables included the VR response measures, Future Self Continuity Scale, and the perspective variables. Furthermore, the modified version of the impact variables, which were adapted for the smoking context, is displayed in Table 6.15.

Table 6.15. The impact variables.

Impact	
importance	What is the level of importance of your nicotine dependence in your current life? 0=Not at all 1=Slightly 2=Moderately 3=Very 4=Extremely
discomfort	What is the level of discomfort induced by your nicotine dependence in your current life? 0=It does not disturb or affect me 1=It disturbs or affects me slightly 2=It moderately disturbs or affects me 3=It disturbs or affects me a lot 4=It disturbs and incapacitates me greatly
help	How much did the intervention help you as regards to your smoking dependence? 0=Not sure 1=Made things a lot worse 2=Made things somewhat worse 3=Made no difference 4=Made things somewhat better 5=Made things a lot better
change	How important or significant to you personally do you consider changing your nicotine dependence? 0=Nothing important 1=A bit important 2=Moderately important 3=Very important 4=Extremely important
different	Are you doing, feeling, or thinking differently about your nicotine dependence from the way you did before? 1=yes 0=no

In addition, the Stages of Change measure was used to categorise participants into different stages of smoking change. This measure was based on the transtheoretical model (DiClemente et al., 1991; Prochaska et al., 1993) and included the stages of pre-contemplation, contemplation, preparation, action, and maintenance, as illustrated in Table 6.16. These stages represent the progression of behaviour change, with pre-contemplation encompassing individuals who have no intention to quit smoking, contemplation involving those considering quitting within the next 6 months, and preparation involving individuals planning to quit within the next 30 days. The action and maintenance stages consist of individuals who have already quit smoking. For this study, participants in the pre-contemplation, contemplation, and preparation stages were recruited. It was expected that participants would potentially shift across these stages after the experiment, indicating changes in their smoking behaviour and readiness to quit.

Table 6.16. Stages of Change of Smoking

Stages of Change	**Interpretation**
precontemplation	Individuals with no intention to quit smoking.
contemplation	Individuals considering quitting within the next 6 months.
preparation	Individuals planning to quit within the next 30 days.
action	Individuals who have already quit smoking.
maintenance	Individuals who have successfully maintained smoking cessation.

Some of the response measures collected in this study focused on assessing physical nicotine dependence. The Fagerström Test for Nicotine Dependence (Heatherton et al., 1991) was employed as a standard 6-item measure to evaluate participants' physiological dependence and withdrawal symptoms associated with nicotine addiction. This measure has been widely used in research settings. To examine its applicability to the Spanish population, a Spanish adaptation of the Fagerström Test for Nicotine Dependence, which was validated by Becoña and Vazques (1998). The Spanish adaptation demonstrated acceptable internal consistency (Cronbach's α = 0.66), and analysis across different groups indicated its usefulness in identifying varying levels of nicotine dependence within the Spanish population. The scores obtained from the Fagerström Test for Nicotine Dependence (Table 6.17) are interpreted as follows: 0-4 points indicating low dependence, 4-6 points indicating medium dependence, and 7-10 points indicating high dependence. Throughout the study, participants' scores on this measure were anticipated to exhibit changes, reflecting alterations in their physical dependence on nicotine. Furthermore, the Timeline Followback (TFB) Method Assessment (Robinson et al., 2014) was utilised to gather quantitative estimates of smoking behaviour, specifically focusing on participants' smoking habits. This method, originally developed by Sobell et al. (1996) to assess drug, cigarette, and marijuana use, was employed in this study to collect detailed information about participants' smoking behaviour.

Table 6.17. The Fagerström Test for Nicotine Dependence

physical dependence	**scores**
low dependence	0-4 points
medium dependence	4-6 points
high dependence	7-10 points

For assessing behavioural dependence on smoking, we collected response outcomes from the Glover-Nilsson Smoking Behavioural Questionnaire (Glover et al., 2005). This unidimensional scale comprises 11 items and aims to capture the behavioural addiction associated with smoking. The questionnaire was initially developed with 18 questions; however, similar questions were eliminated, resulting in the final 11-item version. Internal consistency analysis demonstrated satisfactory reliability (Cronbach's $\alpha = 0.82$). Additionally, the questionnaire was found to be a significant predictor of craving levels ($\beta = .476$, $p < .001$) and showed no correlation with the Fagerström Test for Nicotine Dependence, indicating a clear distinction between behavioural and physical dependence (Rath et al., 2013). Previous studies have employed this questionnaire with the Spanish population to assess behavioural dependence and explore its relationship with smoking cessation (Nerin et al., 2005). The scores obtained from the Glover-Nilsson Smoking Behavioural Questionnaire (Table 6.18) can be classified as follows: <12 indicating mild behavioural dependence, 12-22 indicating moderate behavioural dependence, 23-33 indicating strong behavioural dependence, and >33 indicating very strong behavioural dependence. In this study, we expected to observe changes in the behavioural dependence scores of the participants as a consequence of the VR self-counselling.

Table 6.18. Glover Nilsson Smoking Behavioural Questionnaire (GN-SBQ)

behavioural dependence	**scores**
mild behavioural dependence	less than 12 points
moderate behavioural dependence	between 12-22 points
strong behavioural dependence	between 22-33 points
very strong behavioural dependence	more than 33 points

Furthermore, as part of our data collection, we implemented biomarker verification to assess smoking status by measuring exhaled carbon monoxide levels. This method has been suggested to offer a straightforward, safe, non-invasive, and swift evaluation of individuals' smoking habits (Sandberg et al., 2011). Before the measurement, a clean cardboard mouthpiece was securely attached to the breath analyser. Participants were instructed to inhale and hold their breath for 15 seconds. Subsequently, they were guided to exhale slowly and fully through the mouthpiece once the machine emitted a beep, ensuring complete lung evacuation. Exhaled breath carbon monoxide levels exhibit a notable distinction between non-smokers and smokers, making it a valuable indicator, even when individuals deny current smoking (ranging from 7.5 to 42 parts per million) (Middleton & Morice, 2000). To perform this assessment, we used the piCO™ Smokerlyzer® device, a commonly employed device to measure exhaled carbon monoxide levels.

Finally, participants' responses to open-ended questions were also gathered. Please refer to Table 6.19 for a demonstration of these variables. These open-ended general questions about smoking habits were based on some questions indicated in the motivational enhancement therapy manual (Miller, 1992). However, this thesis did not include the analysis of this qualitative data.

Table 6.19. Qualitative data collection.

variable	**question**
interview	Interview before problem definition. Please answer these questions briefly. What are your expectations of this experience? How did you first start smoking and how long have you been smoking? What kinds of thoughts, emotions or activities trigger smoking? What are the cravings and withdrawal symptoms you experience when you can't smoke or try to quit? What are your reasons for smoking? What are your concerns about smoking? What are your reasons for wanting to quit smoking? What are your concerns about quitting smoking? What are the advantages of smoking cigarettes for you? What are the disadvantages of smoking cigarettes for you? What would your life be like if you had not started smoking? What would your life be like if you stopped smoking?
problem_definition	Define the context of the problem that causes the smoking behaviour in your daily life. Let's summarise your problem in a single sentence structured like this: "When (express the situation, what happens)... I feel (What feelings, emotions, physical sensations come to you when this situation occurs, and when you have these thoughts?).... I think (express the thoughts that come to your mind when this situation occurs)... I act/react/do (how do you react, what do you do or say?).... and I would like to (What is your goal? What would happen if you didn't have this problem? How would you handle the situation if you didn't have this problem?)...". Write your own definition below with this structure: "When... I feel... .... I think... I act/react/do.... and I would like to...".
comments_after_vr	Please now write a short paragraph paying attention to the following points: Thoughts/feelings about the conversation. Having a first/third person perspective. Aspects of the conversation that you like and dislike. Anything else you would like to comment on.

	(It would be helpful if your response could be at least 20 words long without including copying the above sentences).
one_week_after_vr	What kind of thoughts, emotions or activities triggered your smoking during the last week? What were the benefits of smoking cigarettes for you during the last week? What were the disadvantages of cigarette smoking for you during the last week? What were the cravings and withdrawal symptoms you experienced during the last week? Did you notice any other changes related to your smoking during the last week? Please write if you have other opinions or comments.
one_month_after_vr	What kind of thoughts, emotions or activities triggered your smoking during the last month? What were the advantages of cigarette smoking for you during the last month? What were the disadvantages of cigarette smoking for you during the past month? What were the cravings and withdrawal symptoms you experienced during the past month? Did you notice any other changes related to your smoking during the past month? Please write if you have any other opinions or comments.

The results of our study are presented in the subsequent section.

6.3.2. Results

6.2.2.1. Demographic variables

The demographic questions and participant responses are presented in Table 6.20. The analysis of demographic variables did not reveal any significant outcomes for the regression model fit. The distribution of participants across groups was found to be similar.

Table 6.20. Demographic questions and participant responses.

question	response	Current	Future Self Non-Smoking	Future Self Smoking
What is your gender?	Female	8	8	9
	Male	4	3	1
	Non-binary	0	0	0
	Other	0	0	0
What is your age?	Mean ± SD	32.83 ± 12.3	36.45 ± 10.9	35.30 ± 13.1
What is your occupation?	Student	11	13	10
	Employed part-time	3	0	2
	Employed full-time	3	2	2
	Self-employed	0	0	0
	Unemployed	0	2	3
	Retired	0	0	0
What is your level of education?	Secondary Education	2	0	0
	Professional Education	3	2	0
	Graduate Degree	3	3	0
	Postgraduate	3	3	9
	Doctorate	1	3	1
Do you speak Spanish fluently?	Yes	12	11	10
	No	0	0	0
Have you smoked at least 100 cigarettes in your life?	Yes	12	11	10
	No	0	0	0
Are you currently a smoker?	Yes	12	11	10
	No, I quit less than 6 months ago	0	0	0
	No, I have quit more than 6 months ago	0	0	0
	No, I have never smoked	0	0	0

How long have you been smoking cigarettes?	Less than 1 year 1-2 years 2-5 years 5-10 years More than 10 years	0 3 3 1 5	0 0 1 0 10	0 2 2 0 6
How much have you experienced VR before? *1 = never* *7 = a great amount*	Median (IQR)	2(2.5)	2(1)	1(0.75)
What is your level of knowledge of computer literacy? *1 = none* *7 = expert*	Median (IQR)	4(1)	5(1)	4(1)
What is your level of knowledge of computer programming? *1 = none* *7 = expert*	Median (IQR)	1(1.5)	1(1)	1(0)
How many times have you played video games in the past year?	0 times 1-5 times 6-10 times 11-15 times 16-20 times 21-25 times more than 25 times	3 4 0 1 2 1 1	1 6 2 1 0 0 1	2 5 2 0 0 0 1
How many hours have you played video games in the past week?	0 hours 1 hours 2-3 hours 3-5 hours 5-7 hours 7-9 hours more than 9 hours	7 3 1 1 0 0 0	9 0 2 0 0 0 0	7 2 0 0 1 0 0

6.2.2.2. VR response measures

We displayed the boxplot of the participants' responses to VR response outcomes in Figure 6.22. Like Experiment 1, a strong sense of body ownership and agency was observed among participants, as indicated by the median scores and the majority of the interquartile ranges being above 0. Participants expressed high levels of self-recognition for their virtual bodies. In addition, Kruskal-Wallis H test results demonstrated no significant differences between groups for the VR response variables.

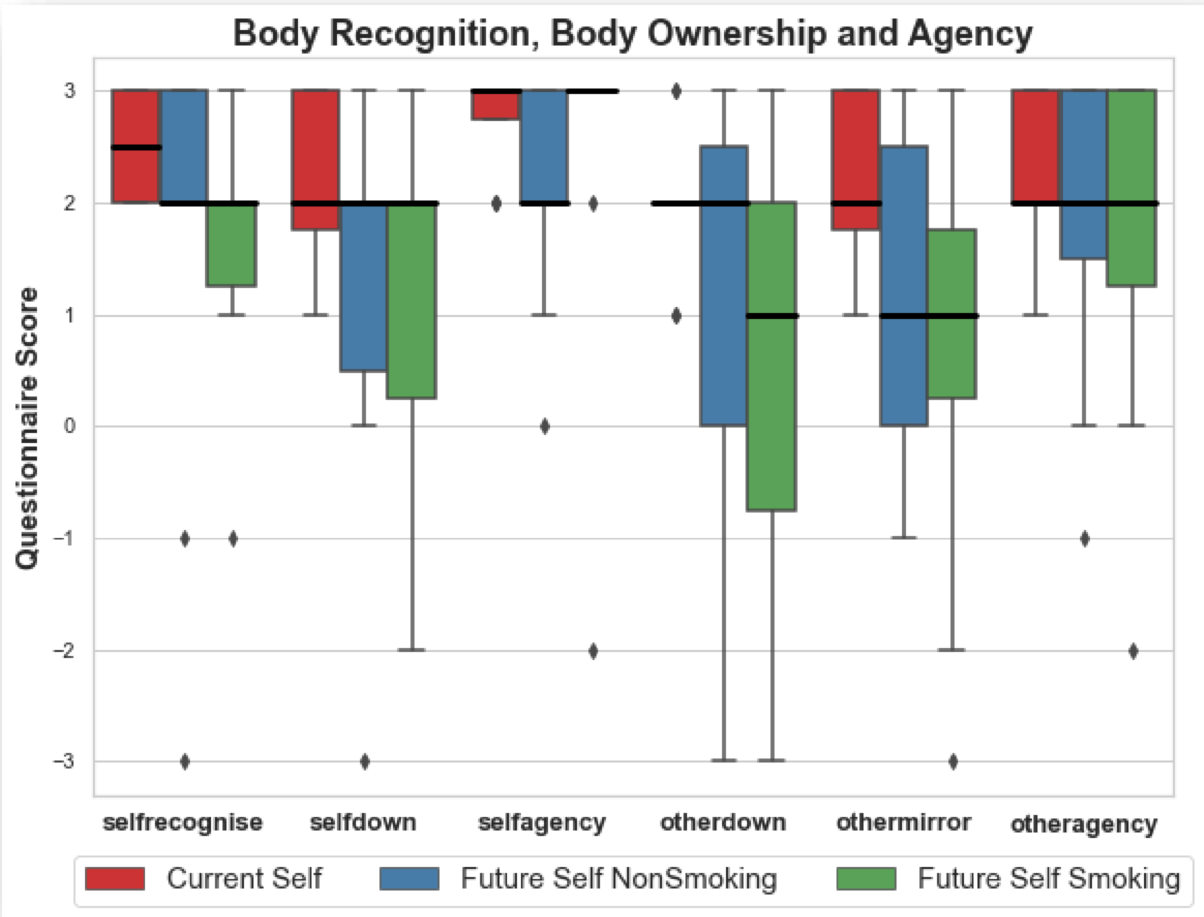

Figure 6.22. VR Response measures. *Body recognition, body ownership and agency between experimental conditions: Current Self, Future Self Non-Smoking, and Future Self Smoking.*

Regarding the age of the counsellor body, similar to Experiment 1, participants in both the Future Self Non-Smoking and Future Self Smoking conditions estimated the age of the counsellor to be approximately 20 years older than their own age. In contrast, participants in the Current Self condition estimated the counsellor's age to be closer to their own age. During the age calculation, one participant from the Future Self Non-Smoking condition and one from the Current Self condition were excluded due to missing numeric data. The average age of the counsellor body for each condition is presented in Table 6.21, and a boxplot illustrating the results after the exclusion is shown in Figure 6.23.

Table 6.21. The actual age of the participants and the estimation of the age of the counsellor's virtual body per condition.

Condition	**Mean ± SD of the actual age of the participants**	**Mean ± SD of the age of the participants after exclusion**	**Mean ± SD of the estimated age of the counsellor body**
Current Self	32.83 ± 12.38	30.72 ± 10.49	35.45 ± 9.80
Future Self Non-Smoking	36.45 ± 10.95	34.80 ± 9.99	56.40 ± 8.24
Future Self Smoking	35.30 ± 13.17	35.30 ± 13.17	53.30 ± 13.86

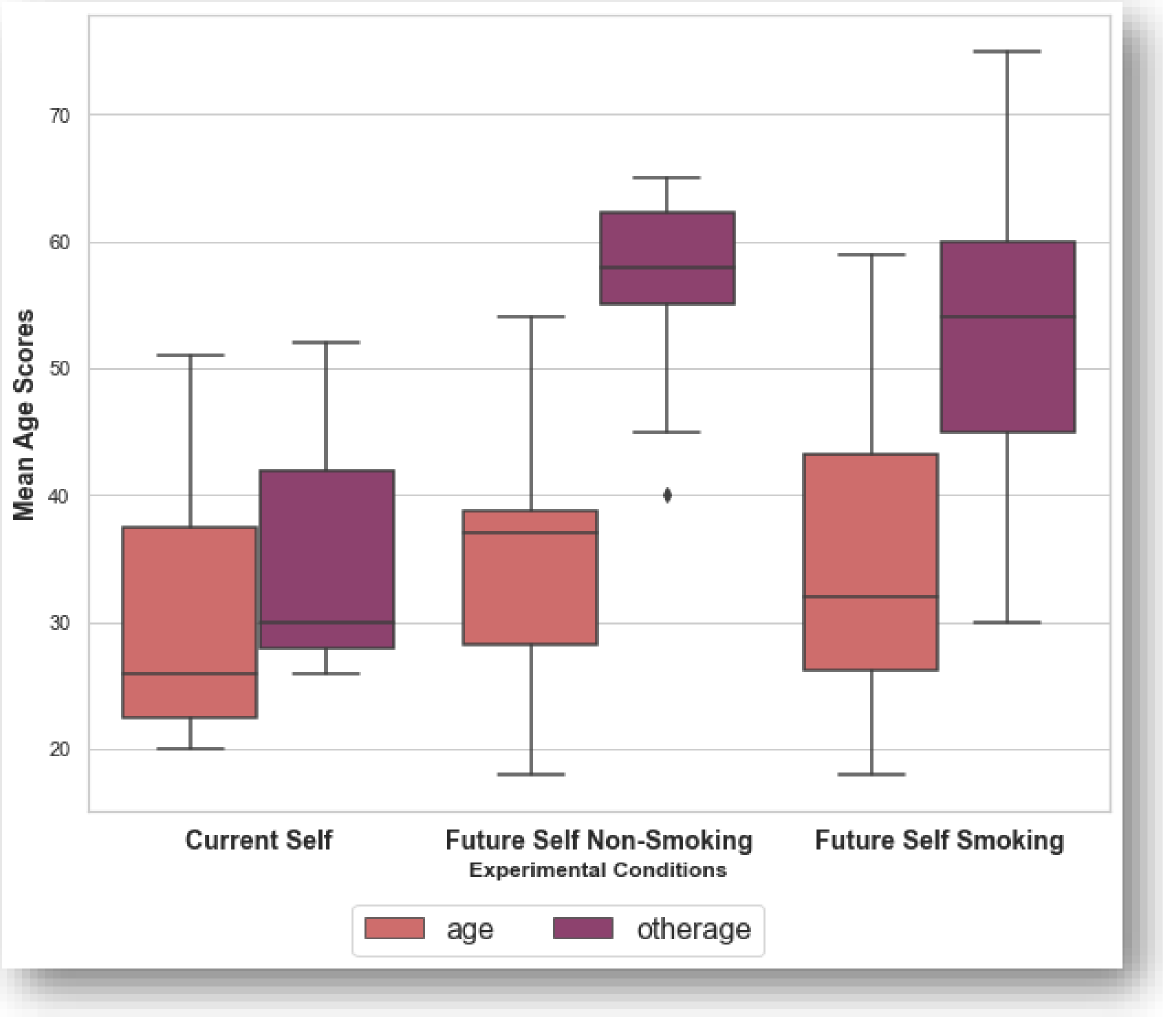

Figure 6.23. The mean of the actual age of the participants and the average estimated age of the counsellor body per condition. *Age variable represents the actual age of the participants while otherage variable represents the predicted age of the counsellor body.*

6.2.2.3. Future Self-Continuity

We collected responses from the Future Self Continuity Scale to explore the participants' perception of the relationship between their current and future selves. We conducted the Wilcoxon signed-rank test to examine the differences in this relationship across the experimental sessions for participants in the Current Self, Future Self Non-Smoking, and Future Self Smoking conditions.

Our findings revealed that participants in the Future Self Non-Smoking condition reported a significant increase in “similarity” to their future selves one week after the VR session (statistic = 4.0, $p = 0.006$, $p < 0.05$). However, no significant differences were observed for the other sessions in this condition. Additionally, participants in the Current Self condition showed a significant increase in similarity to their future selves between the after VR and one month after VR sessions (statistic = 4.0, $p = 0.02$, $p < 0.05$). The boxplot in Figure 6.24 displays the distribution of the similarity variable across the different conditions, providing a visual representation of the observed differences.

Figure 6.24.The boxplot of how “similar” participants felt to their future selves across conditions per session.

Moreover, the responses obtained from the participants in the Future Self Non-Smoking condition revealed a significant difference in the “like” variable between one week before VR and one week after VR sessions (statistic = 0.0, $p = 0.02$, $p < 0.05$). This indicated that participants' liking for their future selves increased significantly one week after the VR session.

However, no significant differences were observed for the liking variable in other sessions. Also, results from the participants in the Future Self Smoking condition showed significantly different liking scores for their future selves between the before VR and after VR sessions (statistic = 0.0, p = 0.02, p < 0.05), and a downward trend in liking was observed. The boxplot in Figure 6.25 provided a visual representation of the like variable between sessions and experimental conditions.

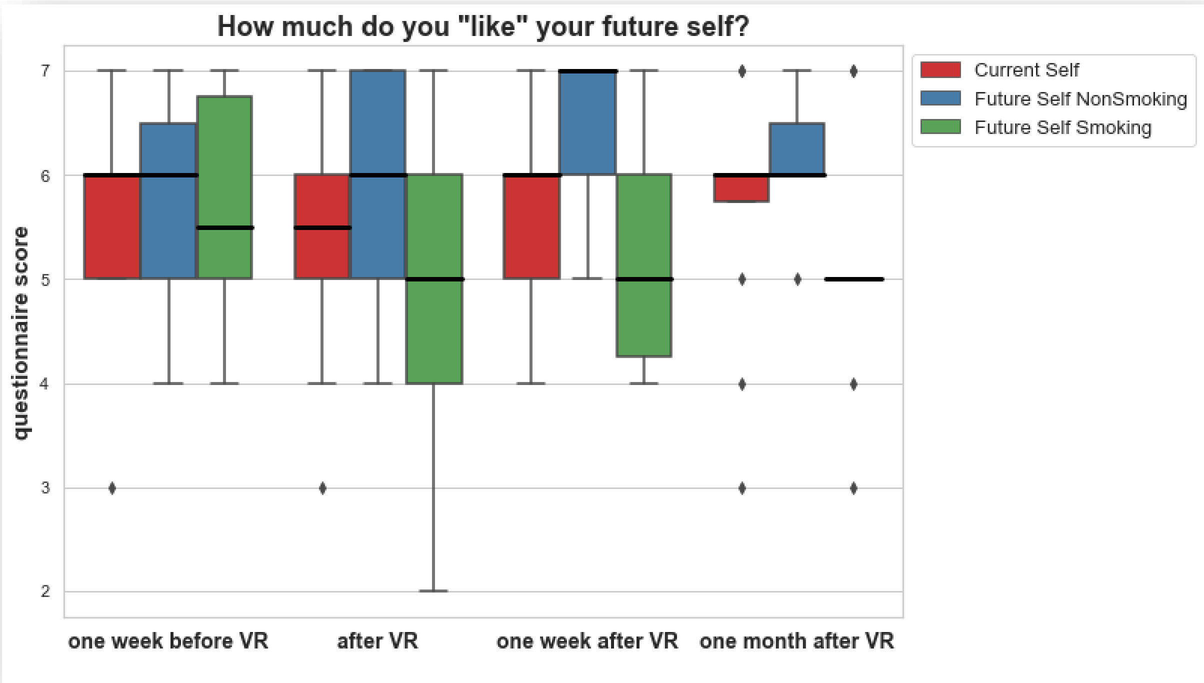

Figure 6.25.The boxplot of how much do participants "like" their future selves across conditions per session.

No significant differences were found between sessions across experimental conditions for the "connected" and "care" variables of the Future Self Continuity Scale. The boxplot of the "connected" and "care" variables was shown in Figure 6.26.

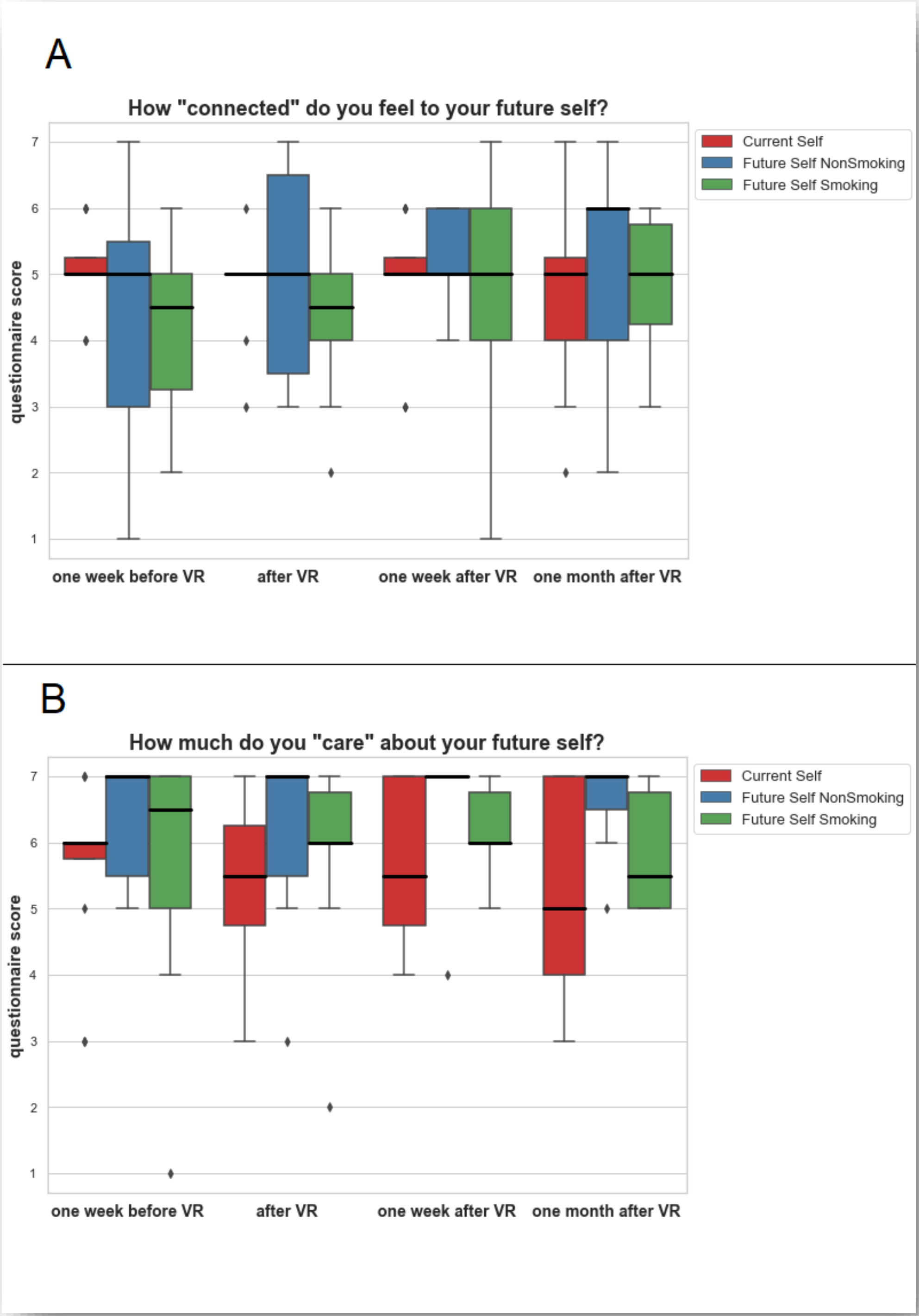

Figure 6.26. The boxplots of the "connected" and "care" variables of the Future Self Continuity Scale. A) *How "connected" participants felt to their future selves.* ***B)*** *How much participants "care" about their future selves.*

6.2.2.3. General Psychological Variables

In Experiment 2, similar to Experiment 1, we evaluated the "impact" and "perspective" general psychological variables. The impact variables were measured in all experimental sessions, which included the initial session one week before the VR session, the session immediately after the VR self-counselling intervention, one week after the VR session, and one month after the VR session. However, the perspective variables were only assessed during the VR session, one week after the VR session, and one month after the VR session.

To compare these variables across different conditions and sessions, we conducted Wilcoxon signed-rank test. However, the results did not reveal any significant differences in either the impact or perspective variables in Experiment 2. It is worth noting that we did not assess the perspective variables in the first session following the problem definition, and this missing data point might have influenced this study's outcomes. Therefore, in contrast to the previous study, we did not find significant differences in the perspective variables between the sessions.

Nonetheless, upon comparing the different experimental conditions, we discovered a significant difference solely in the fourth session (statistic = 6.56, p-value = 0.004, $p<0.05$) for the “importance” variable. This session occurred one month after the VR session and comprised the Current Self, Future Self Non-Smoking, and Future Self Smoking conditions. Remarkably, participants in the Future Self Smoking condition exhibited a reduction in the perceived importance of their nicotine dependence in their lives one month after the VR session. The plot illustrating the distribution of the "importance" variable can be seen in Figure 6.27.

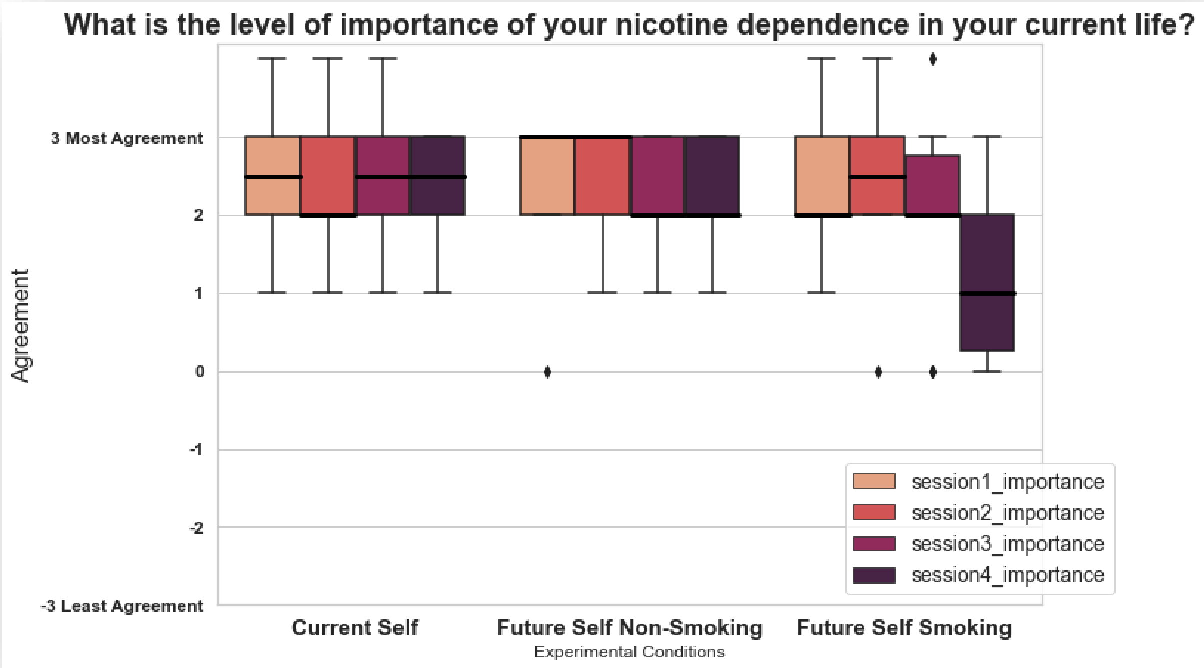

Figure 6.27. The boxplot of the level of importance of nicotine dependence in participants' lives across sessions per condition.

6.2.2.4. Physical Dependence to Nicotine and Cigarette Consumption

We evaluated participants' physical dependence on nicotine using the Fagerström Test for Nicotine Dependence and assessed their weekly cigarette consumption using the Timeline Followback method. Additionally, we measured exhaled carbon monoxide levels to quantify changes in cigarette consumption. These assessments were conducted at three specific time points: before the VR session, one week after the VR session, and one month after the VR session.

The mean scores obtained from the Fagerström Test for Nicotine Dependence were presented in Table 6.22. Across all groups, the mean scores across conditions indicated that participants had low levels of physical dependence on nicotine before the VR session. To compare the results between sessions within each condition, we conducted Wilcoxon signed-rank tests. Although the physical dependence scores in all conditions showed a decreasing trend after the VR session, as depicted in Figure 6.28, we did not find any significant differences between sessions for any of the conditions. Our results demonstrated that, in all conditions, both in before VR and one month after VR as well as one week after VR and one month after VR sessions, behavioural dependence scores were significantly different. However, no significant changes were observed for the before VR and one week after VR sessions.

Table 6.22. Participant scores for the Fagerström Test for Nicotine Dependence before the VR session across experimental conditions.

Experimental Condition	**Mean ± SD of the physical dependence before VR**	**Interpretation of the Score**
Current Self	3.0 ± 2.98	low dependence
Future Self Non-Smoking	2.4 ± 1.86	low dependence
Future Self Smoking	2.8 ± 2.2	low dependence

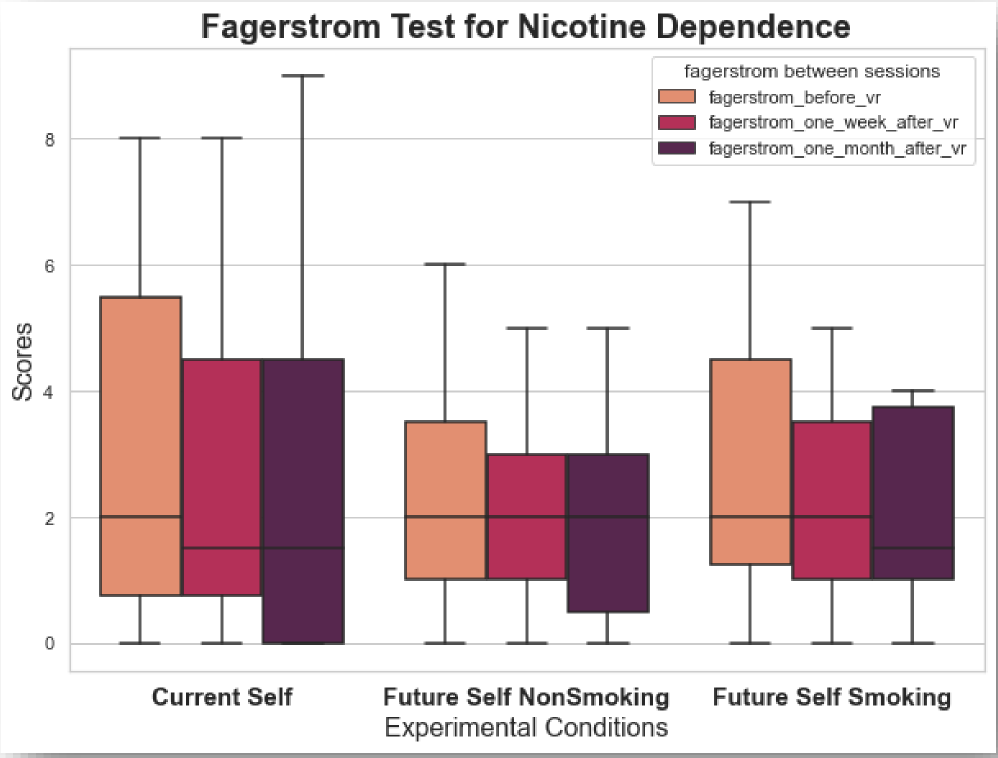

Figure 6.28. The boxplot of the Fagerström Test for Nicotine Dependence across sessions per condition.

The data obtained from the Timeline Followback (TFB) Method Assessment for smoking revealed that participants across all conditions reported an average weekly cigarette consumption of approximately 59-65 cigarettes before the VR session. However, significant differences in cigarette consumption were observed between sessions after the VR session in the Future Self Non-Smoking and Future Self Smoking conditions, while no significant differences were found in the Current Self condition. Specifically, there were significant differences in cigarette consumption between the before VR session and one month after VR session for both the Future Self Non-Smoking (statistic = 6.5, p-value = 0.03, $p < 0.05$) and Future Self Smoking (statistic = 3, p-value = 0.009, $p < 0.05$) conditions. Additionally, a significant difference was observed between the one week after VR session and one month after VR session for the Future Self Smoking condition (statistic = 2.5, p-value = 0.02, $p < 0.05$). These findings indicate a decrease in cigarette consumption following the VR session, which is depicted in the boxplot shown in Figure 6.29.

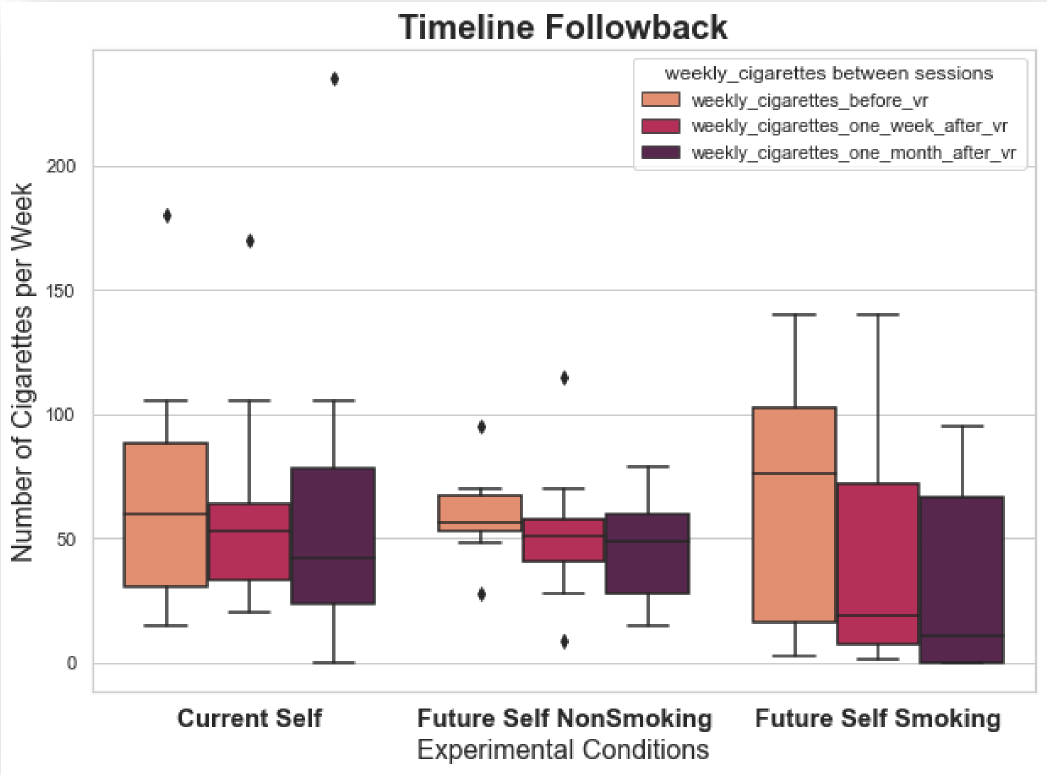

Figure 6.29.The boxplot of the number of cigarettes participants smoked per week across experimental conditions and sessions.

The analysis of biomarker verification using exhaled carbon monoxide (CO) levels in parts per million (ppm) revealed a significant difference between the before VR session and one month after VR session for the Future Self Smoking condition (statistic = 4.0, p = 0.04, $p<0.05$). However, no significant differences were observed for the Future Self Non-Smoking and Current Self conditions. The boxplot displayed in Figure 6.30 visually represents the differences between sessions and the decreased shift in CO levels specifically observed in the Future Self Smoking condition.

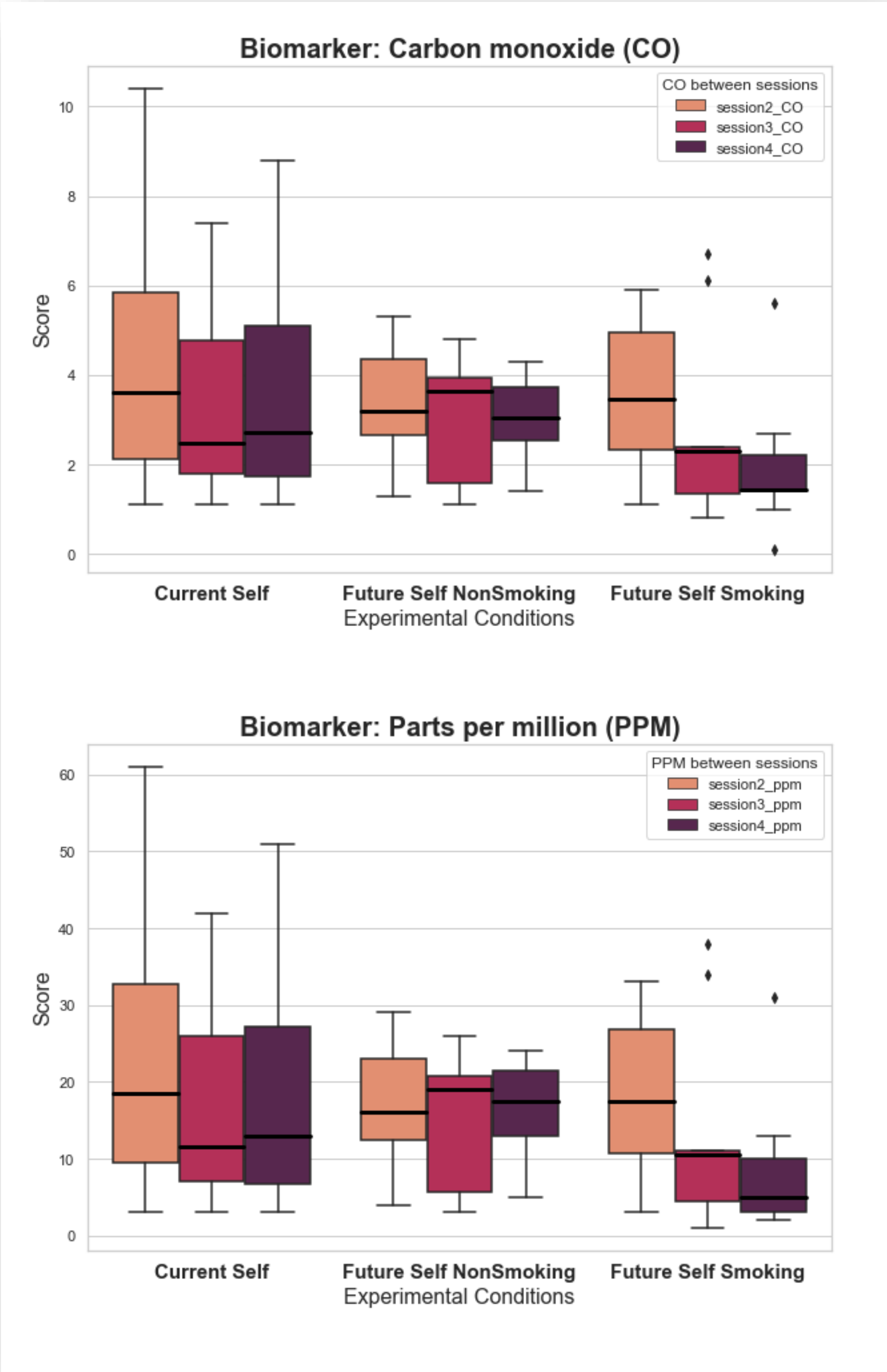

Figure 6.30.The boxplots illustrate the biomarkers, including carbon monoxide (CO) levels measured and parts per million (ppm) scores, across the different experimental conditions and sessions.

6.2.2.5. Behavioural Dependence to Nicotine

The Glover-Nilsson Smoking Behavioural Questionnaire was used to assess participants' behavioural dependence on nicotine. Similar to the assessment of physical dependence, behavioural dependence scores were collected at three time points: before the VR session, one week after the VR session, and one month after the VR session (corresponding to Session 2, Session 3, and Session 4, respectively).

Prior to the VR session, participants in all conditions exhibited moderate levels of behavioural dependence, with average scores ranging from 20 to 22. This indicates a significant level of behavioural dependence on nicotine before engaging in the VR self-counselling.

To examine the changes in behavioural dependence between sessions within each condition, we conducted pairwise comparisons using the Wilcoxon signed-rank test. The results revealed significant differences for all experimental conditions. Specifically, in the Current Self condition, there were significant differences between the before VR session and one month after VR session (Statistic = 3.0, p-value = 0.03, $p<0.05$), as well as between the one week after VR session and one month after VR session (Statistic = 9.0, p-value = 0.03, $p<0.05$). Similarly, in the Future Self Non-Smoking condition, there were significant differences between the before VR session and one month after VR session (Statistic = 8.0, p-value = 0.02, $p<0.05$), and between the one week after VR session and one month after VR session. In the Future Self Smoking condition, significant differences in behavioural dependence were observed immediately after the VR session, with significant results for the before VR session and one week after VR session (Statistic = 5.5, p-value = 0.04, $p<0.05$), as well as for the before VR session and one month after VR session (Statistic = 6.5, p-value = 0.03, $p<0.05$). The results of the Wilcoxon signed-rank test are presented in Table 6.23. Furthermore, the changes in behavioural dependence between conditions for each session are depicted in the boxplot shown in Figure 6.31. The figure illustrates the noticeable changes in behavioural dependence between the before VR session and one month after the VR session for all conditions, indicating a general decrease in behavioural dependence over time. Additionally, it highlights the specific decrease observed in the Future Self Smoking condition, suggesting a significant reduction in behavioural dependence on nicotine following the VR intervention.

Table 6.23. Wilcoxon signed-rank test results for the Glover-Nilsson Smoking Behavioural Questionnaire before the VR session across experimental conditions per session.

Experimental Condition	**Before VR & One Week after VR Sessions**	**Before VR & One Month after VR Sessions**	**One Week after VR & One Month after VR Sessions**
Current Self	Statistic =33.0, p-value = 0.67	Statistic =3.0, p-value = 0.03, p<0.05	Statistic =9.0, p-value = 0.03, p<0.05
Future Self Non-Smoking	Statistic =31.0, p-value = 0.89	Statistic =8.0, p-value = 0.02, p<0.05	Statistic =4.0, p-value = 0.006, p<0.05
Future Self Smoking	Statistic =5.5, p-value = 0.04, p<0.05	Statistic =6.5, p-value = 0.03, p<0.05	Statistic =24.0, p-value = 0.76

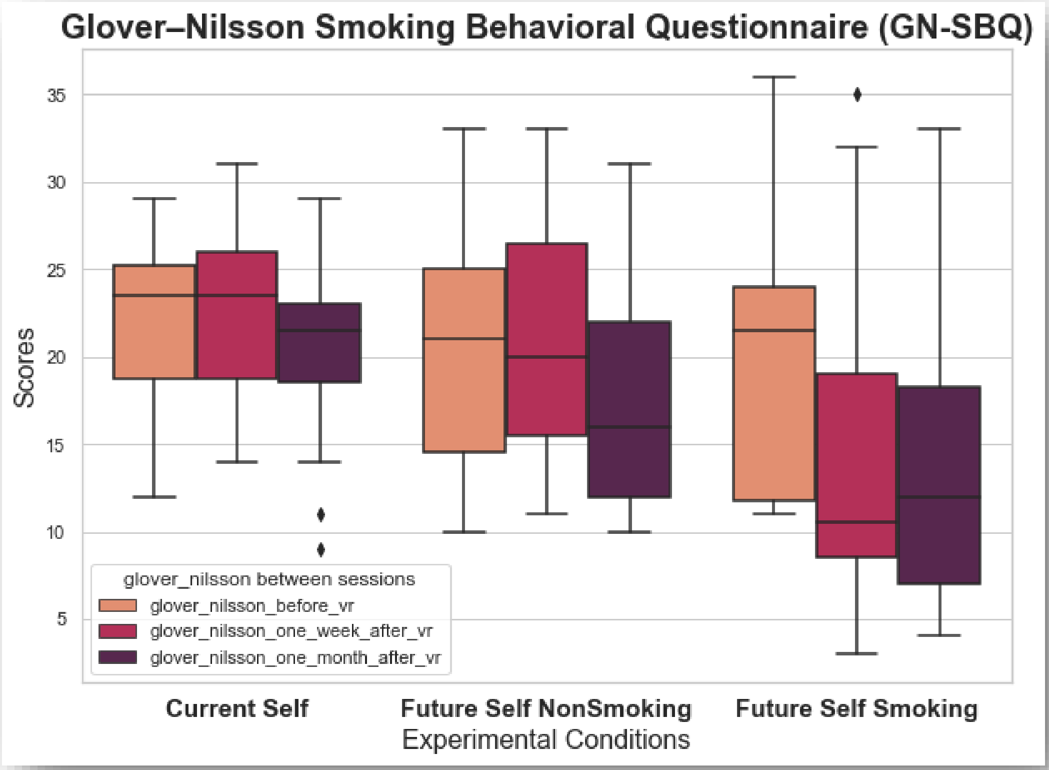

Figure 6.31. The boxplot of the Glover-Nilsson Smoking Behavioural Questionnaire per sessions across experimental conditions.

6.2.2.6. Behavioural Change

The Stages of Change model (Prochaska et al., 1993) was used to assess the progression of participants' smoking behaviour change throughout the study. This evaluation was conducted at three distinct time points: one week prior to the VR session (S1), one week after the VR session (S3), and one month after the VR session (S4). The purpose of using this model was to understand how participants' attitudes and intentions regarding smoking cessation may evolve over time.

In the Current Self condition, which consisted of 12 participants, the distribution of the stages of change of smoking was as follows: 6 participants were in the precontemplation stage, indicating they had no intention to quit smoking; 4 participants were in the contemplation stage, meaning they were considering quitting within the next 6 months; and 2 participants were in the preparation stage, indicating they were planning to quit within the next 30 days. In the Future Self Non-Smoking condition, which included 11 participants, the distribution of the stages of change of smoking was as follows: 7 participants were in the contemplation stage, indicating they were considering quitting within the next 6 months; 3 participants were in the precontemplation stage, meaning they had no intention to quit smoking; and 1 participant was in the preparation stage, indicating they were planning to quit within the next 30 days. Lastly, in the Future Self Smoking condition with 10 participants, the distribution of the stages of change of smoking was as follows: 4 participants were in the precontemplation stage, indicating they had no intention to quit smoking; 3 participants were in the contemplation stage, meaning they were considering quitting within the next 6 months; and 3 participants were in the preparation stage, indicating they were planning to quit within the next 30 days. As with the other conditions, no participants were in the action or maintenance stages. The shifts between stages were demonstrated for each condition in Table 6.24. We performed Chi-Square (χ2) test with contingency table to test the significance of the shift and its either negative or positive direction.

Table 6.24. The number of participants that correspond across stages of change in each experimental session and condition.

	Current Self			Future Self Non-Smoking			Future Self Smoking		
	S1	S3	S4	S1	S3	S4	S1	S3	S4
Precontemplation	6	6	6	3	2	2	4	3	3
Contemplation	4	5	5	7	3	4	3	3	3
Preparation	2	1	1	1	6	5	3	2	1
Action	0	0	0	0	0	0	0	2	3

In the Future Self Smoking condition, significant shifts in smoking behaviour change were observed between the initial session of the study and one week after the VR session (χ^2 = 12.64, p = 0.049), as well as between one week after VR session and one month after VR session (χ^2 = 18.89, p = 0.026). Among the 10 participants in this condition, 3 participants successfully quit smoking one month after the VR session. Their biomarker verification results confirmed a corresponding decrease in carbon monoxide levels. One participant initially started in the contemplation stage, transitioned to the preparation stage after one week, and ultimately quit smoking after one month. The other two participants were already in the preparation stage and successfully quit smoking one week after the VR session. Even though the participants in the Future Self Non-Smoking condition moved from precontemplation and contemplation stages to the preparation stage after the VR session, the analysis did not reveal a significant value. No significant results were observed for the Stages of Change for participants in the Current Self condition. Our findings suggested a positive shift in participants' smoking behaviour, especially pronounced in the Future Self Non-Smoking condition, indicating an increase in motivation and readiness to quit smoking. The results also highlighted the effectiveness of the VR self-counselling intervention in promoting positive behaviour change in the context of nicotine dependence.

6.2.2.7. System Usability Scale

After the VR-Self counselling session, prior to finalising the questionnaires, participants were requested to respond to questions on the 10-item System Usability Scale. This scale was employed to assess the general usability of the ConVRSelf software, as well as for each individual experimental condition. In accordance with the scoring system of this scale, scores above 68 were considered to be above average. Our calculations yielded mean scores for the overall software and each experimental condition, which are presented in Table 6.25. The results indicate that our software demonstrated good usability among the nicotine dependent population overall and for all experimental conditions.

Table 6.25. The mean scores and the interpretation of the System Usability Scale (SUS).

Experimental Conditions	Mean ± SD of the SUS Scores	Interpretation
Current Self	80.00 ± 6.39	>68 above average
Future Self Non-Smoking	76.81 ± 9.94	>68 above average
Future Self Smoking	75.00 ± 16.87	>68 above average
All conditions total	77.42 ± 11.37	>68 above average

6.3.3. Discussion

The goal of this study was to investigate the effects of engaging in a self-conversation about nicotine dependence in virtual reality, specifically focusing on the impact on both physical and behavioural dependence, as well as behavioural change in cigarette smokers. Specifically, the study focused on different representations of future selves as virtual counsellors in the VR self-counselling context—the study comprised three experimental conditions designed to facilitate a self-counselling experience for participants. In the first condition, participants engaged in a self-dialogue by body swapping with a counsellor resembling their Current Selves (CS). The second condition involved a Future Self Non-Smoking version of themselves. Participants did body swapping with a virtual counsellor representing their future selves who had successfully quit smoking 20 years ago (FSNS). The third condition allowed participants to interact with a virtual counsellor representing their Future Self Smoking version who continued to smoke during all these years (FSS).

The VR response measures, which examined participants' body recognition, body ownership and agency assessments, revealed that all participants could recognise their lookalike bodies during the VR self-counselling session. In addition, participants also reported a high sense of agency and ownership over their virtual bodies. These results were consistent with the previous studies of VR self-counselling (Osimo et al., 2015; Slater et al., 2019). Similar to Experiment 1, the Current Self virtual counsellors were perceived as older than the actual ages of participants. However, in Experiment 2, the counsellor bodies in both Future Self Non-Smoking and Future Self Smoking conditions were evaluated as approximately 18-20 years older than the actual mean age of the participants. The age perception results differed from Experiment 1, in which participants evaluated the future self-counsellor body as 15 years older than themselves. It is important to mention that the Future Self virtual counsellor in Experiment 1 and Future Self Non-Smoking virtual counsellor in Experiment 2 were created using the same morphing and skin texture techniques and with the same Character Creator 3 software. This perceptual five years difference between these two counsellor bodies in Experiments 1 and 2 could be attributed to the difference between instructions prior to these experiments. In Experiment 1, participants were not informed about the age of their counsellor bodies but, they were just informed that they would talk with a future representation of themselves who had already solved their problem. However, in Experiment 2, before the VR self-counselling session, participants were told that their future bodies quit smoking 20 years ago. Additionally, the mean of the actual age of participants in Experiment 2 was higher (mean age = 34.78) than the mean actual age of the participants in Experiment 1 (mean age = 25.60). Therefore, the differences including the instructions and the mean age of participants between two experiments might have influence the perceived age of the counsellor bodies of future self-representations between experiments.

Furthermore, in Experiment 2, we observed significant changes in the "similarity" and "like" aspects of the Future Self Continuity Scale between sessions across different experimental conditions. These findings indicated that the context of the VR self-counselling intervention influenced participants' relationships with their future selves. Our first study, which centred around having a self-conversation with a future self to solve a personal problem, contrasted with the previous findings of the future self-continuity studies that showed the positive impact of the vivid perception of future self, which was shown on increasing saving behaviour (Hershfield et al., 2011; Hershfield, 2011) by enabling participants to engage in the age-rendered representations of themselves in VR. However, in our second study, which focused on engaging in a self-dialogue about nicotine dependence, we observed significant differences in participants' perceptions of their future selves after the VR session. Specifically, in the Future Self Non-Smoking condition, participants reported a greater sense of similarity between their current and future selves and a higher level of liking towards their future selves.

These shifts occurred between the initial session of the study and the session that took place one week after the VR intervention.

Similarly, participants in the Current Self condition also demonstrated an increased sense of similarity to their future selves one week after the VR session. On the other hand, participants in the Future Self Smoking condition, who engaged in a self-dialogue with a representation of their future selves as smokers, experienced a significant decrease in liking for their future selves immediately after the VR session. These findings from our study's Future Self Non-Smoking condition align with Ersner-Hershfield et al. (2009), who reported positive correlations between similarity and liking concerning future self-continuity. Accordingly, our study provides further evidence that virtual representations of positive and negative future selves regarding smoking behaviour can significantly affect participants' perceptions of future self-continuity.

Concerning general psychological outcomes, we could not find any differences between experimental conditions and sessions except for the "importance" variable. Only participants in the Future Self Smoking condition reported decreased importance of their smoking dependence a month after the VR session. The decrease in the importance can likely be attributed to the significant reductions in cigarette consumption, as well as the changes in behavioural dependence scores and stages of change measures observed in this condition.

Across all conditions, no significant differences between sessions were found for the physical dependence scores, which were measured with the Fagerstrom Test for Nicotine Dependence. These non-significant results can be attributed to the initial physical dependence level of participants, as the average scores for each condition exhibited low dependence. Therefore, the results could have differed if the population consisted of smokers who reported higher levels of physical dependence.

However, the Timeline Followback method revealed significant decreases in weekly cigarette consumption for both the Future Self Non-Smoking and Future Self Smoking conditions. The reduction in cigarette consumption was more pronounced in the Future Self Smoking condition, particularly one week and one month after the VR sessions. These changes were further supported by biomarker verification results, which showed a corresponding decrease in carbon monoxide levels over time among participants in the Future Self Smoking condition.

On the other hand, the Glover-Nilsson Smoking Behavioural Questionnaire results indicated a decrease in behavioural dependence scores across all conditions following the VR intervention. Our analysis revealed significant differences and reductions in behavioural dependence for the Current Self and Future Self Non-Smoking conditions between the initial session of the experiment and one month after the VR session, as well as between one week after the VR session and one month after the VR session. The boxplot representing these findings showed that although the changes were not statistically significant, participants in the Current Self and Future Self Non-Smoking conditions showed a surprising increase in behavioural dependence scores one week after the VR session, followed by a decrease below the initial levels one month after the VR session. In contrast, the Future Self Smoking condition consistently exhibited a decrease in behavioural dependence, with significant differences observed between the initial and one week after the VR sessions, as well as between the initial and one month after the VR sessions.

In addition, the changes in smoking behaviour were reflected in reporting behaviour changes towards smoking with the Stages of Change measure. In the Future Self Smoking condition, three participants achieved smoking cessation by moving to the action stage a month after the VR session, and the changes between stages were significant for the Future Self Smoking condition. Also, the Future Self Non-Smoking condition revealed positive behaviour change, including the majority of participants starting the experiment in the pre-contemplation and contemplation stages while a month after the study, moving to the preparation stage of change. However, the results for this condition were not significant. Also, no significant changes were found for the Current Self condition.

The findings for the Current Self condition could be attributed to the distribution of participants across conditions. Although the participants did not exhibit any differences in their nicotine dependence scores for physical and behavioural dependence between conditions, most participants in the Current Self condition were in the pre-contemplation stage of smoking. Previous research has suggested that the willingness to quit smoking and the level of motivation for change can significantly influence smoking cessation, behavioural changes, and the effectiveness of addiction treatment (Prochaska & DiClemente, 1983; DiClemente et al., 1991; Lichtenstein et al., 1994; DiClemente, 1999; DiClemente et al., 2004). For the Spanish population, it has also been shown that motivation to quit smoking can be a predictor of smoking cessation (Piñeiro et al., 2016). Therefore, these results of the Current Self condition for the stages of change variables might not serve as a generally representative sample for participants in different stages of change of smoking.

Although we initially anticipated to observe a significant impact on physical and behavioural nicotine dependence levels for participants in the Future Self Non-Smoking condition, our results did not align with our expectations. We hypothesized that the VR self-counselling intervention in this condition would enhance Future Self Continuity, as previous research has shown that increased continuity is associated with improved health behaviours (Rutchick et al., 2018). While we found an increase in future self-continuity for the Future Self Non-Smoking condition and a decrease for the Future Self Smoking condition, as indicated by changes in the similarity and like aspects of the Future Self-Continuity Scale, still, Future Self Non-Smoking condition was found to be less effective on decreasing the number of cigarettes smoked, behavioural dependence and stages of change measures compared to the Future Self Smoking condition.

According to previous studies, smokers often display optimistic bias, with many believing that smoking does not pose a significant health risk (Masiero et al., 2015; Arnett, 2000). Engaging in a self-dialogue with a future self who could not quit smoking might reduce participants' cognitive bias regarding their perception of the risks associated with smoking. Despite the minimal physical differences between the smoker and non-smoker versions of the future self, the instructions provided to participants to distinguish between the two may have prompted them to confront their biases. The prospective studies should incorporate quantitative evaluation methods for cognitive bias in the context of addiction when the future self is incorporated with negative and positive versions to confirm our results.

Smokers were shown not only to perceive health-related risks regarding smoking differently (Murphy-Hoefer et al., 2004), but smoking was also associated with delay discounting (Bickel et al., 1999; Bickel et al., 2008), which refers to the tendency to place less value on future outcomes when compared to immediate rewards. For example, when individuals are faced with choices involving monetary gains that occur at different points in time, they tend to devalue monetary gains that are further in the future. This discounting effect is more pronounced for health outcomes (Chapman et al., 1995; Chapman, 1996), suggesting a tendency to underestimate the value of long-term health decisions. Nonetheless, research has demonstrated that this discounting effect can be reversed as the number of cigarettes smoked decreases (Yi et al., 2008). Additionally, engaging in future episodic thinking, which involves imagining positive autobiographical future events (Stein et al., 2016), has effectively reduced cigarette smoking and temporal discounting. In our study, we observed a decrease in cigarette smoking among participants in the Future Self Smoking condition. However, in our study, Future Self Smoking condition also led to a decrease in liking for the future self, resulting in decreased continuity. To better understand the underlying mechanisms and the impact of different versions of future selves, it would be beneficial to incorporate an independent measure of delay discounting alongside the assessment of increased future self-continuity. This would provide an evaluation of participants' decision-making processes and the potential influence on their smoking behaviour.

The interpretation of the results using the predictive coding framework hints at similar insights as discussed above. The changes in participants' attitudes and behaviours towards smoking may be triggered by the high predictive error between the participant's imaginary future self and the future self smoking avatar, leading to cognitive dissonance. The high dislike score hints that the negative perception of the future self smoking avatar may have also contributed to the prediction error, as the optimistic bias would have led the participants to expect a less negative response to idea of continuing smoking in the future, while facing with the future self smoking condition may have triggered stronger negative emotions than expected. On the other hand, the optimistic bias smokers have may have led the participants to have lower degrees of predictive error when faced with future self non-smoking avatars but would have reinforced the positive perceptions associated with quitting smoking. The close alignment of the prediction and the future self non-smoking avatar would explain the less pronounced effects as well as the higher levels of liking towards the condition as observed in the study.

Overall, the findings of this study highlighted the effectiveness of VR self-counselling interventions with different representations of future selves in promoting positive behavioural change related to smoking cessation. Specifically, engaging with a virtual counsellor representing a future self who continues to smoke resulted in a significant decrease in cigarette consumption, reduced behavioural dependence, and positive behavioural changes, indicating increased motivation for smoking cessation. In addition, interacting with a virtual counsellor representing a future self who successfully quit smoking also led to a decrease in behavioural scores and some behaviour changes. However, the results for the Current Self-representation were less pronounced regarding promoting behavioural change related to smoking cessation. Furthermore, our software demonstrated high usability, as evidenced by the favourable scores from the System Usability Scale. This indicated that our software is a novel and participant-friendly tool in the context of addiction.

7. Conclusions

7.1 General Discussion

Throughout this thesis, we have explored some approaches aimed to improve the usability, applicability, and practicability of Immersive Virtual Reality. Our approach was structured around understanding the complexities, challenges, and potential opportunities this innovative technology presents. We presented results from four studies, detailed in Chapters 4, 5, and 6, which were conducted with human participants to examine the four hypotheses we had formulated. We aimed to interpret the results of our studies with the predictive coding framework to provide further discussions into how participants interact with virtual reality and how those interactions can be utilised to improve usability and promote behavioural change.

- **Hypothesis 1:** "*When moving through a dark virtual environment, participants can travel at a higher velocity and with less simulator sickness than when moving through a bright environment.*"

We started our investigation, seeking solutions to mitigate simulator sickness, a common technical challenge with this technology, to bolster its usability. For this investigation, we built a virtual environment that consisted of a street where participants were instructed to move as fast as possible. In our first experiment, participants navigated this street, segmented into four divisions of alternating lighting conditions: either sequences of dark-light-dark-light or light-dark-light-dark. The primary outcome of our first study underlined the impact of the initial lighting condition on the speed of participants' movement. Compared to starting with a brighter street, participants who began their journey on a darker street moved faster and showed fewer indications of simulator sickness. Following the first experiment, we conducted a second experiment using the same street to solidify our results. In this experiment, however, participants moved through a fully bright street or a street that initially started darker and gradually transitioned to light. Our study indicated that incorporating a dark environment into the early stages of the VR experience could influence participants' speed, thereby mitigating the symptoms of simulator sickness, as most symptoms were reported primarily during the brighter parts of the street. The overall results from both studies confirmed the brightness of the first street was crucial, which impacted participants' velocity. Applying these findings to the development of VR environments that require rapid movements could enhance the usability of this technology, particularly for those who suffer from symptoms of simulator sickness when engaging with virtual environments.

From a predictive coding perspective, the results of this study can be explained by the lower initial prediction error leading to higher performance. A darker starting environment would likely provide a less complex model, with fewer noticeable objects and less salient features, allowing the participants' sensory predictions to be more accurate compared to a brighter starting environment. This initial size of the prediction error can be argued to enhance participant experience by minimising discomfort and sparing more cognitive capacity to facilitate navigation.

- **Hypothesis 2:** "*The gradual changes in the owned and seen virtual bodies can lead to "change blindness" in virtual reality. Therefore, due to the special status of the self-representation giving rise to embodiment, changes to participants' own virtual bodies would be more noticeable than changes to another virtual body*".

Following our exploration of simulator sickness, we also delved into the relationship between body ownership, change blindness, and gradual changes to deepen our understanding of their relevance and application in VR environments. We developed a virtual gym environment in which participants practised a set of Qigong exercises. Participants were assigned a gender-matched body and imitated the exercises demonstrated by the gender-matched instructor. Gradual changes were applied simultaneously and to the same degree to both the participants' own bodies and the instructor's body. Our research revealed that participants failed to notice the change in the instructor body compared to their own. Notably, the incidence of change blindness was high, with 85% recorded for the virtual instructor and 73% for the participants' own bodies. Moreover, our data emphasised a gender-related difference amongst the groups assigned to participants based on their most closely identified gender. For instance, change blindness for participants' own bodies was reported in only 50% of the group, consisting of male participants, as opposed to 82.1% the other group, which comprised female participants and a non-binary participant. However, these distinctions were not observed for instances of change blindness regarding the instructor's avatar across both groups. 75% of the participants in the male dominant group and 89.3% in the female dominant group did not perceive the changes in the instructor.

These results can be explained using the possible differential weighting of prediction errors under the predictive coding framework. When changes are small and gradual, the discrepancies between predictions and sensory inputs might be too small to trigger a prediction update. This result implies a tendency of the brain to focus on more significant differences in favour of missing the less significant ones, a possible resource-saving strategy. The higher degree of change blindness for the participant’s own virtual body versus instructors can be speculated to be an effect of the embodiment. Under the body ownership illusion, the participant would take their virtual body as their own and pay more attention to it, leading to a stronger predictive model, and a lower prediction error threshold associated with changes in their appearance. On the other hand, gender differences in noticing the changes support the Bayesian nature of the predictive coding framework, wherein prior experiences and beliefs of the participants influence the prediction models and as a result, the error detection mechanism. It could be speculated that different genders learn to have different prediction models and error detection thresholds regarding their own bodies and bodies of others.

Later, we conducted two more studies to explore the influence of counsellor representations in VR self-counselling across differing contexts. The first study assessed the practicality and efficacy of this approach in addressing personal problems, whereas the second study investigated its impact on reducing physical and behavioural nicotine dependence to understand behavioural change.

- **Hypothesis 3:** "*Having a self-conversation about a personal problem by swapping between two virtual bodies, explaining the situation from a present-day lookalike body, and swapping bodies with a counsellor representation of a future self, will help participants to solve their personal problems*".

Building on our study of change blindness, we delved into another aspect of VR interactions: self-conversation within the VR setting. Using existing research as our foundation (Osimo et al., 2015; Slater et al., 2019), we examined the influence of different counsellor representations during VR self-counselling. To test our hypothesis and investigate the effect of various virtual counsellor bodies on personal problem-solving, we created a virtual scenario where participants engaged in self-conversation, switching between self and counsellor bodies. The counsellor body represented different versions of participants' representations, including their present and future selves and a gender-matched generic avatar. Initially, we anticipated that the future-self counsellor representation would increase self-continuity (Hershfield, 2011) and result in the most significant improvement.

Contrary to our prediction, we found that the most effective counsellor representation was the generic-looking, gender-matched counsellor. Although clinical measures of depression, anxiety, and stress, as evaluated by the DASS-21 items, did not vary between different sessions or conditions, the general psychological variables concerning the impact of the intervention and the participants' perspectives improved in the condition where participants engaged in self-conversation with a generic-looking, gender-matched counsellor representation. This outcome was followed by the lookalike counsellor representation, which was the second most effective, while the future-self counsellor representation proved to be the least effective condition.

The improved understanding and control of personal problem after conversing with the current and generic self counsellor bodies but not the future self counsellor body can be explained using the predictive coding framework by the amount of prediction errors each self triggers. As the lookalike and generic-looking avatars are more in line with the possible self-model of the participants, more cognitive resources can be spared for problem solving. However, the temporal distance between the virtual counsellor representation and the actual self increases, the prediction error would also increase, leading to discomfort and decreased cognitive resource allocation for problem solving.

- **Hypothesis 4:** *"Having a self-conversation about nicotine dependence by swapping between two virtual bodies, explaining the situation from a present-day lookalike body, and swapping bodies with a counsellor representation of different future selves, will help participants to decrease their behavioural and physical nicotine dependence scores".*

Continuing from the VR self-counselling research line, this study utilised the same virtual scenario of VR self-conversation that we utilised in the first study that addressed personal problems. However, this study focused on understanding whether self-conversations with varying future self-representations, precisely a future self who had quit smoking and a future self who continued to smoke, could impact the levels of nicotine dependence among individuals at varying stages of their smoking addiction. As a control, we once more employed a lookalike counsellor representation of the participants. Even though we expected that participants would exhibit a reduction in behavioural dependence after engaging with future self-representations of themselves who quit smoking, smoker future self-representation of the counsellor body was found to be more effective in reducing the number of cigarettes smoked, behavioural dependence, and measures of stages of change compared to the non-smoker future self-representation. Regardless, our study's findings stressed the effectiveness of VR self-counselling interventions with distinct future self-representations in fostering positive behavioural changes related to smoking cessation.

The interpretation of the personal problem study that argued the smaller prediction errors with one's own virtual body would lead to more cognitive resources to solve the problems does not hold here, as the effect is pronounced in the future self smoking condition. This result may be accounted for by the concept of active inference in predictive coding, where individuals take actions to minimise the prediction errors. In the previous experiment, the future self may have triggered a higher prediction error but without an obvious way or connection to the problem at hand. In this experiment, the higher prediction error, predicted by the optimistic bias of smokers, would have led to motivating the smokers to reduce cigarette use to minimise the discrepancy between their current behaviour and their prediction of their future self. In other words, the smoking future self, would have likely crashed with their more optimistic expectation of their future self, whether one that is healthier looking or one that already quit smoking, leading to high levels of cognitive dissonance and triggering behaviour change in that specific domain.

Previous studies in VR self-counselling have employed a Freud-resembling counsellor avatar (Osimo et al., 2015; Slater et al., 2019) to investigate whether participants overcome their personal problems through VR self-dialogue. Our studies add to this field of research by demonstrating the effectiveness of a general-looking counsellor body. Our findings suggest that the counsellor's body significantly impacts the VR self-dialogue, meaning that our results cannot be solely attributed to perspective-taking (Batson et al., 1997).

Similarly, some studies have used a simplified self-dialogue method in virtual reality, integrating compassion-focused therapy (Gilbert & Irons, 2010) for participants with high self-criticism (Falconer et al., 2014) and later applying this method to patients with depression (Falconer et al., 2016). These successful interventions did not provide participants with a lookalike representation. Instead, they offered arbitrary bodies without repeated body swapping for continuous conversations. Our research also demonstrates that within a VR self-counselling paradigm addressing non-clinical problems, embodying a dialogue with a lookalike virtual body representing the counsellor is not crucial for this context.

7.2 Main Contributions and Limitations

This thesis primarily contributed to the existing research by offering participants experiences that would have been difficult to recreate in real life through other means. We offered participants a platform to have a self-dialogue with themselves from the perspective of their own future selves. Additionally, the participants were provided with their lookalike virtual bodies and virtual body representations of the counsellor for all conditions. This personalisation made each experimental VR session a customised experience for each participant.

Our research showed that this kind of self-dialogue, particularly when participants inhabited the virtual body of their future selves who continued to smoke as a counsellor, helped decrease their behavioural dependence on smoking. Participants smoked fewer cigarettes and underwent a significant behaviour change in their smoking even a month after the study, with some individuals even quitting smoking entirely. While less effective than the Future Self Non-Smoking condition, the Future Self Smoking condition still showed better results than the Current Self condition, allowing the comparison of different temporal selves in the VR-self counselling framework for addiction.

Our Self-dialogue with Virtual Future Self experiments also demonstrated that the content of the dialogue could significantly influence the outcomes. For instance, in the case of VR self-counselling for non-clinical personal problems that caused moderate stress in participants' lives, a generic-looking counsellor representation was enough to improve psychological outcomes, and personalised current self and future self versions of the counsellor representations were not specifically needed. However, when dealing with clinical issues such as addiction, the future self-approach appeared effective for discoursing these issues. Nonetheless, by cultivating the context for a self-dialogue within our participants, VR self-counselling was able to impact real-life behaviour with a good, indicated usability.

Despite the promising results we obtained, our studies had some limitations. Firstly, due to the complex nature of the self-dialogue experiments, which included the creation of personalised virtual environments and the necessity for participants to attend multiple sessions in our laboratory with significant time intervals between sessions, we were only able to recruit a small sample of participants. The COVID-19 pandemic and the exclusion of participants with a low score on the WHO-5 Well-being Index also posed challenges during recruitment. Due to the small sample size, the generalizability of our findings was consequently limited.

Another limitation was that we conducted only a single VR intervention session, despite our study design incorporating multiple sessions. The potential of VR self-counselling for addiction could be further explored through multi-session trials, adding to the depth of our findings. Future research should apply VR counselling at different time points to assess its lasting effectiveness.

We did not compare the VR method with other smoking cessation therapies, which would have allowed us to evaluate its relative effectiveness in addiction. Future studies could investigate different variations of smoking cessation therapies in comparison or conjunction with VR interventions to provide a general understanding. Moreover, we only focused on nicotine dependence, so our results could be limited to nicotine addiction.

Despite these limitations, our method showed promising results and good usability for participants, even in a single session of VR self-dialogue. Prospecting studies should explore the potential of VR self-counselling applications with this methodology to extend beyond personal problems and nicotine addiction to clinical populations suffering from anxiety, depression, alcohol dependence, and substance dependence.

Our focus on exploring different self-representations meant we did not delve deeply into alternate representations of the counsellor avatar, unlike previous studies that used figures like Sigmund Freud. While our novel approach of employing different counsellor representations for addiction studies was innovative, a broader exploration of other potential avatar representations could further enrich the field. Therefore, future research could examine the effectiveness of different virtual counsellor representations, such as a body representing Sigmund Freud compared to a general-looking virtual body, as well as different representations of the self-body, including lookalike versus generic-looking gender-matched versions, to ascertain whether similar improvements can be observed across these varying conditions.

Regarding the Qigong experiment, even though we identified a noticeable gender difference in our study, the number of male participants was quite limited. Therefore, the generalisability of this finding to a broader population may be constrained, and we should be cautious about making definitive conclusions. This limitation emphasises the need for future studies to strive for a more balanced gender distribution, facilitating a general understanding of gender dynamics concerning change blindness in VR.

Our study also differed from traditional change blindness research, mainly focusing on observational tasks involving gradual changes. In contrast, our participants were not merely observers; they were active agents required to observe, listen to, and replicate exercises demonstrated by a virtual instructor. This might have added an extra layer of complexity and contributed to the gender differences observed in our study. It would be interesting for future work to delve deeper into these interactions, particularly how task nature and gender interplay in the context of change blindness.

Lastly, our research has suggested a practical way that might be useful in reducing the chance of simulator sickness. We observed that as the VR exposure progressed, participants could attain similar velocity levels regardless of the initial darkness, suggesting some level of adaptation. However, the early stages of VR exposure are indeed crucial. If participants experience severe simulator sickness early on, they may altogether cease VR usage. The chosen speed might not have been potent enough to trigger sickness in most participants, a decision we made consciously for participant safety. The maximum velocity attained by participants during different segments of the street could hint at a habituation effect. This phenomenon is worth exploring in detail in future studies. As such, every measure, from the design and weight of the head-mounted displays to strategies that reduce the likelihood of simulator sickness, should be considered when crafting a comfortable VR experience. Further studies are needed to continue refining these strategies and confirm our findings across broader and more diverse participant groups and various hardware configurations.

The predictive coding interpretation of these studies also sought to suggest a potential approach for comprehending the influence of the brain's predictive models on perceptions and behaviours across various contexts. This perspective may also present avenues for further research, which will be examined more closely in the subsequent section.

7.3 Future Work

The experiments we introduced in this thesis opened new directions for future work. Starting from the Simulator Sickness experiments, even though our studies demonstrated a potential impact of a darker street at the beginning of the experience, all participants reached the maximum velocity of movement at the end of the experiments. Therefore, subsequent studies with a similar design could involve faster velocities to examine the impact of the darker street on the velocity and simulator sickness. In addition, it might be useful to introduce a new condition that begins with a light environment and gradually transitions to darkness and compare this with an exclusively dark environment to increase the variation of the conditions. Furthermore, participants stood on their feet in our experiment and moved down a straight street. As previous research has indicated, rotation and seated/standing positions can influence simulator sickness (Dennison & D'Zmura, 2017), future research could scrutinise the effects of rotational movement and differing postures, such as seated versus standing. In addition, future studies can explore combining other techniques shown to reduce simulator sickness symptoms, such as vibration and auditory stimuli (Kemeny et al., 2020), which could complement a darker virtual environment, providing a general understanding of this phenomenon. Similar to the study of Llobera et al. (2021), that utilised psychophysical methods to allow participants to make choices between alternatives that were presented by a reinforcement learning algorithm suggesting potential configurations to participants, allowing participants to adjust darkness and lightness parameters through configuration transitions could provide further insights into their preferences for darker or lighter environments or environments with different configurations. Lastly, the efficacy of our strategies for mitigating simulator sickness should be tested across different types of VR hardware and software, including various headsets, tracking systems, and types of VR content.

Given that we only utilised the Meta Quest 2 headset, other hardware could provide insights into whether our findings are universally applicable or if different strategies are needed for different VR setups. According to the predictive coding interpretation of this, minimising the initial prediction errors in an environment can improve usability. In other words, we could expect improved user experience in VR environments where the initial perception model of the participant is relatively simple. This can be tested by comparing the user experience metrics of participants between a simpler environment and a more complex one, as well as dynamic ones where the environment complexity changes over time.

Turning to the Qigong Experiment, the gradual change and its relationship with the embodiment could have broader potential applications within virtual reality, particularly for studies examining implicit attitudes. For instance, research on racial bias has shown a reduced implicit racial bias within VR environments (Banakou et al., 2016). Applying this mechanism to a gradual transition from one race to another of an embodied avatar in a VR scenario could potentially uncover further implicit mechanisms, significantly if these subtle, unnoticed changes influence participants' attitudes and behaviours. Similarly, as VR has been employed to investigate ageism (Scott, 2023), embodying a virtual body that ages could serve as a novel approach to investigating implicit bias towards different age groups.

Finally, our work on Self-Dialogue with Virtual Future Self experiments has expanded the knowledge in the field of VR self-counselling research. Our first study found improved psychological outcomes when participants discussed a personal problem with a gender-matched, generic-looking counsellor representation. Yet, surprisingly, the Future Self condition did not yield the same effect and brought no changes on the future self-continuity scale. On the contrary, our second study, focusing on nicotine dependence, reported significant behavioural shifts, alterations in behavioural dependence and reductions in the number of cigarettes smoked by participants in the Future Self Smoking condition. Both the Future Self Non-Smoking and Current Self conditions demonstrated less striking effects. Considering the differences between the two studies, future VR self-counselling research should concentrate on the content of the self-dialogue. Moreover, demographic factors such as participant age and gender could be investigated to comprehend these differences better.

The implicit negative attitudes towards older people among the participants could account for the relative ineffectiveness of the Future Self condition in the first study and the Future Self Non-Smoking condition in the second. The possibility of unrealistic expectations about the representation of their future selves, influenced by the prevalent ageism on social media (Brooke & Jackson, 2020), should be considered in future studies.

Additionally, concerning virtual bodies, potentially integrating other virtual representations like a General Self or a Freud-like figure, as in previous studies (Osimo et al., 2015; Slater et al., 2019), should be assessed. Numerous researchers have already utilised a simplified self-dialogue method in a virtual reality context, incorporating compassion-focused therapy (Gilbert & Irons, 2010) for participants with high self-criticism (Falconer et al., 2014) and depression (Falconer et al., 2016). Furthermore, many research papers have suggested that altered body representations in virtual reality can significantly influence participants' attitudes, perceptions, behaviours, and cognitive performance. Implementing different body representations could lead to obtaining insightful outcomes. Future studies need to explore a broader range of virtual counsellor representations to enhance the field of VR self-counselling further. Additionally, it is crucial to consider the different possible representations of participants' self-bodies within the virtual environment. Further studies could be designed to compare lookalike self-representations with a generic self-representation of the participants' avatars.

The interpretation we proposed from the predictive coding perspective, that enhanced problem-solving performance might be attributed to reduced cognitive dissonance arising from smaller prediction errors, could be evaluated by conducting a self-counselling experiment in a virtual environment that closely mirrors the participant's real-world surroundings, such as their home or office, in contrast to a more foreign environment. Regarding the interpretation of the decreased behavioural dependence on smoking observed in the future self smoking condition from the predictive coding perspective, this result attributed to behaviour modification through active inference. If an increased prediction error between the expected future self and the virtual future self does indeed prompt behaviour modification via active inference, this could also be tested. A future study might involve presenting participants with versions of their future selves underperforming in areas where the aim is to stimulate behavioural change. An example can include evaluating academic performance after conversing with the academically unsuccessful future selves.

Furthermore, larger sample sizes and repeated VR intervention sessions could lead to more robust findings, allowing researchers to explore long-term effects more effectively. As for behavioural change and smoking cessation, the efficacy of the VR self-dialogue approach could be evaluated in conjunction with other therapeutic strategies, including cognitive behavioural therapy (CBT), mindfulness-based interventions, and motivational interviewing, which have shown success in addressing addictive behaviours (Magill & Ray, 2009). The intersection of VR and these approaches remains unexplored and could yield impactful results. Moreover, we recommend expanding the application of our VR self-counselling methodology to address a broader range of issues and clinical populations, such as those struggling with anxiety, depression, alcohol, or substance dependence. The research with diverse clinical populations could significantly advance our understanding of the role and potential impacts of VR self-counselling methods.

In conclusion, this thesis has aimed to contribute to the existing knowledge regarding the potential of VR in experimental psychology and cognitive neuroscience while laying the groundwork for future studies in this captivating field. We hope that our work has established a solid foundation for future research

References

AECC. (March 25, 2021). Prevalence of tobacco use in Spain in 2020, by type of smoker [Graph]. In *Statista*. Retrieved November 18, 2021, from https://www-statista-com.sire.ub.edu/statistics/1069099/tobacco-use-prevalence-in-spain

AECC. (March 25, 2021). Share of daily smokers in the Spanish autonomous community of Catalonia in 2020, by gender and age [Graph]. In *Statista*. Retrieved November 18, 2021, from https://www-statista-com.sire.ub.edu/statistics/1068698/daily-smokers-in-catalonia-spain-by-gender-and-age/

Alais, D., & Burr, D. (2004). The ventriloquist effect results from near-optimal bimodal integration. *Current biology*, *14*(3), 257-262.

Alsop, T (2022, September 20th) *Virtual reality (VR) headset sales volume worldwide from 2017 to 2027(in million pieces)* [Infographic]. Statista. https://www.statista.com/forecasts/1331896/vr-headset-sales-volume-worldwide

Andermane, N., Bosten, J. M., Seth, A. K., & Ward, J. (2019). Individual differences in change blindness are predicted by the strength and stability of visual representations. *Neuroscience of consciousness*, *2019*(1), niy010.

Anastasiadou, D., Herrero, P., Sebastián, V. D., Garcia-Royo, P., Spanlang, B., Álvarez de la Campa, E., Slater, M., Ciudin, A., Comas, M., Ramos-Quiroga, J.A. & Lusilla-Palacios, P. (2023). Virtual self-conversation using motivational interviewing techniques to promote healthy eating and physical activity: A usability study. *Frontiers in psychiatry*, 14, 999656.

Anastasiadou, D., Spanlang, B., Slater, M., Sebastian, J. V. D., Ramos-Quiroga, J. A., Puig, G. P., Ciudin, A., Comas, M., & Lusilla-Palacios, P. (2021). A Virtual Reality tool using embodiment and body swapping techniques for the treatment of obesity: A pilot usability study. *ANNUAL REVIEW OF CYBERTHERAPY AND TELEMEDICINE 2021*, 105.

Arnett, J. J. (2000). Optimistic bias in adolescent and adult smokers and nonsmokers. *Addictive behaviors*, *25*(4), 625-632.

Bados, A., Solanas, A., & Andrés, R. (2005). Psychometric properties of the Spanish version of depression, anxiety and stress scales (DASS). *Psicothema*, 679-683.

Bailenson, J. N., Beall, A. C., Blascovich, J., Raimundo, M., & Weisbuch, M. (2001, August). Intelligent agents who wear your face: Users' reactions to the virtual self. In International workshop on intelligent virtual agents (pp. 86-99). Berlin, Heidelberg: Springer Berlin Heidelberg.

Bailenson, J. N., Swinth, K., Hoyt, C., Persky, S., Dimov, A., & Blascovich, J. (2005). The independent and interactive effects of embodied-agent appearance and behavior on self-report, cognitive, and behavioral markers of copresence in immersive virtual environments. Presence, 14(4), 379-393.

Banakou, D., Beacco, A., Neyret, S., Blasco-Oliver, M., Seinfeld, S., & Slater, M. (2020). Virtual body ownership and its consequences for implicit racial bias are dependent on social context. *Royal Society open science*, *7*(12), 201848.

Banakou, D., Groten, R., & Slater, M. (2013). Illusory ownership of a virtual child body causes overestimation of object sizes and implicit attitude changes. *Proceedings of the National Academy of Sciences*, *110*(31), 12846-12851.

Banakou, D., Hanumanthu, P. D., & Slater, M. (2016). Virtual embodiment of white people in a black virtual body leads to a sustained reduction in their implicit racial bias. *Frontiers in human neuroscience*, 601.

Banakou, D., Groten, R., & Slater, M. (2013). Illusory ownership of a virtual child body causes overestimation of object sizes and implicit attitude changes. *Proceedings of the National Academy of Sciences*, *110*(31), 12846-12851.

Banakou, D., & Slater, M. (2014). Body ownership causes illusory self-attribution of speaking and influences subsequent real speaking. *Proceedings of the National Academy of Sciences*, *111*(49), 17678-17683.

Banakou, D., Kishore, S., & Slater, M. (2018). Virtually being Einstein results in an improvement in cognitive task performance and a decrease in age bias. *Frontiers in psychology*, 917.

Barberia, I., Oliva, R., Bourdin, P., & Slater, M. (2018). Virtual mortality and near-death experience after a prolonged exposure in a shared virtual reality may lead to positive life-attitude changes. *PloS one*, *13*(11), e0203358.

Barfield, W., & Weghorst, S. (1993). The sense of presence within virtual environments: A conceptual framework. *Advances in Human Factors Ergonomics*, *19*, 699-699.

Bellido Rivas, A. I., Navarro, X., Banakou, D., Oliva, R., Orvalho, V., & Slater, M. (2021). The Influence of Embodiment as a Cartoon Character on Public Speaking Anxiety. *Frontiers in Virtual Reality*, *2*, 695673.

Benowitz, N. L., Bernert, J. T., Foulds, J., Hecht, S. S., Jacob III, P., Jarvis, M. J., Joseph A., Oncken C., & Piper, M. E. (2020). Biochemical verification of tobacco use and abstinence: 2019 update. *Nicotine and Tobacco Research, 22*(7), 1086-1097.

Bickel, W. K., Odum, A. L., & Madden, G. J. (1999). Impulsivity and cigarette smoking: delay discounting in current, never, and ex-smokers. *Psychopharmacology*, *146*, 447-454.

Bickel, W. K., Yi, R., Kowal, B. P., & Gatchalian, K. M. (2008). Cigarette smokers discount past and future rewards symmetrically and more than controls: is discounting a measure of impulsivity?. *Drug and Alcohol Dependence*, *96*(3), 256-262.

Blanchard, C., Burgess, S., Harvill, Y., Lanier, J., Lasko, A., Oberman, M., & Teitel, M. (1990). Reality built for two: a virtual reality tool. In *Proceedings of the 1990 symposium on Interactive 3D graphics* (pp. 35-36).

Blanke, O. (2012). Multisensory brain mechanisms of bodily self-consciousness. *Nature Reviews Neuroscience*, *13*(8), 556-571.

Bles, W., Bos, J. E., De Graaf, B., Groen, E., & Wertheim, A. H. (1998). Motion sickness: only one provocative conflict?. *Brain research bulletin*, *47*(5), 481-487.

Bodner, E. (2009). On the origins of ageism among older and younger adults. *International Psychogeriatrics*, *21*(6), 1003-1014.

Bordnick, P. S., Graap, K. M., Copp, H. L., Brooks, J., & Ferrer, M. (2005). Virtual reality cue reactivity assessment in cigarette smokers. *CyberPsychology & Behavior*, *8*(5), 487-492.

Bordnick, P. S., Traylor, A. C., Carter, B. L., & Graap, K. M. (2012). A feasibility study of virtual reality-based coping skills training for nicotine dependence. *Research on social work practice*, *22*(3), 293-300.

Botvinick, M. (2004). Probing the neural basis of body ownership. *Science*, *305*(5685), 782-783.

Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel'touch that eyes see. *Nature*, *391*(6669), 756-756.

Bourdin, P., Barberia, I., Oliva, R., & Slater, M. (2017). A virtual out-of-body experience reduces fear of death. *PloS one*, *12*(1), e0169343.

Box, G. E., & Draper, N. R. (1987). *Empirical model-building and response surfaces*. John Wiley & Sons.

Brooke, J. (1996). SUS: A quick and dirty usability scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester, & I. L. McClelland (Eds.), Usability Evaluation in Industry (pp. 189-194). London: Taylor & Francis.

Brooke, J., & Jackson, D. (2020). Older people and COVID-19 isolation, risk and ageism. *Journal of clinical nursing*.

Burr, D., & Cicchini, G. M. (2014). Vision: efficient adaptive coding. *Current Biology*, *24*(22), R1096-R1098.

Bystrom, K. E., Barfield, W., & Hendrix, C. (1999). A conceptual model of the sense of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, *8*(2), 241-244.

Cardoso-Leite, P., Mamassian, P., Schütz-Bosbach, S., & Waszak, F. (2010). A new look at sensory attenuation: Action-effect anticipation affects sensitivity, not response bias. *Psychological science*, *21*(12), 1740-1745.

Carnegie, K., & Rhee, T. (2015). Reducing visual discomfort with HMDs using dynamic depth of field. *IEEE computer graphics and applications*, *35*(5), 34-41.

Chang, E., Kim, H. T., & Yoo, B. (2020). Virtual reality sickness: a review of causes and measurements. *International Journal of Human–Computer Interaction*, *36*(17), 1658-1682.

Chapman, G. B. (1996). Temporal discounting and utility for health and money. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*(3), 771.

Chapman, G. B., & Elstein, A. S. (1995). Valuing the future: Temporal discounting of health and money. *Medical decision making*, *15*(4), 373-386.

Clark, A. (2013). Whatever next? Predictive brains, situated agents, and the future of cognitive science. *Behavioral and brain sciences*, *36*(3), 181-204.

Clarke, A. C. (2000). Profiles of the Future: An Inquiry into the Limits of the Possible (Millennium Edition). London: Indigo.

Comisión de Salud Pública (May, 2019). LINEAS DE ACTUACIÓN 2019-20 EN EL ÁMBITO DE LA PREVENCIÓN Y CONTROL DEL TABAQUISMO. Comisión de Salud Pública, Ministerio de Sanidad. Retrieved from: https://www.mscbs.gob.es/ciudadanos/proteccionSalud/tabaco/docs/Acuerdo_Lineas_actuacion_tabaquismo.pdf

Cruz-Neira, C., Sandin, D. J., DeFanti, T. A., Kenyon, R. V., & Hart, J. C. (1992). The CAVE: audio visual experience automatic virtual environment. *Communications of the ACM*, *35*(6), 64-73.

D'Argembeau, A., Xue, G., Lu, Z. L., Van der Linden, M., & Bechara, A. (2008). Neural correlates of envisioning emotional events in the near and far future. *Neuroimage*, *40*(1), 398-407.

David, E., Laloyaux, C., Devue, C., & Cleeremans, A. (2006). Change blindness to gradual changes in facial expressions. *Psychologica Belgica*, *46*(4).

De Vignemont, F., Ehrsson, H. H., & Haggard, P. (2005). Bodily illusions modulate tactile perception. *Current Biology*, *15*(14), 1286-1290.

Dennison, M. S., & D'Zmura, M. (2017). Cybersickness without the wobble: Experimental results speak against postural instability theory. *Applied ergonomics*, *58*, 215-223.

DiClemente, C. C. (1999). Motivation for change: Implications for substance abuse treatment. *Psychological Science*, *10*(3), 209-213.

DiClemente, C. C., Prochaska, J. O., Fairhurst, S. K., Velicer, W. F., Velasquez, M. M., & Rossi, J. S. (1991). The process of smoking cessation: an analysis of precontemplation, contemplation, and preparation stages of change. *Journal of consulting and clinical psychology*, *59*(2), 295.

DiClemente, C. C., Schlundt, D., & Gemmell, L. (2004). Readiness and stages of change in addiction treatment. *American journal on addictions*, *13*(2), 103-119.

DiZio, P., & Lackner, J. R. (1997). Circumventing side effects of immersive virtual environments. *Advances in human factors/ergonomics*, *21*, 893-896.

Draper, J. V., Kaber, D. B., & Usher, J. M. (1998). Telepresence. *Human factors*, *40*(3), 354-375.

Dużmańska, N., Strojny, P., & Strojny, A. (2018). Can simulator sickness be avoided? A review on temporal aspects of simulator sickness. *Frontiers in psychology*, *9*, 2132.

Ehrsson, H. H. (2007). The experimental induction of out-of-body experiences. *Science*, *317*(5841), 1048-1048.

Ehrsson, H. H. (2012). 43 The concept of body ownership and its relation to multisensory integration. *The New handbook of multisensory process*.

Ehrsson, H. H., Holmes, N. P., & Passingham, R. E. (2005). Touching a rubber hand: feeling of body ownership is associated with activity in multisensory brain areas. *Journal of neuroscience*, *25*(45), 10564-10573.

Ersner-Hershfield, H., Garton, M. T., Ballard, K., Samanez-Larkin, G. R., & Knutson, B. (2009). Don't stop thinking about tomorrow: Individual differences in future self-continuity account for saving. *Judgment and Decision making*, *4*(4), 280-286.

Ersner-Hershfield, H., Wimmer, G. E., & Knutson, B. (2009). Saving for the future self: Neural measures of future self-continuity predict temporal discounting. *Social cognitive and affective neuroscience*, *4*(1), 85-92.

Eyal, T., Sagristano, M. D., Trope, Y., Liberman, N., & Chaiken, S. (2009). When values matter: Expressing values in behavioral intentions for the near vs. distant future. *Journal of experimental social psychology*, *45*(1), 35-43.

Fernandes, A. S., & Feiner, S. K. (2016, March). Combating VR sickness through subtle dynamic field-of-view modification. In *2016 IEEE symposium on 3D user interfaces (3DUI)* (pp. 201-210). IEEE.

Filik, R., & Barber, E. (2011). Inner speech during silent reading reflects the reader's regional accent. *PloS one*, *6*(10), e25782.

Freeman, D., Haselton, P., Freeman, J., Spanlang, B., Kishore, S., Albery, E., Denne, M., Brown, P., Slater, M. & Nickless, A. (2018). Automated psychological therapy using immersive virtual reality for treatment of fear of heights: a single-blind, parallel-group, randomised controlled trial. *The Lancet Psychiatry*, *5*(8), 625-632.

Freeman, D., Reeve, S., Robinson, A., Ehlers, A., Clark, D., Spanlang, B., & Slater, M. (2017). Virtual reality in the assessment, understanding, and treatment of mental health disorders. *Psychological medicine*, *47*(14), 2393-2400.

Friston, K. (2002). Functional integration and inference in the brain. *Progress in neurobiology*, *68*(2), 113-143.

Friston, K. (2003). Learning and inference in the brain. *Neural Networks*, *16*(9), 1325-1352.

Friston, K. (2005). A theory of cortical responses. Philosophical transactions of the Royal Society B: Biological sciences, 360(1456), 815-836.

Friston, K. (2010). The free-energy principle: a unified brain theory?. Nature reviews neuroscience, 11(2), 127-138.

Girard, B., Turcotte, V., Bouchard, S., & Girard, B. (2009). Crushing virtual cigarettes reduces tobacco addiction and treatment discontinuation. *CyberPsychology & Behavior*, *12*(5), 477-483.

Glover, E. D., Nilsson, F., Westin, Å., Glover, P. N., Laflin, M. T., & Persson, B. (2005). Developmental history of the Glover-Nilsson smoking behavioral questionnaire. *American journal of health behavior*, 29(5), 443-455.

Grossmann, I., & Kross, E. (2014). Exploring Solomon's paradox: Self-distancing eliminates the self-other asymmetry in wise reasoning about close relationships in younger and older adults. *Psychological science*, *25*(8), 1571-1580.

Hayden, D. (2021). Retrieved from. https://www.oculus.com/blog/five-years-of-vr-a-look-at-the-greatest-moments-from-oculus-rift-to-quest-2/

Heather, N., & Bradley, B. P. (1990). Cue exposure as a practical treatment for addictive disorders: why are we waiting?. *Addictive Behaviors*, *15*(4), 335-337.

Heather, N., & Greeley, J. (1990). Cue exposure in the treatment of drug dependence: the potential of a new method for preventing relapse. *Drug and alcohol review*, *9*(2), 155-168.

Heatherton, T. F., Kozlowski, L. T., Frecker, R. C., & Fagerstrom, K. O. (1991). The Fagerström test for nicotine dependence: a revision of the Fagerstrom Tolerance Questionnaire. *British journal of addiction*, *86*(9), 1119-1127.

Held, R., & Durlach, N. (1991). Telepresence, time delay and adaptation. Pictorial communication in virtual and real environments. 232 – 246.

Held, R. (1992). Telepresence. The Journal of the Acoustical Society of America, 92(4), 2458-2458.

Hershfield, H. E. (2011). Future self-continuity: How conceptions of the future self transform intertemporal choice. *Annals of the New York Academy of Sciences*, *1235*(1), 30-43.

Hershfield, H. E., Cohen, T. R., & Thompson, L. (2012). Short horizons and tempting situations: Lack of continuity to our future selves leads to unethical decision making and behavior. *Organizational Behavior and Human Decision Processes*, *117*(2), 298-310.

Hershfield, H. E., Goldstein, D. G., Sharpe, W. F., Fox, J., Yeykelis, L., Carstensen, L. L., & Bailenson, J. N. (2011). Increasing saving behavior through age-progressed renderings of the future self. *Journal of marketing research*, *48*(SPL), S23-S37.

Heydari, G., Masjedi, M., Ahmady, A. E., Leischow, S. J., Lando, H. A., Shadmehr, M. B., & Fadaizadeh, L. (2014). A comparative study on tobacco cessation methods: a quantitative systematic review. *International journal of preventive medicine*, 5(6), 673.

Hobson, J. A., & Friston, K. J. (2012). Waking and dreaming consciousness: neurobiological and functional considerations. *Progress in neurobiology*, *98*(1), 82-98.

Hohwy, J. (2016). The self-evidencing brain. *Noûs*, *50*(2), 259-285.

Hohwy, J. (2020). New directions in predictive processing. *Mind & Language*, *35*(2), 209-223.

Jaeger, B. K., & Mourant, R. R. (2001, October). Comparison of simulator sickness using static and dynamic walking simulators. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 45, No. 27, pp. 1896-1900). Sage CA: Los Angeles, CA: SAGE Publications.

Kemeny, A., Chardonnet, J. R., Colombet, F., Kemeny, A., Chardonnet, J. R., & Colombet, F. (2020). Reducing cybersickness. *Getting Rid of Cybersickness: In Virtual Reality, Augmented Reality, and Simulators*, 93-132.

Kennedy, R. S., & Frank, L. H. (1985). A review of motion sickness w ith special reference to simulator sickness.

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology*, *3*(3), 203-220.

Keshavarz, B., Riecke, B. E., Hettinger, L. J., & Campos, J. L. (2015). Vection and visually induced motion sickness: how are they related?. *Frontiers in psychology*, *6*, 472.

Kilteni, K., Groten, R., & Slater, M. (2012). The sense of embodiment in virtual reality. *Presence: Teleoperators and Virtual Environments*, *21*(4), 373-387.

Kilteni, K., Maselli, A., Kording, K. P., & Slater, M. (2015). Over my fake body: body ownership illusions for studying the multisensory basis of own-body perception. *Frontiers in human neuroscience*, *9*, 141.

Kilteni, K., Normand, J. M., Sanchez-Vives, M. V., & Slater, M. (2012). Extending body space in immersive virtual reality: a very long arm illusion. *PloS one*, *7*(7), e40867.

Kim, K., Rosenthal, M. Z., Zielinski, D. J., & Brady, R. (2014). Effects of virtual environment platforms on emotional responses. *Computer methods and programs in biomedicine*, *113*(3), 882-893.

Knill, D. C., & Pouget, A. (2004). The Bayesian brain: the role of uncertainty in neural coding and computation. *TRENDS in Neurosciences*, *27*(12), 712-719.

Kolasinski, E. M. (1995). Simulator sickness in virtual environments.

Kokkinara, E., Kilteni, K., Blom, K. J., & Slater, M. (2016). First person perspective of seated participants over a walking virtual body leads to illusory agency over the walking. *Scientific reports*, *6*(1), 28879.

Kollins, S. H. (2003). Delay discounting is associated with substance use in college students. *Addictive behaviors*, *28*(6), 1167-1173.

Kumparak, G. (2015) Retrieved from. https://techcrunch.com/2015/12/08/htc-vive-finally-gets-a-release-date-april-2016/?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAALh44JFdALl70ZbLXiqwObBMUcFCzQ5OuujfhDWs7Y3gpyfphaaMhwe6jDg6t_wnfI7gvCnnFzVTt5Z1Jw_1XjG8bSZI2IFSbdvGXO5G3lWra3JJjz_lw98FK46DWf0pXLv-hVKLm4LvOTdAbpU3TLUIl39wQfWHBBIcTiBkOW2q

Lackner, J. R. (1988). Some proprioceptive influences on the perceptual representation of body shape and orientation. *Brain*, *111*(2), 281-297.

Lanier, J. (1988). A vintage virtual reality interview, whole earth review. Retrieved from. http://www.jaronlanier.com/jaron%20whole%20earth%20review.pdf

Lanier, J. (2017). Dawn of the new everything: Encounters with reality and virtual reality. Henry Holt and Company.

Lackner, J. R. (1988). Some proprioceptive influences on the perceptual representation of body shape and orientation. *Brain*, *111*(2), 281-297.

LaViola Jr, J. J. (2000). A discussion of cybersickness in virtual environments. *ACM Sigchi Bulletin*, *32*(1), 47-56.

Lee, J. H., Ku, J., Kim, K., Kim, B., Kim, I. Y., Yang, B. H., ... & Kim, S. I. (2003). Experimental application of virtual reality for nicotine craving through cue exposure. *CyberPsychology & Behavior*, *6*(3), 275-280.

Lee, J., Lim, Y., Graham, S. J., Kim, G., Wiederhold, B. K., Wiederhold, M. D., ... & Kim, S. I. (2004). Nicotine craving and cue exposure therapy by using virtual environments. *CyberPsychology & Behavior*, *7*(6), 705-713.

Lenggenhager, B., Tadi, T., Metzinger, T., & Blanke, O. (2007). Video ergo sum: manipulating bodily self-consciousness. *Science*, *317*(5841), 1096-1099.

Levy, B. R., Slade, M. D., & Kasl, S. V. (2002). Longitudinal benefit of positive self-perceptions of aging on functional health. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *57*(5), P409-P417.

Levy, B. R., Slade, M. D., Kunkel, S. R., & Kasl, S. V. (2002). Longevity increased by positive self-perceptions of aging. *Journal of personality and social psychology*, *83*(2), 261.

Levin, D. T., & Simons, D. J. (1997). Failure to detect changes to attended objects in motion pictures. *Psychonomic Bulletin & Review*, *4*, 501-506.

Liberman, N., & Trope, Y. (1998). The role of feasibility and desirability considerations in near and distant future decisions: A test of temporal construal theory. *Journal of personality and social psychology*, *75*(1), 5.

Lichtenstein, E., Lando, H. A., & Nothwehr, F. (1994). Readiness to quit as a predictor of smoking changes in the Minnesota Heart Health Program. *Health Psychology*, *13*(5), 393.

Lin, J. W., Duh, H. B. L., Parker, D. E., Abi-Rached, H., & Furness, T. A. (2002, March). Effects of field of view on presence, enjoyment, memory, and simulator sickness in a virtual environment. In *Proceedings ieee virtual reality 2002* (pp. 164-171). IEEE.

Llobera, J., Beacco, A., Oliva, R., Şenel, G., Banakou, D., & Slater, M. (2021). Evaluating participant responses to a virtual reality experience using reinforcement learning. *Royal Society Open Science*, *8*(9), 210537.

Lohse, A. L., Kjær, C. K., Hamulic, E., Lima, I. G., Jensen, T. H., Bruni, L. E., & Nilsson, N. C. (2019, March). Leveraging change blindness for haptic remapping in virtual environments. In *2019 IEEE 5th Workshop on Everyday Virtual Reality (WEVR)* (pp. 1-5). IEEE.

Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behaviour research and therapy, 33*(3), 335-343.

Lucas-Carrasco, R. (2012). Reliability and validity of the S panish version of the W orld H ealth O rganization-F ive W ell-B eing I ndex in elderly. *Psychiatry and Clinical Neurosciences*, *66*(6), 508-513.

Luo, Y., Jackson, T., Wang, X., & Huang, X. (2013). Neural correlates of self-appraisals in the near and distant future: an event-related potential study. *Plos one*, *8*(12), e84332.

Magill, M., & Ray, L. A. (2009). Cognitive-behavioral treatment with adult alcohol and illicit drug users: a meta-analysis of randomized controlled trials. *Journal of studies on alcohol and drugs*, *70*(4), 516-527.

Maister, L., Slater, M., Sanchez-Vives, M. V., & Tsakiris, M. (2015). Changing bodies changes minds: owning another body affects social cognition. *Trends in cognitive sciences*, *19*(1), 6-12.

Martin, D., Sun, X., Gutierrez, D., & Masia, B. (2023). A Study of Change Blindness in Immersive Environments. *IEEE Transactions on Visualization and Computer Graphics*, *29*(5), 2446-2455.

Martínez, C., Martínez-Sánchez, J. M., Ballbe, M., Nieva, G., Fu, M., Puig, M., Carabasa, E., Sánchez-García, J. M., Saltó, E., Fernández, E., & Tobacco Cessation Program Project Coordinators. (2012). Smoking cessation in hospital workers: Effectiveness of a coordinated program in 33 hospitals in Catalonia (Spain). *Cancer Nursing, 35*(5), 327-336.

Markus, H., & Nurius, P. (1986). Possible selves. *American psychologist*, *41*(9), 954.

Masiero, M., Lucchiari, C., & Pravettoni, G. (2015). Personal fable: optimistic bias in cigarette smokers. *International journal of high risk behaviors & addiction*, *4*(1).

McCauley, M. E., & Sharkey, T. J. (1992). Cybersickness: Perception of self-motion in virtual environments. *Presence: Teleoperators & Virtual Environments*, *1*(3), 311-318.

Meta Quest Blog (2021). https://www.meta.com/en-gb/blog/quest/introducing-oculus-air-link-a-wireless-way-to-play-pc-vr-games-on-oculus-quest-2-plus-infinite-office-updates-support-for-120-hz-on-quest-2-and-more/

Middleton, E. T., & Morice, A. H. (2000). Breath carbon monoxide as an indication of smoking habit. *Chest*, *117*(3), 758-763.

Miller, W. R. (1992). Motivational enhancement therapy manual: A clinical research guide for therapists treating individuals with alcohol abuse and dependence (Vol. 2). US Department of Health and Human Services, Public Health Service, Alcohol, Drug

Abuse, and Mental Health Administration, National Institute on Alcohol Abuse and Alcoholism.

Moon, J., & Lee, J. H. (2009). Cue exposure treatment in a virtual environment to reduce nicotine craving: a functional MRI study. *CyberPsychology & Behavior*, *12*(1), 43-45.

Moreno-Briseño, P., Díaz, R., Campos-Romo, A., & Fernandez-Ruiz, J. (2010). Sex-related differences in motor learning and performance. *Behavioral and brain functions*, *6*(1), 1-4.

Morin, A., & Everett, J. (1990). Inner speech as a mediator of self-awareness, self-consciousness, and self-knowledge: An hypothesis. *New ideas in psychology*, *8*(3), 337-356.

Morin, A., & Hamper, B. (2012). Self-reflection and the inner voice: activation of the left inferior frontal gyrus during perceptual and conceptual self-referential thinking. *The open neuroimaging journal*, *6*, 78.

Morin, A., & Michaud, J. (2007). Self-awareness and the left inferior frontal gyrus: inner speech use during self-related processing. *Brain research bulletin*, *74*(6), 387-396.

Moss, J. D., & Muth, E. R. (2011). Characteristics of head-mounted displays and their effects on simulator sickness. *Human factors*, *53*(3), 308-319.

Murphy-Hoefer, R., Alder, S., & Higbee, C. (2004). Perceptions about cigarette smoking and risks among college students. *Nicotine & Tobacco Research*, *6*(Suppl_3), S371-S374.

Naito, E., & Ehrsson, H. H. (2001). Kinesthetic illusion of wrist movement activates motor-related areas. *Neuroreport*, *12*(17), 3805-3809.

Nerín, I., Crucelaegui, A., Novella, P., Beamonte, A., Sobradiel, N., Bernal, V., & Gargallo, P. (2005). Evaluación de la dependencia psicológica mediante el test de Glover-Nilsson en el tratamiento del tabaquismo. *Archivos de Bronconeumología*, 41(9), 493-498.

Normand, J. M., Giannopoulos, E., Spanlang, B., & Slater, M. (2011). Multisensory stimulation can induce an illusion of larger belly size in immersive virtual reality. *PloS one*, *6*(1), e16128.

Nussbaum, S., Liberman, N., & Trope, Y. (2006). Predicting the near and distant future. *Journal of Experimental Psychology: General*, *135*(2), 152.

Oliva, R., Beacco, A., Navarro, X., & Slater, M. (2022). QuickVR: A standard library for virtual embodiment in unity. *Frontiers in Virtual Reality*, 128.

Oculus VR (2018) https://www.oculus.com/blog/introducing-oculus-quest-our-first-6dof-all-in-one-vr-system-launching-spring-2019/

Oculus VR (2020) https://developer.oculus.com/blog/introducing-oculus-quest-2-the-next-generation-of-all-in-one-vr/

O'regan, J. K., & Noë, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and brain sciences*, *24*(5), 939-973.

Osimo, S. A., Pizarro, R., Spanlang, B., & Slater, M. (2015). Conversations between self and self as Sigmund Freud—A virtual body ownership paradigm for self counselling. *Scientific reports*, *5*(1), 1-14.

Palmisano, S., Mursic, R., & Kim, J. (2017). Vection and cybersickness generated by head-and-display motion in the Oculus Rift. *Displays*, *46*, 1-8.

Parker, K. I. (1992). Solomon as philosopher king? The nexus of law and wisdom in 1 Kings 1-11. *Journal for the Study of the Old Testament*, *17*(53), 75-91.

Peck, T. C., Seinfeld, S., Aglioti, S. M., & Slater, M. (2013). Putting yourself in the skin of a black avatar reduces implicit racial bias. *Consciousness and cognition*, *22*(3), 779-787.

Peres, S. C., Pham, T., & Phillips, R. (2013, September). Validation of the system usability scale (SUS) SUS in the wild. In *Proceedings of the human factors and ergonomics society annual meeting* (Vol. 57, No. 1, pp. 192-196). Sage CA: Los Angeles, CA: SAGE Publications.

Pericot-Valverde, I., Germeroth, L. J., & Tiffany, S. T. (2016). The use of virtual reality in the production of cue-specific craving for cigarettes: a meta-analysis. *Nicotine & Tobacco Research*, *18*(5), 538-546.

Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: perceptual illusion of body swapping. *PloS one*, *3*(12), e3832.

Petkova, V. I., Khoshnevis, M., & Ehrsson, H. H. (2011). The perspective matters! Multisensory integration in ego-centric reference frames determines full-body ownership. *Frontiers in psychology*, *2*, 35.

Piñeiro, B., López-Durán, A., Del Río, E. F., Martínez, Ú., Brandon, T. H., & Becoña, E. (2016). Motivation to quit as a predictor of smoking cessation and abstinence maintenance among treated Spanish smokers. *Addictive Behaviors*, *53*, 40-45.

Prochaska, J. O., DiClemente, C. C., & Norcross, J. C. (1993). In search of how people change: Applications to addictive behaviors. *Addictions Nursing Network*, *5*(1), 2-16.

Pronin, E., Olivola, C. Y., & Kennedy, K. A. (2008). Doing unto future selves as you would do unto others: Psychological distance and decision making. *Personality and social psychology bulletin*, *34*(2), 224-236.

Pronin, E., & Ross, L. (2006). Temporal differences in trait self-ascription: when the self is seen as an other. *Journal of personality and social psychology*, *90*(2), 197.

Prothero, J. D. (1998). The role of rest frames in vection, presence and motion sickness. University of Washington.

Ramachandran, V. S., & Hirstein, W. (1998). The perception of phantom limbs. The DO Hebb lecture. *Brain: a journal of neurology*, *121*(9), 1603-1630.

Rao, R. P., & Ballard, D. H. (1999). Predictive coding in the visual cortex: a functional interpretation of some extra-classical receptive-field effects. *Nature neuroscience*, *2*(1), 79-87.

Rath, J. M., Sharma, E., & Beck, K. H. (2013). Reliability and validity of the Glover-Nilsson smoking behavioral questionnaire. *American journal of health behavior*, 37(3), 310-317.

Reason, J. T. (1978). Motion sickness adaptation: a neural mismatch model. *Journal of the Royal Society of Medicine*, *71*(11), 819-829.

Reason, J. T., & Brand, J. J. (1975). *Motion sickness*. Academic press.

Rebenitsch, L., & Owen, C. (2016). Review on cybersickness in applications and visual displays. *Virtual Reality*, *20*, 101-125.

Reinhard, R., Rutrecht, H. M., Hengstenberg, P., Tutulmaz, E., Geissler, B., Hecht, H., & Muttray, A. (2017). The best way to assess visually induced motion sickness in a fixed-base driving simulator. *Transportation research part F: traffic psychology and behaviour*, *48*, 74-88.

Rensink, R. A., O'regan, J. K., & Clark, J. J. (1997). To see or not to see: The need for attention to perceive changes in scenes. *Psychological science*, *8*(5), 368-373.

Riccio, G. E., & Stoffregen, T. A. (1991). An ecological theory of motion sickness and postural instability. *Ecological psychology*, *3*(3), 195-240.

Riva, G., & Serino, S. (2020). Virtual reality in the assessment, understanding and treatment of mental health disorders. *Journal of clinical medicine*, *9*(11), 3434.

Robertson, D. A., King-Kallimanis, B. L., & Kenny, R. A. (2016). Negative perceptions of aging predict longitudinal decline in cognitive function. *Psychology and aging*, *31*(1), 71.

Robinson, S. M., Sobell, L. C., Sobell, M. B., & Leo, G. I. (2014). Reliability of the Timeline Followback for cocaine, cannabis, and cigarette use. *Psychology of addictive behaviors*, *28*(1), 154.

Ross, M., & Wilson, A. E. (2003). Autobiographical memory and conceptions of self: Getting better all the time. *Current Directions in Psychological Science, 12*(2), 66-69.

Rosson, L. (2014). The virtual interface environment workstation (VIEW), 1990. Retrieved from. https://www.nasa.gov/ames/spinoff/new_continent_of_ideas/

Rutchick, A. M., Slepian, M. L., Reyes, M. O., Pleskus, L. N., & Hershfield, H. E. (2018). Future self-continuity is associated with improved health and increases exercise behavior. *Journal of Experimental Psychology: Applied*, *24*(1), 72.

Sagnier, C., Loup-Escande, E., Lourdeaux, D., Thouvenin, I., & Valléry, G. (2020). User acceptance of virtual reality: an extended technology acceptance model. *International Journal of Human–Computer Interaction*, *36*(11), 993-1007.

Sanchez-Vives, M. V., & Slater, M. (2005). From presence to consciousness through virtual reality. *Nature Reviews Neuroscience*, *6*(4), 332-339.

Sanchez-Vives, M. V., Spanlang, B., Frisoli, A., Bergamasco, M., & Slater, M. (2010). Virtual hand illusion induced by visuomotor correlations. *PloS one*, *5*(4), e10381.

Sandberg, A., Sköld, C. M., Grunewald, J., Eklund, A., & Wheelock, Å. M. (2011). Assessing recent smoking status by measuring exhaled carbon monoxide levels. *PloS one*, *6*(12), e28864.

Şenel, G., & Slater, M. (2020). Conversation with your future self about nicotine dependence. In Virtual Reality and Augmented Reality: 17th EuroVR International Conference, EuroVR 2020, Valencia, Spain, November 25–27, 2020, Proceedings 17 (pp. 216-223). Springer International Publishing.

Senel, G., Macia-Varela, F., Gallego, J., Jensen, H. P., Hornbæk, K., & Slater, M. (2023). Imperceptible body transformation in virtual reality: Saliency of self representation. *Iscience*, *26*(10).

Scott, T. L. (2023). Silver tsunamis, gray ceilings, and 'the problem of older adults': Commentary on "Combatting ageism through virtual embodiment? Using explicit and implicit measures" by Ayalon et al. *International Psychogeriatrics*, *35*(3), 127-130.

Sharples, S., Cobb, S., Moody, A., & Wilson, J. R. (2008). Virtual reality induced symptoms and effects (VRISE): Comparison of head mounted display (HMD), desktop and projection display systems. *Displays*, *29*(2), 58-69.

Shen, Y. I., Nelson, A. J., & Oberlin, B. G. (2022). Virtual reality intervention effects on future self-continuity and delayed reward preference in substance use disorder recovery: pilot study results. *Discover Mental Health*, *2*(1), 19.

Sheridan, T. B. (1992). Musings on telepresence and virtual presence. *Presence Teleoperators Virtual Environ.*, *1*(1), 120-125.

Sheridan, T. B. (1996). Further musings on the psychophysics of presence. *Presence: Teleoperators & Virtual Environments*, *5*(2), 241-246.

Simons, D. J. (2000). Current approaches to change blindness. *Visual cognition*, *7*(1-3), 1-15.

Simons, D. J., Franconeri, S. L., & Reimer, R. L. (2000). Change blindness in the absence of a visual disruption. *Perception*, *29*(10), 1143-1154.

Simons, D. J., & Levin, D. T. (1997). Change blindness. *Trends in cognitive sciences*, *1*(7), 261-267.

Simons, D. J., & Levin, D. T. (1998). Failure to detect changes to people during a real-world interaction. *Psychonomic Bulletin & Review*, *5*, 644-649.

Simons, D. J., & Rensink, R. A. (2005). Change blindness: Past, present, and future. *Trends in cognitive sciences*, *9*(1), 16-20.

Slater, M. (2009). Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1535), 3549-3557.

Slater, M. (2018). Immersion and the illusion of presence in virtual reality. *British Journal of Psychology*, *109*(3), 431-433.

Slater, M., Banakou, D., Beacco Porres, A., Gallego Vila, J., Macia Varela, F., & Oliva Martínez, R. (2022). A separate reality: an update on place illusion and plausibility in virtual reality. *Frontiers in virtual reality*, *3*(Article 914392), 1-16.

Slater, M., Cabriera, C., Senel, G., Banakou, D., Beacco, A., Oliva, R., & Gallego, J. (2022). The sentiment of a virtual rock concert. *Virtual Reality*, 1-25.

Slater, M., Gonzalez-Liencres, C., Haggard, P., Vinkers, C., Gregory-Clarke, R., Jelley, S., ... & Silver, J. (2020). The ethics of realism in virtual and augmented reality. *Frontiers in Virtual Reality*, *1*, 1.

Slater, M., Navarro, X., Valenzuela, J., Oliva, R., Beacco, A., Thorn, J., & Watson, Z. (2018). Virtually being lenin enhances presence and engagement in a scene from the Russian revolution. *Frontiers in Robotics and AI*, *5*, 91.

Slater, M., Neyret, S., Johnston, T., Iruretagoyena, G., Crespo, M. Á. D. L. C., Alabèrnia-Segura, M., Spanlang, B., & Feixas, G. (2019). An experimental study of a virtual reality counselling paradigm using embodied self-dialogue. *Scientific reports*, *9*(1), 1-13.

Slater, M., Pérez Marcos, D., Ehrsson, H., & Sanchez-Vives, M. V. (2008). Towards a digital body: the virtual arm illusion. *Frontiers in human neuroscience*, 6.

Slater, M., & Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. *Frontiers in Robotics and AI*, *3*, 74.

Slater, M., Spanlang, B., Sanchez-Vives, M. V., & Blanke, O. (2010). First person experience of body transfer in virtual reality. *PloS one*, *5*(5), e10564.

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, *6*(6), 603-616.

So, R. H., Lo, W. T., & Ho, A. T. (2001). Effects of navigation speed on motion sickness caused by an immersive virtual environment. *Human factors*, *43*(3), 452-461.

Sobell, L. C., Sobell, M. B., Buchan, G., Cleland, P. A., Fedoroff, I., & Leo, G. I. (1996, November). The reliability of the Timeline Followback method applied to drug, cigarette, and cannabis use. In *30th Annual Meeting of the Association for Advancement of Behavior Therapy, New York, NY*.

Somrak, A., Humar, I., Hossain, M. S., Alhamid, M. F., Hossain, M. A., & Guna, J. (2019). Estimating VR Sickness and user experience using different HMD technologies: An evaluation study. *Future Generation Computer Systems*, *94*, 302-316.

Spanlang, B., Fröhlich, T., Descalzo, V. F., Antley, A., & Slater, M. (2007). The making of a presence experiment: Responses to virtual fire. In *Annual International Workshop on Presence* (pp. 303-307).

Spiegel, J. S. (2018). The ethics of virtual reality technology: Social hazards and public policy recommendations. *Science and engineering ethics*, *24*(5), 1537-1550.

Stanney, K. M., & Hash, P. (1998). Locus of user-initiated control in virtual environments: Influences on cybersickness. *Presence*, *7*(5), 447-459.

Stanney, K. M., Kennedy, R. S., & Drexler, J. M. (1997, October). Cybersickness is not simulator sickness. In *Proceedings of the Human Factors and Ergonomics Society annual meeting* (Vol. 41, No. 2, pp. 1138-1142). Sage CA: Los Angeles, CA: SAGE Publications.

Stanton, A., & Grimshaw, G. (2013). Tobacco cessation interventions for young people. *Cochrane Database of Systematic Reviews*, (8).

Stein, B. E., & Stanford, T. R. (2008). Multisensory integration: current issues from the perspective of the single neuron. *Nature reviews neuroscience*, *9*(4), 255-266.

Stein, J. S., Wilson, A. G., Koffarnus, M. N., Daniel, T. O., Epstein, L. H., & Bickel, W. K. (2016). Unstuck in time: episodic future thinking reduces delay discounting and cigarette smoking. *Psychopharmacology*, *233*, 3771-3778.

Steinicke, F., Bruder, G., Hinrichs, K., & Willemsen, P. (2011). Change blindness phenomena for virtual reality display systems. *IEEE Transactions on visualization and computer graphics*, *17*(9), 1223-1233.

Suma, E. A., Clark, S., Krum, D., Finkelstein, S., Bolas, M., & Warte, Z. (2011, March). Leveraging change blindness for redirection in virtual environments. In *2011 IEEE Virtual Reality Conference* (pp. 159-166). IEEE.

Sutherland, I.E.: The ultimate display. Proc. IFIPS Congress. 2, 506–508 (1965)

Tanaka, N., & Takagi, H. (2004). Virtual reality environment design of managing both presence and virtual reality sickness. *Journal of physiological anthropology and applied human science*, *23*(6), 313-317.

Topp, C. W., Østergaard, S. D., Søndergaard, S., & Bech, P. (2015). The WHO-5 Well-Being Index: a systematic review of the literature. *Psychotherapy and psychosomatics*, *84*(3), 167-176.

Treisman, M. (1977). Motion sickness: an evolutionary hypothesis. *Science*, *197*(4302), 493-495.

Tsakiris, M., Prabhu, G., & Haggard, P. (2006). Having a body versus moving your body: How agency structures body-ownership. *Consciousness and cognition*, *15*

Van Gelder, J. L., Cornet, L. J., Zwalua, N. P., Mertens, E. C., & Van der Schalk, J. (2022). Interaction with the future self in virtual reality reduces self-defeating behavior in a sample of convicted offenders. *Scientific reports*, *12*(1), 2254.

Van Gelder, J. L., Hershfield, H. E., & Nordgren, L. F. (2013). Vividness of the future self predicts delinquency. *Psychological science*, *24*(6), 974-980.

Wallis, G., & Bulthoff, H. (2000). What's scene and not seen: Influences of movement and task upon what we see. *Visual Cognition*, *7*(1-3), 175-190.

Wakslak, C. J., Nussbaum, S., Liberman, N., & Trope, Y. (2008). Representations of the self in the near and distant future. *Journal of personality and social psychology*, *95*(4), 757.

Weech, S., Kenny, S., & Barnett-Cowan, M. (2019). Presence and cybersickness in virtual reality are negatively related: a review. *Frontiers in psychology*, *10*, 158.

Wegner, D. M. (2004). Précis of the illusion of conscious will. *Behavioral and Brain Sciences*, *27*(5), 649-659.

White, C. B., & Caird, J. K. (2010). The blind date: The effects of change blindness, passenger conversation and gender on looked-but-failed-to-see (LBFTS) errors. *Accident Analysis & Prevention*, *42*(6), 1822-1830.

Wienrich, C., Weidner, C. K., Schatto, C., Obremski, D., & Israel, J. H. (2018, September). A virtual nose as a rest-frame-the impact on simulator sickness and game experience. In *2018 10th international conference on virtual worlds and games for serious applications (VS-Games)* (pp. 1-8). IEEE.

Wilson, A. E., & Ross, M. (2000). The frequency of temporal-self and social comparisons in people's personal appraisals. *Journal of personality and social psychology*, *78*(5), 928.

Wilson, A., & Ross, M. (2003). The identity function of autobiographical memory: Time is on our side. *Memory*, *11*(2), 137-149.

World Health Organization (1998). Wellbeing Measures in Primary Health Care/The Depcare Project. *WHO Regional Office for Europe: Copenhagen*.

World Health Organization Homepage (2021, November 17). *Tobacco*, Leading cause of death, illness and impoverishment. https://www.who.int/news-room/fact-sheets/detail/tobacco

Yi, R., Johnson, M. W., Giordano, L. A., Landes, R. D., Badger, G. J., & Bickel, W. K. (2008). The effects of reduced cigarette smoking on discounting future rewards: An initial evaluation. *the Psychological record*, *58*(2), 163-174.

Appendices

Appendix A

In this Appendix, we present the information sheet and participant informed consent form used in the Simulator Sickness study described in Chapter 4.

All forms were available in English and Spanish, depending on the preference of the participant. Here we present the English version of this document.

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eventLAB
Entorns virtuals en neurociencias i tecnologia
Entornos virtuales en neurociencias y tecnología
Experimental virtual environments for neuroscience

Study Information

This study is part of the European Research Council Advanced Grant MoTIVE (Moments in Time in Immersive Virtual Environments) research grant number 742989.

The Principal Investigator is: Dr Mel Slater, melslater@ub.edu, of the Facultat de Psicologia, Universitat de Barcelona.

This experimental study is approved by the Comissió de Bioètica de la Universitat de Barcelona, IRB number: IRB00003099.

Study on Moving Through a Virtual Reality Under Different Conditions

Thank you for your interest in participating in this virtual reality (VR) study.

Please follow the instructions of the experimenter throughout.

If at any time you wish to end your participation please inform the experimenter.

Safety Notice:

Before continuing please read the following safety notice:

When people use a Virtual Reality system, some experience a certain feeling of nausea, that we call simulator sickness. This feeling is similar to motion sickness or sea sickness. Some symptoms are: general discomfort, fatigue, dizziness, and blurred vision.

If at any point in the study you wish to stop due to this or any other reason, please just do so.

Some research suggests that people who wear a VR headset may experience some minor visual disturbance soon after. We are not aware of long-term studies but there are studies that suggest the presence of this effect after 30 minutes. It has also been documented that sometimes some people have 'flashbacks' related to the virtual experience. With some types of video there is the possibility of generating an epileptic episode, which can happen in some video games, this phenomenon has never happened in our experiments. Remember if at any time you want to stop please just do so, and you will not be required to give any reason.

What is this study about?

The purpose of this study is to understand how people move through a virtual reality scenario depending on the conditions with which they are presented.

In the virtual reality you will be facing a street and your task will be simply to move along the street in a fixed direction.

You will be able to control the speed of movement by using the trigger on the Oculus controller. The amount by which you pull the trigger will determine the speed at which you go.

It is vital that you only go as fast as you are comfortable.

If you feel symptoms of "simulator sickness" then you might be able to overcome that by adjusting your speed.

If you cannot stop feeling simulator sickness then you should stop participating in the study.

The street has 4 segments, 2 night and 2 day.

<u>Oculus Quest 2 headset and controllers</u>

In addition

• The Principle Investigator (Dr Mel Slater) and the researchers on this project commit that confidentiality of personal data that can be obtained in the project will be scrupulously respected, both concerning its academic use and its public dissemination.

• The data collected will not be used for any other study.

• This project is carried out as part of the normal research work of the Principle Investigator and the researchers on the project, and there will be no additional financial or other compensation accruing to these other than their normal salaries or research grant payments.

• You will be paid **10€** for your participation.

Thank you for your participation!

Name(s) and surname(s):

Date:

Signature:

PARTICIPANT CONSENT FORM

Project Title: ………………………………………………………………

The volunteer must read and answer the following questions carefully:
(You must circle the answer that is considered correct)

Have you read all the information that has been provided to you about this project? YES / NO

Have you had the opportunity to ask and comment on questions about the project? YES / NO

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

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

What researcher has told you about this project? (Name and surname) …………………………………………….

Have you understood that you are free to withdraw from this project without this decision causing you any harm? YES / NO

At any time YES / NO

Without giving any reason YES / NO

Have you understood the possible risks associated with your participation in this project? YES / NO

Do you agree to participate? YES / NO

Will you receive any kind of compensation to participate? YES / NO

Do you agree to be videotaped? YES / NO

I certify that:
- I am of legal age (18 years or older).
- I have not consumed more than two units of alcohol in the last 6 hours (2 units of alcohol = 1 beer or 2 glasses of wine).
- I am not taking any type of psychoactive medication.
- I do not suffer from epilepsy.
- I suffer from no pathology that causes dizziness
- I will not be driving a motorised vehicle or be using any type of complex machinery that can be a danger to myself or others for at least 3 hours after finishing the virtual reality experience
- I am not strongly susceptible to motion sickness such as when travelling in a car, boat, or airplane.
- I understand and accept that this experience might cause me to have some feelings of simulator sickness (dizziness)

Signature: ……………………………………… Date: ………………………………………

Name and Surname of the participant: ………………………………………………………………

In the event that you later want to ask a question or comment about this project, or if you want To revoke your participation in it, please contact:
Mel Slater, EVENT Lab for Neuroscience and Technology - Facultat de Psicologia, Universitat de Barcelona, Departament de Psicologia Clinica i Psicobiologia Campus de Mundet. Passeig de la Vall d'Hebron 171, 08035 Barcelona, Spain Tel. +34 93 403 9618 - www.event-lab.org

Place, date, and signature of the researcher: ……………………………………………………………

Appendix B

In this Appendix, we present the information sheet and participant informed consent form used in the Qigong study described in Chapter 5.

All forms were available in English and Spanish, depending on the preference of the participant. Here we present the English version of this document.

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Study Information

Thanks for your participation in the evaluation of this virtual reality experience where you will complete a series of Qigong exercises. This study is part of a series of projects to understand people's responses within a virtual reality environment.

Please read this information carefully and feel free to ask any questions you may have. The researchers will answer all your questions. However, the specific aspects that we are studying in this study cannot be discussed with you until all the sessions are completed.
You will experience a virtual reality recreation of a Qigong session. The study will consist of a single experimental session that will last approximately **30 minutes**. During this session, you will be asked to answer some questions and to perform a task that requires using a Virtual Reality system with an Oculus Quest or Oculus Quest 2 headset and its trackers. You will receive **10 euros** for your participation.

Remember that you are free to leave the experiment at any time without giving explanations. You can also ask us to delete any records of your responses.

Figure 1: Oculus Quest headset and controllers

The information collected during the study will be disseminated in such a way that the participants cannot be individually identified. In all the reports of this work (scientific publications, congresses, etc.) the participants will be discussed as a group and no individual will be identified. In case of mentioning any of the comments or any of the responses of a specific participant, it will always be done completely anonymously.

IMPORTANT

When people use a Virtual Reality system, some often experience a certain feeling of nausea. If at any point in the study you wish to stop due to this or a different reason, please say so and we will stop the experience immediately. Some research suggests that people who use a virtual reality headset may experience some minor visual disturbance soon after. We do not know any long-term studies, but there are studies that prove the presence of this effect after 30 minutes. It has also been documented that sometimes after 30 minutes there are those who have temporary flashbacks related to the virtual experience. With some types of video there is the possibility of generating an epileptic episode, as has been reported to occur in some video games.

Immersive Virtual Reality can have lasting psychological and behavioral influences on participants. Since virtual reality has only recently been introduced to the public, some risks may currently be unknown. However, in all the studies conducted under Prof. Mel Slater's research group over the past 3 decades, no adverse effect of technology on psychology or behavior has ever been found.

Please read, understand well, and sign your informed consent (consent refers to both sessions of the experiment). Remember that you can leave the study at any time without giving any reason. In case you have any questions or comments related to the study please contact us: Prof. Mel Slater (melslater@ub.edu), Gizem Senel (gizemsenel@ub.edu) or Francisco Macia (franciscomacia@ub.edu)

Thank you for your participation!

Name(s) and surname(s):

Date:

Signature

PARTICIPANT CONSENT FORM

Project Title: ………………………………………………………………

The volunteer must read and answer the following questions carefully:
(You must circle the answer that is considered correct)

Have you read all the information that has been provided to you about this project? YES / NO

Have you had the opportunity to ask and comment on questions about the project? YES / NO

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

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

What researcher has told you about this project? (Name and surname) ……………………………………………….

Have you understood that you are free to withdraw from this project without this decision causing you any harm? YES / NO

At any time YES / NO

Without giving any reason YES / NO

Have you understood the possible risks associated with your participation in this project? YES / NO

Do you agree to participate? YES / NO

Will you receive any kind of compensation to participate? YES / NO

<u>I certify that:</u>
- I am of legal age (18 years or older).
- I have not consumed more than two units of alcohol in the last 6 hours (2 units of alcohol = 1 beer or 2 glasses of wine).
- I am not taking any type of psychoactive medication.
- I do not suffer from epilepsy.
- I will not drive cars, motorcycles, or bicycles or use any type of complex machines that could be dangerous for me or others, during the three hours after finishing any Virtual Reality experience in this study.
- I do not suffer from prosopagnosia (face blindness).

Signature: ……………………………………… Date: ………………………………………

Name and Surname of the participant: ………………………………………………………………

In the event that you later want to ask a question or comment about this project, or if you want To revoke your participation in it, please contact:
Mel Slater, EVENT Lab for Neuroscience and Technology - Facultat de Psicologia, Universitat de Barcelona, Departament de Psicologia Clinica i Psicobiologia Campus de Mundet. Passeig de la Vall d'Hebron 171, 08035 Barcelona, Spain Tel. +34 93 403 9618 - www.event-lab.org

Place, date, and signature of the researcher: ……………………………………………………………

Appendix C

In this Appendix, we present the information sheet and participant informed consent form used in the Self-Dialogue with a Virtual Future Self about a Personal Problem study described in Chapter 6.

All forms were available in English and Spanish, depending on the preference of the participant. Here we present the English version of this document.

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Study Information

This study is part of a series of projects to understand people's responses within a virtual reality environment.

Please read this information carefully and feel free to ask any questions you may have. The researchers will answer all your questions. However, the specific aspects that we are studying in this study cannot be discussed with you until all the sessions are completed.

The study will consist of three sessions: the first session will last 25 minutes, the second session will last approximately 50 minutes, and the third session will last 25 minutes. During the first session, you will answer some questions and provide us with your front-facing and full-body pictures in the required format that we will use to build your virtual body. During the second session, you will be asked to perform a task that requires using a Virtual Reality system with an Oculus Quest headset and its trackers, complete questionnaires before and after the virtual task and respond to some interview questions. During the third session, you will be asked to respond to some questions. Each session will take place one week apart from each other.

Remember that you are free to leave the experiment at any time without giving explanations. You can also ask us to delete any records of your responses.

Figure 1: Oculus Quest headset and controllers

The information collected during the study will be disseminated in such a way that the participants cannot be individually identified. In all the reports of this work (scientific publications, congresses, etc.) the participants will be discussed as a group and no individual will be identified. In case of mentioning any of the comments or any of the responses of a specific participant, it will always be done completely anonymously.

The payment will be made in the following way: 10 euros after the second session and 10 euros after the third session.

IMPORTANT

When people use a Virtual Reality system, some often experience a certain feeling of nausea. If at any point in the study you wish to stop due to this or a different reason, please say so and we will stop the experience immediately. Some research suggests that people who use a virtual reality headset may experience some minor visual disturbance soon after. We do not know any long-term studies, but there are studies that prove the presence of this effect after 30 minutes. It has also been documented that sometimes after 30 minutes there are those who have temporary flashbacks related to the virtual experience. With some types of video there is the possibility of generating an epileptic episode, as has been reported to occur in some video games.

Immersive Virtual Reality can have lasting psychological and behavioral influences on participants. Since virtual reality has only recently been introduced to the public, some risks may currently be unknown. However, in all the studies conducted under Prof. Mel Slater's research group over the past 3 decades, no adverse effect of technology on psychology or behavior has ever been found.

Please read, understand well, and sign your informed consent (consent refers to both sessions of the experiment). Remember that you can leave the study at any time without giving any reason. In case you have any questions or comments related to the study please contact us: Prof. Mel Slater (melslater@ub.edu), Gizem Senel (gizemsenel@ub.edu) or Valeria Baragona

(valeria.baragona01@estudiant.upf.edu)

Thank you for your participation!

Name(s) and surname(s):

Date:

Signature:

PARTICIPANT CONSENT FORM

Project Title: …………………………………………………………………

The volunteer must read and answer the following questions carefully:
(You must circle the answer that is considered correct)

Have you read all the information that has been provided to you about this project? YES / NO

Have you had the opportunity to ask and comment on questions about the project? YES / NO

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

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

What researcher has told you about this project? (Name and surname) …………………………………………….

Have you understood that you are free to withdraw from this project without this decision causing you any harm?

YES / NO

At any time YES / NO

Without giving any reason YES / NO

Have you understood the possible risks associated with your participation in this project? YES / NO

Do you agree to participate? YES / NO

Will you receive any kind of compensation to participate? YES / NO

Do you agree to be videotaped? YES / NO

<u>I certify that:</u>
- I am of legal age (18 years or older).
- I have not consumed more than two units of alcohol in the last 6 hours (2 units of alcohol = 1 beer or 2 glasses of wine).
- I am not taking any type of psychoactive medication.
- I do not suffer from epilepsy.
- I will not drive cars, motorcycles, or bicycles or use any type of complex machines that could be dangerous for me or others, during the three hours after finishing any Virtual Reality experience in this study.
- I do not suffer from post-traumatic stress disorder or any other type of psychological disorder.

Signature: ……………………………………… Date: ………………………………………

Name and Surname of the participant: ………………………………………………………………

In the event that you later want to ask a question or comment about this project, or if you want To revoke your participation in it, please contact:
Mel Slater, EVENT Lab for Neuroscience and Technology - Facultat de Psicologia, Universitat de Barcelona, Departament de Psicologia Clinica i Psicobiologia Campus de Mundet. Passeig de la Vall d'Hebron 171, 08035 Barcelona, Spain Tel. +34 93 403 9618 - www.event-lab.org

Place, date, and signature of the researcher: ……………………………………………………………

Appendix D

In this Appendix, we present the information sheet and participant informed consent form used in the Self-dialogue with Virtual Future Self about Nicotine Dependence study described in Chapter 6.

The forms were only available in Spanish.

HOJA DE INFORMACIÓN (HCB/2022/0083, versión 4.0)

Título del estudio: Auto-diálogo con el yo virtual del futuro sobre la dependencia a la nicotina.

(Self-dialogue with Virtual Future Self about Nicotine Dependence.)

Promotor:

August pi i Sunyer Biomedical Research Institute (IDIBAPS)

Investigador principal:

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Investigador responsable de las sesiones de realidad virtual:

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Introducción

Este documento informa sobre un estudio de investigación en el que se le invita a participar. El estudio ha sido aprobado por un Comité de Ética de la Investigación, de acuerdo con la legislación vigente, Ley de Investigación Biomédica 14/2007.

Nuestra intención es tan solo que usted reciba la información correcta y suficiente para que pueda evaluar y juzgar si quiere o no participar en este estudio. Para ello lea esta hoja informativa con atención y nosotros le aclararemos las dudas que le puedan surgir después de la explicación. Además, puede consultar con las personas que considere oportuno.

Participación voluntaria

Debe saber que su participación en este estudio es voluntaria y que puede decidir no participar o cambiar su decisión y retirar el consentimiento en cualquier momento, sin que por ello se altere la relación con su médico o un profesional de la salud ni se produzca perjuicio alguno en su tratamiento.

Compensacion economica

Los participantes recibirán 20 euros por su participación. Recibirán 15 euros tras la segunda sesión y 5 euros tras la última sesión.

Descripción general del estudio:

La realidad virtual (VR) es una interfaz de computadora que simula un entorno realista. Los participantes pueden moverse e interactuar en el mundo virtual. La realidad virtual se puede utilizar para comprender, evaluar y tratar los trastornos mentales y la adicción.

El estudio constará de cuatro sesiones: la primera sesión tendrá una duración de 15 minutos, la segunda sesión tendrá una duración aproximada de 50 minutos, la tercera sesión tendrá una duración de 25 minutos, y la cuarta de 25 minutos. Durante la primera sesión, responderá algunas preguntas y luego nos enviará sus fotos de frente y de cuerpo completo en el formato requerido que usaremos para construir su cuerpo virtual. Sus archivos de imagen solo se utilizarán para crear sus avatares virtuales y se mantendrán en una carpeta cifrada en un servidor seguro de HCB al que solo podrán acceder los investigadores de este experimento. La segunda sesión tendrá lugar una semana después de la primera sesión. Durante la segunda sesión, se le pedirá que realice una tarea que requiere el uso de un sistema de realidad virtual con un casco Oculus Quest y sus controles, completar cuestionarios antes y después de la tarea virtual y responder algunas preguntas de la entrevista. La tercera sesión tendrá lugar una semana después de la segunda sesión y se le pedirá que responda algunas preguntas. La cuarta sesión, que es una sesión de seguimiento, tendrá lugar un mes después de la tercera sesión. Durante las sesiones 2, 3 y 4 le pediremos que realice también una medida de los niveles de monóxido de carbono en el aire expirado, que nos servirá para evaluar de manera bioquímica qué cantidad de tabaco ha fumado en las horas o días previos. Para ello sólo deberá soplar a través de un pequeño tubo conectado a una máquina que mide el monóxido de carbono.

El estudio tiene como objetivo reclutar a 90 participantes, para asignarlos aleatoriamente a una de tres condiciones diferentes: “Futuro no fumador”, “Futuro fumador” y “Yo actual”. Los participantes tendrán una probabilidad de 1/3 de estar en el grupo controlado, que es la condición “Yo actual”.

Riesgos

Cuando la gente usa un sistema de RV, algunas personas podrían experimentar cierta sensación de mareo o estrés. Algunos tipos de video podrían llegar a generar un episodio epiléptico, como se ha informado que ocurre en algunos videojuegos. Por tanto, por razones de seguridad, participantes con epilepsia, jaquecas o mareos y personas que vayan a conducir coches/motos/bicicletas o a trabajar con maquinaria compleja o peligrosa inmediatamente después del estudio, no pueden participar en este estudio.

Además, el estudio podría desencadenar algunos pensamientos y emociones relacionados con el tabaquismo. Durante toda la sesión se seguirá el protocolo de seguridad de COVID-19 especial aprobado por el Comité de Ética de Investigación.

Las gafas de realidad virtual
con los mandos

El dispositivo de desinfección Cleanbox
para limpiar las gafas de RV

Beneficios

El tratamiento puede proporcionar disminución de la dependencia física y conductual de fumar cigarrillos. Asimismo, es posible que el participante no obtenga ningún beneficio.

Confidencialidad

El Hospital Clínic de Barcelona, con CIF 0802070C, como responsable del tratamiento de sus datos, le informa que el tratamiento, la comunicación y la cesión de los datos de carácter personal de todos los participantes se ajustará al cumplimiento del Reglamento UE 2016/679 del Parlamento Europeo y deo de 27 de abril de 2016 relativo a la protección de las personas físicas en cuanto al tratamiento de datos personales y la libre circulación de datos, siendo de obligado cumplimiento a partir del 25 de mayo del 2018. La base legal que justifica el tratamiento de sus datos es el consentimiento que da en este acto, conforme a lo establecido en el artículo 9 del Reglamento UE 2016/679.

Los datos recogidos para estos estudios se recogerán identificados únicamente mediante un código, por lo que no se incluirá ningún tipo de información que permita identificar a los participantes. Sólo el médico del estudio y sus colaboradores con un permiso específico podrán relacionar sus datos recogidos en el estudio con su historia clínica.

Su identidad no estará al alcance de ninguna otra persona a excepción de una urgencia médica o requerimiento legal. Podrán tener acceso a su información personal identificada, las autoridades sanitarias, el Comité de Ética de Investigación y personal autorizado por el promotor del estudio, cuando sea necesario para comprobar datos y procedimientos del estudio, pero siempre manteniendo la confidencialidad de acuerdo a la legislación vigente.

Sólo se cederán a terceros y a otros países los datos codificados, que en ningún caso contendrán información que pueda identificar al participante directamente (como nombre y apellidos, iniciales, dirección, número de la seguridad social, etc.). En el supuesto de que se produjera esta cesión, sería para la misma finalidad del estudio descrito y garantizando la confidencialidad.

Si se realizara una transferencia de datos codificados fuera de la UE, ya sea a entidades relacionadas con el centro hospitalario donde usted participa, a prestadores de servicios o a investigadores que colaboren con su médico, sus datos quedarán protegidos por salvaguardas como contratos u otros mecanismos establecidos por las autoridades de protección de datos.

Además de los derechos que ya contemplaba la legislación anterior (acceso, modificación, oposición y cancelación de datos, supresión en el nuevo Reglamento) ahora también puede limitar el tratamiento de datos que sean incorrectos, solicitar una copia o que se trasladen a un tercero (portabilidad) los datos que usted ha facilitado para el estudio. Para ejercitar estos derechos, o si desea saber más sobre confidencialidad, deberán dirigirse al investigador principal del estudio o al Delegado de Protección de Datos del Hospital Clínic de Barcelona a través de protecciodades.recerca@clinic.cat. Asímismo tienen derecho a dirigirse a la Agencia de Protección de Datos si no quedara satisfecho/a.

Los datos ya recogidos no se pueden eliminar aunque usted abandone el estudio, para garantizar la validez de la investigación y cumplir con los deberes legales y los requisitos de autorización de medicamentos. Pero no se recogerán nuevos datos si usted decide dejar de participar.

El Investigador y el Promotor están obligados a conservar los datos recogidos para el estudio al menos hasta 5 años tras su finalización. Posteriormente, la información personal solo se conservará por el centro para el cuidado de su salud y por el promotor para otros fines de investigación científica si el paciente hubiera otorgado su consentimiento para ello, y si así lo permite la ley y requisitos éticos aplicables.

Grabacion de imágenes

El promotor del estudio, en el marco de sus capacidades docentes y de divulgacion cientifica tiene interes en grabar imagenes del acto definido en el encabezado de este documento.

Con la finalidad del estudio, el promotor podrá utilizar las imagenes y guardarlas, manteniendo siempre al confidencialidad de los datos personales como se describe a continuacion. Estas grabaciones serán utilizadas exclusivamente en el marco del estudio. Si se utilizan fotografías (grabaciones de audio / video) para presentaciones o publicaciones de cualquier tipo, los nombres u otra información de identificación no se asociarán con ellas y se garantiza el anonimato completo. [Las grabaciones serán destruidas una vez que se complete el estudio.]

Segun lo previsto en el articulo 2.2 de la Ley organica del 1/1982, del 4 Mayo, de proteccion del derecho al honor, la intimidad y la propia imagen, por la presente usted da su consentimiento a la utilizacion de su imagen por el acto y para el uso y difusion en los temas estipulados en este consentimiento.

De acuerdo con lo establecido en el reglamento UE 2016/679 del 27 Abril relativo a la proteccion de personas fisicas en relacion al tratamiento de sus datos personales el promotor como a responsable del tratamiento, con CIF Q5856414G y domicilio Rosselló 149-156, 08036, Barcelona informa que puede contactar con el delegado de proteccion de datos por correo electrónico: protecciodades.recerca@clinic.cat

Sus datos seran tratados con la finalidad indicada en el encabezado de este documento y se le informará de todas las novedades institucionales que puedan ser de su interes, en base al consentimiento que nos da a traves de la firma de este documento.

Sus imagenes podran ser utilizadas por terceros segun las condiciones indicadas en este documento, sin ceder otra informacion, ni transferir a terceros paises.

Sus datos serán conservados durante el periodo necesario para cumplir con la finalidad para lo que fueron recogidas, asi como determinar posibles responsabilidad derivadas de esta finalidad.
Usted tiene derecho a acceder a sus datos, solicitar la rectificacion de datos inexactos o, si es el caso, solicitar su supresion. Asi como limitar su tratamiento, oponerse y retirar el consentimiento del uso para determinadas finalidades. Estos derechos los puede ejercer a traves de un correo electronico (msanche3@clinic.cat). Tambien le informamos de su derecho a presentar una reclamacion a la Agencia Catalana de Proteccion de Datos frente a cualquier actuacion que considere que vulnera sus derechos.

El promotor se reserva los derechos necesarios para el uso, difusion y explotacion de los materiales y del contenido y no asume ninguna responsabilidad del uso que puedan hacer terceros.

INFORMACION ADICIONAL

Si usted decide retirar el consentimiento para participar en este estudio, ningún dato nuevo será añadido a la base de datos. También debe saber que puede ser excluido del estudio si el promotor y/o los investigadores del estudio lo consideran oportuno, ya sea por motivos de seguridad, por cualquier acontecimiento adverso que se produzca y se considere relacionado con su participación en el estudio o porque consideren que no está cumpliendo con los procedimientos establecidos. En cualquiera de los casos, usted recibirá una explicación adecuada del motivo que ha ocasionado su retirada del estudio

Al firmar la hoja de consentimiento adjunta, se compromete a cumplir con los procedimientos del estudio que se le han expuesto.

Hoja de Consentimiento de Participante

Título del estudio:

“Auto-diálogo con el yo virtual del futuro sobre la dependencia a la nicotina.”. Código de protocolo: *XXXXX (Versión X, fecha)*

Yo, *(nombre y apellidos del participante)* ....

- He leído la hoja de información que se me ha entregado sobre el estudio.
- He podido hacer preguntas sobre el estudio.
- He recibido suficiente información sobre el estudio.
- He hablado con: *(nombre del investigador)* ....
- Comprendo que mi participación es voluntaria.
- Comprendo que puedo retirarme del estudio:
    - Cuando quiera.
    - Sin tener que dar explicaciones.
    - Sin que esto repercuta en mis cuidados médicos.

- De conformidad con lo que establece el Reglamento UE 2016/679 del Parlamento Europeo y del Consejo de 26 de abril de 2016 relativo a la protección de las personas físicas en cuanto al tratamiento de datos personales y la libre circulación de datos, y a la Ley Orgánica 3/2018, de 5 de diciembre, de Protección de Datos Personales y garantía de los derechos digitales, declaro haber sido informado de la existencia de un fichero o tratamiento de datos de carácter personal, de la finalidad de la recogida de éstos y de los destinatarios de la información.

- Presto libremente mi conformidad para participar en el estudio.

Firma del participante | Firma del investigador

Fecha: ____/____/____ | Fecha: ____/____/____

Deseo que me comuniquen la información derivada de la investigación que pueda ser relevante para mí salud:

☐ SI ☐ NO

Firma del participante | Firma del investigador

Fecha: ____/____/____ | Fecha: ____/____/____

Appendix E

Here we present the participants' rights of information in relation to the data processing.

eventLAB
Entorns virtuals en neurociencias i tecnologia
Entornos virtuales en neurociencias y tecnología
Experimental virtual environments for neuroscience

UNIVERSITAT DE BARCELONA

Rights of information in relation to the data processing

When we collect your personal data, they will be pseudonymised, which means that we will assign a code to your personal data, with which your data will be processed from that moment on. Thus, researchers will not have access to data that allows you to be identified, and only the principal investigator will have access to the list in which your data and codes are correlated.

Regarding to the processing of your personal data, we inform you that the General Secretary of the University of Barcelona will be the legal responsible (data controller), with postal address Gran Via de les Corts Catalanes, 585, 08007 Barcelona, and e-mail address secretaria.general@ub.edu.

The purpose of the data processing is managing and executing the MoTIVE project. The lawful basis for the processing of your personal data within the research project is your consent, which you can revoke at any time without having retroactive effect. Your data will be kept for the time necessary to fulfil the purpose for which they were collected and to determine the possible responsibilities that could be derived. The recipient of your personal data is the University itself and those in charge of processing your data on behalf of the University, if applicable. No transfer of data to third parties is envisaged unless there is a legal obligation to do so.

You can access to the data, request data rectification, data erasure and data portability, and request objection or restriction of processing. You can write to the General Secretary, attaching a copy of your DNI or any other appropriate identity document. If you consider that your rights were not attended well enough, you can contact UB's Data Protection Officer, with postal address Gran Via de les Corts Catalanes, 585, 08007 Barcelona and e-mail address protecciodedades@ub.edu. Also, you can lodge a complaint with the Catalan Data Protection Authority.

☐ I confirm that I have read the right of information and I consent the processing of my personal data in the cited terms.

Signature: ……………………………………… Date: ………………………………………