Re-evaluating Reality in the Age of VR: Toward an Embodied VR

by

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Abstract

Virtual reality in its digital and non-digital forms has been followed by a long history of criticisms concerning the reality of the impressions it generates and the justified beliefs we can form about such experiences. Faced with the recent breakthroughs of digital VR, a re-evaluation of past skeptical views (Nozick, 1974; Malcolm, 1963; Radford, 1966) alongside alternative approaches that allow for an accurate comparison between virtual experiences and their non-virtual counterparts is timelier than ever. An embodied approach to virtual experiences can qualify some of the over-generalizations made by skeptics of VR, while at the same time it poses new body-specificity challenges that future VR applications should address if they want to create accurate simulations for all users.

Virtual realism (Heim, 1998; Chalmers, 2016) can explain the material foundation of the digital entities and provide an ontological grounding for virtual entities. At the same time, embodied cognition sheds light on the dynamics of virtual and non-virtual actions and explains how our knowledge about the world and the activities we conduct within it are tightly coupled with how we perceive the world through our bodies. As a result, an embodied definition of VR, which takes the social (Brey, 2003) and physical aspects (Ziemke, 2006) of embodied activities into account, can act as a crucial criterion in determining how similar a virtual experience is to its physical counterpart and whether it is justified for users to hold similar beliefs about the two. In particular, body-ownership, as an important consequence of embodied cognition, can shine light on the extent of the embodiment we can achieve given the technical limitations of today's VR, while it also highlights some of the deficiencies that a one-fits-all approach to virtual embodiment will pose for every future VR application.

Dedication

I dedicate this work to my wife who made everything better.

Acknowledgments

I would like to express my deep gratitude to every faculty member who I had the privilege of learning from at the Digital Humanities program. I'm particularly grateful to Dr. Astrid Ensslin, Dr. Geoffrey Rockwell and Dr. Sean Gouglas for their time, patience and the constructive feedback that allowed me to overcome the obstacles I had to face during this research.

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1. Introduction

When anything new comes along, everyone, like a child discovering the world, thinks that they've invented it, but you scratch a little and you find a caveman scratching on a wall is creating a virtual reality in a sense.

- *Morton Heilig (Hamit 1993, p 57)*

Today's virtual reality (VR) symbolizes one of the greatest breakthroughs of digital technology in recent history. However, modern VR is rooted in a longstanding and constantly evolving tradition of non-digital technologies aimed at bringing into existence something that is –somewhat paradoxically– not "real". A suspicious phenomenon that tries to deceive us with fake impressions if we let it. This has made VR the target of criticism and skepticism that question the extent of VR's ability and the meaning of its virtual experiences. Arguably the most promising –yet sometimes ignored– characteristic of modern VR that can push back against many of these criticisms, is the fact that it involves the human body more than ever before.

If we define VR as any attempt to create desired impressions in users, then even ancient civilizations such as the Egyptians, Chaldeans, Jews, Romans, and Greeks (whose magical illusions were employed to both entertain and control the masses), as well as the more recent 1800s (which experienced a revival of the same platforms for recreational use) all had their own versions of virtual reality.

Despite this rich history, it is not surprising that the artificially manufactured nature of VR spaces would lead some to frame it as an inauthentic or fictitious illusion. According to this view, only the physical world and the attributes associated with "real" experiences are natural, while there is something intrinsically unnatural and unreal about believing one is walking in a park when, in fact, they have been at home, strapped to a computer all along.

The superior status of the physical world in this line of thought is attributed to different ontological and epistemological factors, including the concrete materiality of objects, the consistent and omnipresent causality between actions and reactions, the complex implication of actions, the unpredictability and uniqueness of the reactions to said actions, and the different underlying mechanisms that rule all aspects of our world experience, and that are reflected in the laws of physics, biology and biochemistry.

Also, according to some critics of VR (Langan 2000), virtual events have a superficial underlying structure, and virtual objects are a mere imitation of their physical counterparts that carry enough simulated properties to fool the observer. This leads VR critics to conclude that the effects of VR experience are inferior –and at best temporary– when compared to our real-life experiences. To these critics, since the virtual actions are not really taking place, VR experiences are devoid of the meanings and values typically attributed to the same actions in the real world. For instance, if the virtual chair one sees is not a real chair –and sitting on the said chair might not require the physical act of sitting– then feeling rested as a result of the experience, no matter how powerful the impression might be, is still just fictional.

This relatively old tradition of criticizing virtual experiences does not mean that the expectations from VR and its affordances were any less rigorous, in fact, they have been rapidly increasing during different periods. The most recent wave was in 2016 when - after years of speculation, crowdfunding campaigns, big-money investments and a reincarnated hype around VR, it finally culminated in commercially available products. Many have hoped that this would be the moment of ushering in a new frontier in interactive entertainment (Benedictus, 2014; Burgess, 2016; Parisi, 2015). Initial sales and pre-order figures for headsets such as the HTC Vive, the Facebook-backed Oculus Rift, and the Sony PlayStation VR all seemed to indicate an upcoming voracious market for these new technologies, but the excitement was short-lived. Although experts believed that VR/AR would deliver $4.4billion in revenue by 2018 in the US, one study showed that by the end of 2018 it only achieved $1.8billion and a 6% adoption rate in the US (Roberts 2018). On top of this Takahashi (2018) estimated that this rate of adoption will continue to grow at a slow 2% rate until 2020. To put this into perspective, the share of Americans that own smartphones in 2018 reached 81%, up from 35% in Pew Research Center's first survey of smartphone ownership conducted in 2011. (Pew Research Center, 2018).

This research is not concerned with the market fluctuations of VR products which can have many causes, but it aims to focus our attention on something substantial that many VR discussions miss even though it can explain why some VR experiences might be unsatisfactory. Embodiment as the way through which we experience the world is more than just seeing your avatar through an HDM. By drawing on neurological evidence, this thesis will show that in addition to the multisensory foundation of embodied cognition, the sensorimotor correlations between senses and movements are the basis for the sense of ownership users feel toward their avatars. The body ownership phenomenon can be triggered to transcend the physical body and include external objects and virtual avatars alike. This ownership then lends itself to accurate virtual simulations that will invoke expected results in VR users.

1-1. A Reflection on the Definition

Given the long evolution of VR, one can anticipate that at different periods, the term was used to convey different meanings. News media nowadays, for example, tends to use it as an umbrella term to describe any type of imaginary world created with computer graphics. The symbols for VR in the press are also usually images of hardware such as head-mounted displays, headphones, motion-sensing gloves and etc. (Steuer, 1992, p. 72). This undeniably eases the identification of VR for the broader audience. However, VR as a topic of study in communications, policy making, software development, and media studies, such a hardware-driven definition is too restrictive (Steuer, 1992, p. 73).

A technological definition enforces an oversimplified way of distinguishing what qualifies as VR while at the same time it also ignores all the distinctions that two VR settings might have. For example, based on this definition, putting on an HMD headset is synonymous with using VR, but it does not offer much about an application that only interacts with users through touch and wrist movements as is the case with using a computer mouse.

Early scholarly works attempting to give a working definition for VR tended to be broader than how we understand VR today. For instance, Sutherland (1965) defined VR as the *ultimate display,* a room within which the computer can control the existence of matter. "A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal" (Sutherland 1965, p 508).

Greenbaum (1992) tried to give a more feasible and computer-based definition, according to which VR is an alternate world filled with computer-generated images that respond to human movements. Such a simulated environment is usually visited with the aid of an expensive data suit that features stereo-phonic video goggles and fiber-optic data gloves (Greenbaum, 1992, p.58). The advantage of this definition is that it pinpoints an underlying source of stimuli which is digital computers while also defining the type of stimuli to expect, although it does not cover all our senses.

Another approach explored was to define VR based on the human experience it can create, which shows a shift of focus from the object to the subject, as a result. Against the theoretical backdrop, terms like *presence* (originally known as *telepresence)* and *immersion*, started to appear. Steuer (1992), for example, defines VR as a real or simulated environment through which a perceiver experiences the sensation of being in place without physically being there (Steuer, 1992, p. 76-77). Ijsselsteijn and Riva (2003) also defined VR as an environment capable of producing the sensation of presence. Such a paradigm shift frees VR from the technology used in its implementation, and in the future, versions of VR using only biological or chemical manipulation of neuron systems can still make use of this definition.

The most agreed-upon definition today is that of VR as a computer-generated digital environment that can be experienced and interacted with using the human body (Jerald, 2015; Sherman & Craig, 2003; Jayaram et al., 1997). Creating a connection to computers is justified only because they are so far the most capable systems available for artificially generate sensory stimuli.

This thesis subscribes to the definition of VR as a computer-generated environment with a focus on the role of our embodied interaction with the virtual environment. Such interactions will be analyzed in terms of motor and sensory stimuli from our internal and external senses to investigate how they can contribute to and embodied experience of the virtual environment in chapters 4 and 5. Also, for this work, immersion, and presence will be intentionally left out since, although arguably the topic of the thesis overlaps with both of the concepts, one of the goals of this investigation is to also argue for putting embodiment at the center of how we define both terms. An embodied experience can encompass both presence and immersion and future studies can be dedicated to clarifying their relation.

1-2. Thesis Structure

The second chapter gives a brief history of the long line of technologies that tried to simulate reality. VR in its current digital form is, in a sense, an extension of earlier attempts, dating back to more than 2000 years ago, aimed at re-creating the impression of a phenomenon without necessarily having its usual underlying present. Hence, it is not a surprise that questioning the nature of such simulations has always been a concern for observers. However, the rapid improvements of VR thanks to digital computers has convinced many observers that a comprehensive simulation of reality is within reach and this generation has to find answers for such pressing concerns.

The third chapter provides an assessment of some of the above-mentioned, long-established criticisms of VR by categorizing them into two broad groups. First, it addresses the *skepticisms* that have historically surrounded different iterations of VR regardless of its technological underpinnings. These skepticisms can be further divided it into *skepticism of doing*, *skepticism of being*, and *skepticism of reality* (Cogburn & Silcox, 2014). These skepticisms represent three perspectives that historically have cast doubt on the similarities between the physical and virtual world in terms of the type of actions we can perform, the freedom we can exercise as an actor in VR, and the elements (like objects and properties) that we perceive or interact with inside a virtual environment.

After responding to the skeptics, the chapter then moves on to tackle the *fictionalist* interpretation of VR, by analyzing the epistemological criticisms revolving around the relationship between VR and the mental processes that interpret physical stimuli. Although some fictionalists acknowledge that VR can have the power to trigger authentic cognitive processes, they still believe that the majority of what goes on in VR is limited to a fictional realm inside our heads. In order to respond to this criticism, this thesis employs a more developed iteration of *virtual realism* which was originally introduced by Michael Heim (1998) and later expanded by Philip Brey and David Chalmers (2016). Virtual realism argues for acknowledging virtual objects, virtual properties and virtual events as real physical entities in the outside world. It also explains how the social reality of objects and events is potentially transferable between the virtual and non-virtual worlds, making our virtual experiences potentially as significant as those in the physical realm.

The chapter closes with a discussion on the value of virtual actions and experiences. Even for the proponents of VR, there are legitimate concerns as to how one should think and feel about having done something in a virtual environment. For instance, is it really empathy we are experiencing when we put ourselves in the shoes of immigrants fleeing violence in a VR game? And if so, is that any different from watching a movie on the same topic? And finally, what are the determining factors in terms of the behavioral impact this technology can have on its users?

I argue that, at least for certain types of activities, we can intuitively rely on the accuracy of simulations to answer the questions posed earlier. However, even when we accept that an accurate virtual simulation justifies attributing the value of physical activities to their virtual counterpart, we still need a comprehensive definition for this notion of accuracy. To simplify our analysis, a distinction between what is called *well-defined* activities, such as playing football or practicing martial arts, and not well-defined activities such as sex is proposed. For the first category, accurate simulation means employing all the physical and mental skills involved in performing that activity in the physical world. I argue that, for well-defined activities, accurate simulation will give the virtual activity the same instrumental value as its physical counterpart. Conversely, for not well-defined activities, even defining the notion of accuracy is problematic and sometimes impossible. As a result, something like virtual sex should be primarily analyzed through the subjective psycho-social factors that shape how each individual defines sexual pleasure.

The fourth chapter focuses on expanding the concept of accurate simulations for well-defined actions. Here it is argued that in order to achieve accurate simulations, we should begin with realizing that human cognition is inherently embodied and an accurate simulation is an embodied one. This means that thoughts and actions ranging from high-level mental constructs (such as concepts and categories), performance on various cognitive tasks (such as reasoning or judgment) or even simple physical tasks (such as moving an object) are strongly influenced by aspects of the human body beyond the brain itself. By using the findings of an emerging framework in cognitive science known as Embodied Cognition (EC), this chapter outlines two aspects for embodiment, namely physical and social embodiment which are integral to achieving an embodied virtual experience.

Drawing on some key EC findings, this chapter argues that having a representation of the physical body is a necessary precondition of the physical embodiment. However, this representation should not be limited to audiovisual stimuli and must ultimately even go beyond the traditional big-five senses and cover the proprioceptive and vestibular senses plus their interaction with the rest of our internal and external senses.

Social embodiment is the more subtle and less discussed aspect of embodiment that acknowledges the social functions of that representation as an integral element in interpersonal communications, identity expressions, and broader cognitive processes. Even performing a mundane task like picking up a cup of coffee, is influenced by socio-cultural norms that are not just a necessary result of our physical limitations and follow the conventions of the rest of society and how they go about performing this task.

The fourth chapter ends by identifying three types of affordances needed as preconditions for a physically and socially embodied VR experience. Sensory stimuli, motor controls, and psycho-social considerations for expressing personal and social identity constitute a comprehensive list of what an embodied VR application should provide. However, as the fifth chapter will demonstrate, these affordances can have conflicting impact on users and reaching a perfect alignment between all three groups might not always be possible.

The fifth chapter first begins with a discussion of the *body-specificity hypothesis*, which claims that since our mental processes are formed by our individual and unique bodies, any technology trying to change said processes through some generic manipulation of the body will fall short in its goal. For instance, a VR setting where a person is given a ten feet long mechanical arm will conflict with the existing mappings that have already been formed in individuals based on the length of their real arms which ultimately alienates them from the virtual limb.

This concern presents an opportunity in this chapter to discuss the body-ownership phenomenon and the neural system's capability to adapt and rapidly respond to changes in the body or its virtual extensions. This ability gives major flexibilities to a virtual environment to utilize the correlation of motor, tactile and proprioceptive stimuli with audiovisual inputs in order to overcome some of the body-specificity challenges. The ability to incorporate virtual entities into our existing body schema and establishing an intimate relationship between an avatar and the user can then be used to further involve the user in the virtual environment and utilize VR to trigger unique and unprecedented changes to users.

In particular, three emerging VR applications that utilize correlation principles to benefit from body-ownership in unprecedented ways are outlined. *Body transformation*, *body-swap empathy*, and *implicit learning* are VR applications that primarily rely on sensory and motor correlations to increase body ownership over virtual avatars. By manipulating the avatar in terms of skin color, shape, age, clothing and gender, these applications show how quickly we can adapt to changes in our body which not only induces empathy, reflected in our unconscious bias towards others, it also shines light on the semantics of actions and their preconceived meaning within the social context play a role in how we respond to the changes.

The chapter ends with a discussion of some of the legitimate challenges that the body-specificity hypothesis poses in terms of physical capabilities, sensory sensitivity, body objectification and gender disparity, and that should be taken into account in all future VR applications. These challenges signal that there can be a limit to the flexibility of body-ownership for different user groups and a successful VR design needs to be tailored to meet the additional requirements of these users.

2. A Brief History of VR

VR is often associated with high-tech HMDs[1] that provide audiovisual stimuli. Maybe in the near future, VR even manages to communicate with all our senses (Blascovich & Bailenson, 2011; Jerald, 2015), but it is important to note that there is a much longer history to VR than what has transpired in the past decade. And what ties these technologies together seem to have remained mostly unchanged.

As is the case with other technologies, digital VR seems like a new discovery, but upon further thinking, we find similarities between escaping zombies in a VR video game today and a shadow play in Central Asia in the 1st millennium BCE, the smoke and mirror magic to summon ghosts in the Middle Ages or the panoramic murals of the 19th century battles. They all try to simulate what one would experience if they were to be attacked by a zombie, to hear a dog talk, to see a ghost or to stand in the middle of an epic battle. The goal is to create an impression while circumventing the actual source that such impressions usually rely on.

Smith (1985) describes an apparatus found in many ancient Greek temples that possessed chambers only known to the priests and not the public and priests would introduce themselves using the elevated doors at the end of those chambers and invisible to the masses which would help to create mysteries around them. The most remarkable feature of these doors was that sometimes they were connected to a number of tubes or hollow conduits connecting the interior of the temple ending in different parts of the surrounding walls. Then a simple mechanism would directly connect the door to a trumpet that would make sounds as the door opened for the priest in order to deliver oracles.

[1] Head-mounted display

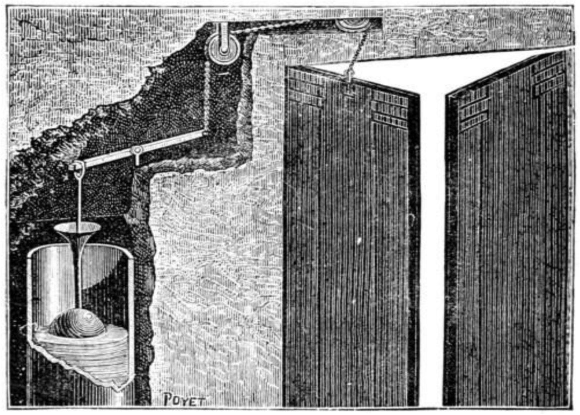

Fig. 1: Apparatus for sounding a trumpet when the door of the temple was opened (Hopkins, 1977, p. 215).

In his book *Spiritalia* (circa 150 B.C.), Heron described a device called Singing Birds Automaton which was a proto-VR installation simulating bird song. It was an airtight metal box, divided into four compartments by horizontal plates. On the top of the box, there was a basin that would receive the water from a fountain and four birds each connected through pipes to different compartments. As the water would fill each compartment and compress the air, it would escape through the beak of each bird that was hollowed out in a way that would make certain musical notes. As the water filled the box, birds would start singing those notes altogether and create amusing music.

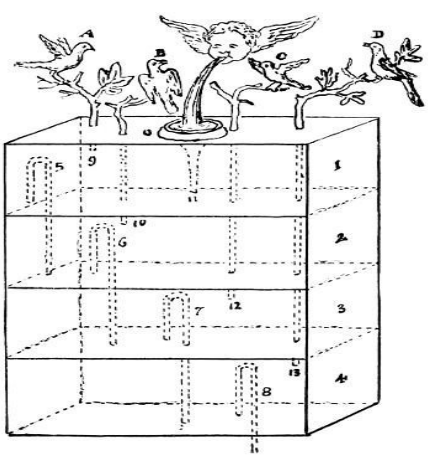

Fig. 2: The Singing Birds Automaton (Hopkins, 1977, p. 242)

Although one can find numerous other examples of such illusions ever since[2], I will skip to more recent cases, starting from the 19th century, in which the main focus of such apparatuses became audience entertainment. Cases such as the stereoscope -a set of goggles invented before photography in 1832 and showed different images to each eye via mirrors- were described by one viewer at the time as: "(...) a surprise such as no painting ever produced. The mind feels its way into the very depth of the picture" (Jerald, 2015, p. 16), which in some ways is very similar to how we perceive VR images today.

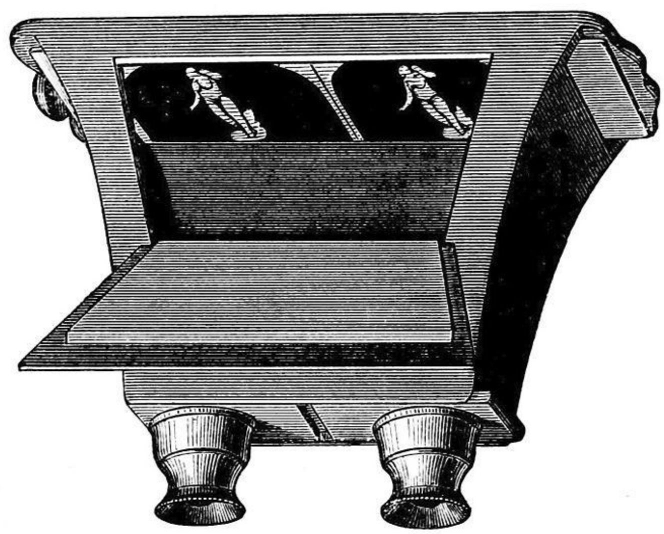

Fig. 3: The Brewster Stereoscope Design (1849).

By the 1860s, a smaller version of stereoscopes with moving handles that would let viewers navigate between pictures were being sold in the order of a million (Jerald, 2015, p. 17).

Towards the end of the 19th century, the film industry was becoming mainstream, which gave the public a chance to see moving pictures for the first time. The idea of moving images itself has a lot in common with the original goal of creating something that is not real. One notable

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[2] To see more examples please refer to *Dictionary of Greek and Roman Antiquities (1853) by* William Smith.

example was the 1896's silent film *Arrival of a Train at La Ciotat*[3] (Loiperdinger, 2004), which, thanks to the angle and the zoom, gave the impression that the approaching train would run over its audience, producing an unprecedented and exciting experience that became an instant hit at the time. This was one of the earliest examples of providing a point of view in a film that could help the audience understand the experience of standing on the tracks as a train approaches.

But it was the twentieth century that witnessed the broadest range of inventions in technologies that by today's standards fall into the category of VR. The first instance of what we now call flight simulators was invented by Edwin Link in 1982 (Jerald, 2015, p. 18), in the form of a small model plane with a cockpit fitting one person that would mechanically move as a result of the pilot pulling some levers. It gave users a rough feeling of what it would be like to pilot a plane. By the end of 1935, reportedly 10,000 of this system were sold.

Fig. 4: Malone Patt's Air Force Link Trainer (1947)

Science fiction novels, like *Pygmalion's Spectacles* (Weinbaum, 1935), also joined the movement, creating narratives meant to be perceived through eyeglasses and other sensory

[3] L'Arrivée d'un train en gare de La Ciotat

equipment. Although at the time they failed to attract any big audience, these inventions paved the way for head-mounted technologies, the most common characteristic of all commercially available VR packages today.

During the second half of the twentieth century, the design of such inventions started to look more and more similar the commercial VR products we see today. Morton Heilig officially patented both a head-mounted and fixed displays in the 1960s through inventions like *Telesphere Mask* and *Big Pix 3D Viewer* that look similar to the VR HMDs we see today (Fig. 3).

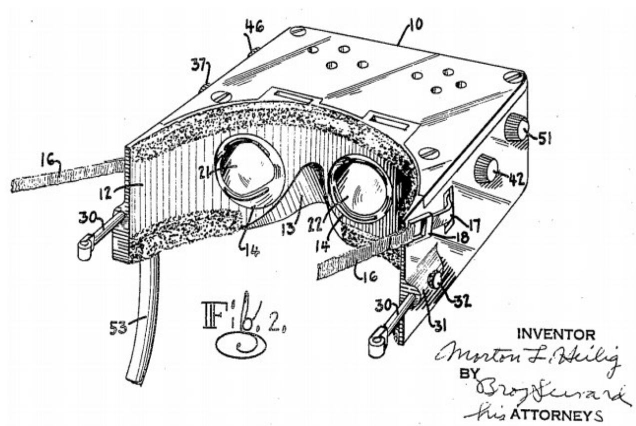

Fig. 5: A drawing from Heilig's 1960 Stereoscopic Television Apparatus patent

By 1961 the capability to track head movements was developed by Philco Corporation, which allowed the user to control the direction of a camera placed in a different room using their head movements. Around the same time, the first instance of a glove designed to ease the interaction between the fingers and a computer was introduced by IBM (Fig. 4).

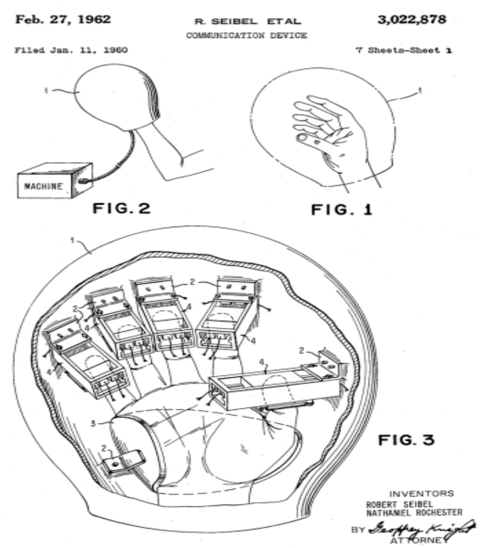

Fig. 6: An image from IBM's 1962 glove patent.

In 1968, Ivan Sutherland became the first person ever to integrate head tracking with computer generated graphics, which he called the *Sword of Damocles* (Sutherland, 1968). Before the end of the 20th century, big institutions like NASA started to get involved in VR with projects like NASA VIEW or Grope-III. In 1985, NASA also released their first commercially available HMD with motion tracking called the LEEP[4] system (Jerald, 2015, p. 23).

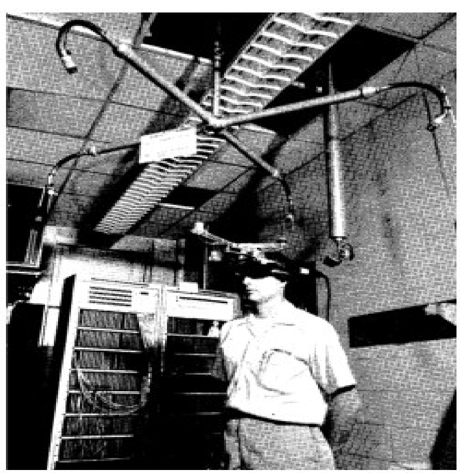

Fig. 7: Ivan Sutherland's Sword of Damocles Setting

[4] Large Expanse, Extra Perspective

During the 1990s, companies like Sega, Disney, and General Motors all started to venture into VR as well. At the time, popular culture in the form of books –*Neuromancer* (1984) and *Virtual Light* (1993) by William Gibson and *The Otherland* (1996) by Tad Williams to mention a few– and movies –*Lawnmower Man* (1992), *Johnny Mnemonic* (1995), *Dark City* (1998), *The Matrix* (1999), *eXistenZ* (1999) – were making their way to the public, creating an imaginary of what this new technology was capable of.

Specialized academic journals like *Presence: Teleoperators & Virtual Environments* (1992) and *Virtual Reality* (1995) dedicated to VR started to appear, and alongside other innovations like AI, virtual reality became the source of wild speculations and predictions.

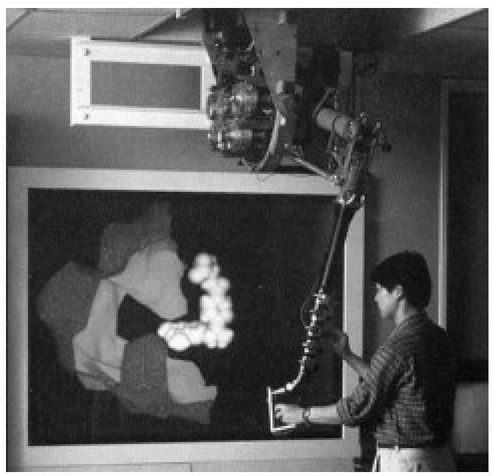

Fig. 8: The GROPE-III haptic display for molecular docking.

The early 21st century, however, marked the winter of VR enthusiasm in both the consumer products and private sector investment. Discoveries on the topic were limited to government and academia, with no new VR products entering the markets. At the time, technical shortcomings such as low-quality displays and heavy computational demands of the software were addressed by shifting the focus of the research into human-centered designs, and the questions concerning

VR were now focused on what needed to be done “right enough” so the average user could feel the magic of VR. For instance, the fact that users need a wide field of view to judge the distance and position of virtual objects is a discovery of this period. A collaboration of the University of South California’s MxR Lab and FakeSpace Lab (Jerald, 2015, pp. 27-28) resulted in an HMD with a 150-degree field of view that eventually became what we now know as Oculus Rift. Starting in 2012, VR appeal experienced a revival, in part because computing technology was becoming powerful enough to be portable, cheap and accessible, which would finally address many of the previous restraints of VR experiments. As a result, both start-ups and Fortune 500 companies - like Facebook, Sony and Amazon –invested in the development of new VR models with thin, light and high-resolution displays, capable of supporting high frame rates were accompanied by powerful batteries and wireless communications techniques that would connect the screens, processing units and controllers together. A new generation of VR was finally here.

3. Re-evaluating Reality in VR

Like alchemy, the theatre is developed from a certain number of fundamentals which are the same for all the arts and which aim on the spiritual and imaginary level at an efficacy analogous to the process which in the physical world actually turns all matter into gold.

- *Antonin Artaud (1958)*

3-1. Introduction

My first experience with virtual reality was playing *Everest (Sólfar Studios, 2016),* a walking simulator which promises users an experience of incomparable fidelity to the real climb. As someone who is not particularly afraid of heights, I was surprised when my legs refused to move when I got close to the summit, while in my mind I chastised myself for being paralyzed by images on a small screen. I jokingly told myself: "My brain is fully aware that what I'm seeing is not real, but someone needs to tell that to the rest of me!".

The significance of that brief experience, with its paradoxical implications –I was there on the mountain, but also safe in my home– triggered an interest to reflect on why I had such contradictory expectations from virtual reality. VR, in all its forms, was only supposed to function as a break from the serious, complex and impactful situations we find in our everyday life, but it was also signaling that it was able to be much more than that.

As we will see later in this chapter, such attitudes towards VR are not new. Critics of VR have consistently expressed skepticism both toward the authenticity of what users sense and feel in

VR and the artificial conditions that underlie those sensations. Terms such as illusory, imaginary, fictional or inauthentic have been used to describe almost every aspect of human interaction with VR systems.

The goal of the current chapter is to offer counterarguments to some of these criticisms and argue that the similarities between virtual and non-virtual experiences, in certain cases, significantly outweigh their differences. In order to do so, the chapter first breaks down these criticisms into two categories, namely *skepticism* and the *fictionalism*.

Skeptics such as Nozick (1974), Malcolm (1963) and Radford (1966) questioned the realness of VR from three different angles: S*kepticism of Doing* is the doubt over whether we can justifiably say that an activity can or even needs to take place inside a virtual environment. Hence, the mentioned virtual activity will not have anything in common with the physical counterpart and, as a result, it is not real. *Skepticism of Being* argues that VR is incapable of allowing its users to exert a sense of personhood, which is in great contrast to our daily experience in the physical world. Finally, *Skepticism of Reality* rejects the authenticity of VR experiences due to the predefined and rigidly programmed dynamics of all virtual environments.

Fictionalists like Juul (2005), Tavinor (2009) and Bateman (2011) frame VR as a newly discovered type of *fiction*, which this thesis will counter using Michael Heim's theory of *Virtual Realism* (1998). Heim argues against the fictional characterization of VR by affirming that virtual objects, properties, and events rely on concrete physical entities and mechanisms, making VR just another newly developed extension of the physical world.

The chapter then moves on to address the social factor in VR and its ability to legitimize virtual experiences. Incorporating John Searle's (1995) framing of *Social Reality* to explain this legitimacy is very useful in this context. Social reality refers to a mixture of beliefs, actions and immaterial entities that are solely dependent upon the social constructs and dynamics of human society to exist, as opposed to *Physical Realities* that are rooted in material entities. This chapter also argues for the *transferability* of social realities into VR and notes that virtual spaces are equally capable of generating their own unique social realities that are then transferred to the non-virtual world.

Finally, the chapter ends with a discussion on how we can evaluate the value of a VR experience relative to its real-world counterpart. Here, two cases, namely *Virtual Martial Arts* and *Virtual Sex,* each representing a broader group of activities, are considered in order to show how different non-virtual experiences draw their value from different sources. Hence, it is argued that virtually simulated martial arts heavily relies on the accuracy of the simulation to provide similar values, while the idea of accuracy becomes an irrelevant factor in cases like virtual sex.

3-2. VR Skepticism

The first known instance of the term virtual reality (VR) was used by the French playwright Antonin Artaud to address the spectrum of characters, objects, images, scenes, plots and all other special effects that were involved in bringing out a reaction from audiences who have been adequately attuned (Artaud 1958, p. 49). The purpose of said factors was to immerse the spectators in the theatrical experience, causing delirium, or trance-like state in them through which it would be possible to convince them of illusions that are not possible under normal conditions. In his view, VR taps into a fertile aspect of the mind with a potential waiting for the right circumstances to flourish and once it is utilized it can heavily influence how audiences interpret their sensory data. This influence reaches a point where what was previously dismissed as an illusion starts to be taken very seriously by the audience.

Today, as the capabilities of digital technology grows and Artaud's vision of VR, in a sense, becomes more feasible, there has been an increase in moral, ethical[5], psychological and behavioral alarmism regarding how VR will adversely influence humans (Durlach & Mavor, 1995; Stanney et al., 1998). Many observers of contemporary culture have long feared that VR, alongside Artificial Intelligence (Yudkowsky, 2008), might become the most imminent threat to our future mental and physical well-being. These concerns, in some respects, have their roots in a reincarnated epistemic worry about all that is artificial and pre-programmed (Cogburn & Silcox, 2014).

In this view, our rich and complex natural world that generally refuses simplification gets replaced with a superficially constructed representation highly tailored to appeal to us. As a result, we get plugged into a world where the surroundings are reduced to what our senses can detect and interactions boil down to their most immediate outcome (Nozick, 1974). For example, a jungle is the objects and properties we can sense regardless of the hidden ecosystems it contains and the relationships that individual elements have formed with each other. Similarly, walking in that jungle becomes equal to changing the observer's point of view while ignoring the fact that each step impacts the jungle and the observer in unpredictable ways.

Whether those who are worried about VR realize it or not, it seems René Descartes had already articulated the root of their epistemic concern in his *Meditations on First Philosophy* (1641).

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[5] Some people think of morality as something personal and normative, whereas ethics is the standards of "good" and "bad" distinguished by a certain community or social setting.

Descartes' hypothesis, commonly known as the evil demon theory, imagines a supernatural evil demon of the utmost power and cunning, who has employed all his might to deceive us into thinking that we are having our everyday life experiences. He argued that since there is no way for us to verify whether we are indeed living under such deception or not, there is always a chance that some - or all - of our beliefs about the outside world are false.

Placed in the context of human-technology interaction, different interpretations of Cartesian skepticism have been used frequently to lay the foundations for a pessimistic view of the human relationship with digital technology. According to such views, the more our social relations and personal experiences are mediated through communication technologies, the more susceptible we are to unwittingly experience a distorted version of reality (Brueckner 1986, p. 148).

This distortion has two independent yet fundamental implications for us. On the epistemic level, it casts doubt on our knowledge of the external world, and on an axiological level, it questions whether there is any genuine value to VR experiences or other artificially generated environments. In articulating their skepticism different philosophers have taken slightly distinct approaches. According to Baudrillard (2000),

> [as media consumers] we are no longer even spectators but receivers… when nothing really ever takes place, since everything is already calculated, audited, and realized in advance. (p. 37)

For skeptics like Baudrillard, VR is inherently deterministic, since the belief that one shapes their own experience in any meaningful way when interacting with VR is just an illusion, and no matter what you do, the result will be a selection from a predefined set of outcomes (Baudrillard

2001, p. 37). As a result, VR's highly customized–and sometimes without original[6]– world pushes all our mental functions –including memory, emotions, sexuality, and intelligence– to become progressively weaker and eventually useless since all they do in VR is to interact with symbols and not reality itself, or worse, with symbols that do not have any reality behind them.

Baudrillard concludes that the fundamental problem with such a grotesque and unbridled technological outgrowth is one of alienation for subjects, the fatal destiny of the subject and the abandoning of critical thought (Baudrillard 2001, p. 17). Everything around us will soon pass beyond its limits by going beyond the laws of physics and metaphysics of our world[7] into what he calls a state of absurd irony and parody.

For example, a highly customized virtual experience designed to draw your attention to an event that is unfolding right in front of you, by stimulating you in all the right ways, can be so powerful that it will undermine any effort not to pay attention to it. This manipulation can be applied further to ensure you make all the expected decisions and behave exactly as the designers expect you to without realizing that nothing you do is causing anything to actually unfold since all of this was already meant to happen and it was the only thing that could have happened.

This brings us to another related criticism regarding the inauthenticity of VR experiences (Bazin, 1967; Gualeni 2015, Relph, 2007; McMahon, 2002). According to this view, authenticity is a state in which the individual becomes aware of the true nature of their human condition. This condition is inherently uncertain, random and, at times, unpleasant for us. In contrast,

[6] Simulacra

[7] Baudrillard calls this the state of Pata-physics, which seems to point at a specific type of metaphysics rather than actually something beyond it. He borrowed the term from Alfred Jarry (1963) who originally defined it as the science of imaginary solutions, which symbolically attributes the properties of objects to their most distinctive attributes (lineaments) (Jarry 1963, p. 131).

inauthenticity happens when the individual is either ignorant or in denial of the true nature of reality.

Broadly speaking, any mediated experience - including those taking place in VR - is likely to be inauthentic, since it carries the possibility to intentionally or unintentionally hide unbearable or undesirable aspects of life in the real world, or to at least partially distort them. A capable VR technology can be very successful in providing its users with a pleasant experience unparalleled in the real world which makes it, in this sense, inauthentic.

This criticism has roots all the way back to Plato's *Allegory of the Cave* (Plato, 1943) in which humans are constrained by the illusory shadows and appearances of ideals that are different from the ideals themselves and one has to always try to push the superficial aside to reach the underlying source of the appearance. However, this version of authenticity, prevalent in existential philosophy, has a particular focus on the distinction between the agencies we should exercise in the real world versus what we are allowed to exercise virtually.

In her article, "Popping a Bitter Pill: Existential Authenticity in *The Matrix* and *Nausea,*" Jennifer McMahon gives an analysis of *The Matrix* protagonist (Neo) and argues the lack of authenticity in the VR environment created by machine overlords justifies leaving the Matrix. McMahon says:

> As Neo illustrates, the insights that authenticity brings are only unbearable as long as we resist them. Though existence may not be everything we want, it is only overwhelming if we insist that it be something other than it is. If one lets go of these expectations, one can see things as they are. Only at this point can one fully appreciate and make use of the remarkable gift of existence. (McMahon 2002, p.177)

This type of interpretation is prevalent when existential philosophy is confronted with the nature of reality. Existential philosophy speaks at length of the sort of choice that Neo, a symbolic presence of each individual, makes between honesty and ignorance, or truth and illusion (McMahon 2002, p. 166). Though some might have used different terminologies, the issue of VR for them boils down to the choice between authenticity and inauthenticity.

Looking at VR as a medium for communication, alongside TV and cinema, makes it the target of another type of criticism pertaining to reductionism. Here, VR is thought to force its users to passively receive flattened down information while complex facts are forced to fit the techniques and forms of the medium. This causes entirely different contents to be presented in the same sensory format. For example, the same screen that can show a Holocaust documentary also shows cereal commercials, making use of the same visual and auditory effects to either focus the attention on the tragic nature of war or leave a greater impression on potential buyers of cereal (Mander 1978, p. 375). This will either eventually desensitize the audience or put the burden back on them to make a judgment about which content was important. The fact that this puts more pressure on the audience undermines the goal of creating content with deeper substance which was probably the goal in the case of a war documentary.

In addition to the above criticism, proponents of subjectivity as the root cause of meaningful experiences are concerned about the widespread use of any communication medium (including VR), since, as the demand for content increases, we tend to start turning our most ordinary acts into movie actions and undaunted and undifferentiated sensory materials (Virilio 1994, p. 47-48). A good demonstration of this phenomenon is how the early and glorious era of cinema - where creating great art was supposedly the goal (Sontag, 1996; Cheshire, 1999; Elsaesser, 2005) – has now been replaced by millions of hours of commercial or user-generated online videos that nobody can possibly watch in their entirety.

It is worth mentioning that there have been other traditions of skepticism toward modern technology, particularly among continental philosophers. Martin Heidegger, a mid-twentieth century philosopher, expressed grave concerns about the very essence of all *extreme* technologies and how they try to dominate our world. He drew attention to technology's place in bringing about our decline by constricting our experience of things as they are and arguing that we now view nature - and increasingly human beings too - only technologically, as raw material for technical operations (Heidegger 1993, p. 314).

For Heidegger, everything we perceive or think of or interact with "emerges out of concealment into unconcealment" (Heidegger 1993, 12). By entering into a particular relation with reality, reality is 'revealed' in a specific way. And this is where technology–including VR– comes in, since technology is the way of revealing that defines our time. Technology embodies a specific way of revealing the world, a revelation in which humans take power over reality. While the ancient Greeks experienced the 'making' of something as 'helping something to come into being'– as Heidegger explains by analyzing classical texts and words– modern technology is rather a 'forcing into being'. Technology reveals the world as raw material, available for production and manipulation.

In order to better understand Heidegger's claim, we have to start by acknowledging two different, yet not mutually exclusive, views on what perception is. The *data-oriented* view understands perception largely as a matter of data input to the mind from the environment. Many VR researchers consider this to be the starting point for understanding perception, and according to this view, we need more and more input (greater quality and quantity) to the senses in order to produce a sense of something real. The implication of this view for our body is that it characterizes the human body as an elaborate device, where “our eyes are stereo input devices mounted on sophisticated gimbal called the neck and so on” (Rheingold 1991, p. 63).

The second view sees perception as primarily *constructed.* According to constructivism, we rely on simple cues from the environment and can be immersed in any situation, depending on our state of mind, culture, interests, personal and collective expectations, and familiarity with the medium (Coyne 1994, p. 66). This view claims that VR can be particularly effective because the users are immersed in their task, and also because they will become part of a culture where VR experiences/culture are commonplace.

Heidegger himself cannot be definitely positioned into either of these two groups; however, Coyne (1994) claims that Heidegger would likely categorize VR as a field of research that favors the first view, since in practice it presumes that the images it generates and presents to the viewer are general, invariant and can capture the essence of a scene, independent of who the viewer is, to the point that it will amount to the same experience for everyone.

VR, as we have it today, seems to have implicitly accepted that its aim is to provide a universal array of sensory inputs, independent of the users’ own constructions, which would reinforce Descartes’ priority of subject-object distinction and Heidegger was never in favor of such distinction. Additionally, relying on a mathematical model of the world that simulates reality through geometry and math and bombards the viewer with sense data would be a characteristic of the Cartesian approach that Heidegger opposed. To sum up, whether it is by virtue of being an artificial, preprogrammed and limited technology that prevents real discovery, or due to its shortcomings as a medium for communication, the consensus of skeptics is that VR diverges from reality and will be a tool of deception.

Although all of the above criticisms are deep-rooted and in no way limited to VR, the serious questions that they raise are worthy of separate responses which likely expand over different fields and disciplines. In what comes next, I will argue why it is impossible to fully take away the user's ability to explore, decide, and act in a virtual environment as some critics have claimed.

3-3. Classifying Skepticism

To better respond to the opponents of VR, first, we can divide their criticism into main categories, after all, the meaning behind words like “illusory” or “fake” can target different and specific facets of the VR experience. In order to do so, the categories of skepticism articulated in Robert Nozick’s (1974) work are being used. Nozick outlined three categories, namely: the skepticism of doing, the skepticism of being, and the skepticism of reality (Nozick 1974, p. 42-50). It also should be noted that the VR experience machine that Nozick had in mind was not limited to digital VR. For him, computer-generated perceptual inputs, direct manipulation of the neural system or chemically induced hallucinations would qualify as variations of VR.

3-3-1. Skepticism of Doing

The skepticism of doing claims that one would want to actually do certain things instead of just the memory of having enacted them (Nozick 1974, p. 44) and since VR can ultimately make this possible, the idea of doing something in VR will eventually become meaningless. In other words, really doing something and not doing it has no difference in VR. Essentially, VR gives an alternative to bring us to the exact final state by only manipulating our neural system. For example, VR can fully replace having exercised for two hours with the illusion of this exercise happening in the past.

Admittedly, doing as defined here is not the only thing that VR affords us since we can have passive VR experiences where we passively receive stimuli, but as far as this particular skepticism is concerned there is a significant cognitivist premise at play that claims neural firings are all that is needed to bring about the expected bodily changes involved in an action (Cogburn & Silcox, 2014, p. 567) and in the same way that manipulating neurons can form new memories, it can also bring about any other bodily states.

Since there is a neural motivation for every action and sensation, the perception of having completed actions can always be artificially created once we figure out exactly which neurons to activate. The fictional world of the movie trilogy *The Matrix* (1999) –where humans are tricked by machines into thinking they are living full lives, doing all sorts of activities when, in fact, most have never used their bodies– is a good depiction of how this cognitivist premise would ultimately look like.

In the real world, however, there are other mechanisms at play and neural manipulation alone cannot explain why different people –due to their unique background experiences– will react differently to the same neural stimuli. For example, a very powerful VR simulation, where users see their own hands masterfully use a knife to chop onions, is probably activating many of the same visual neurons that are triggered for experienced chefs as they look at their hand masterfully chop onions. However, the VR user is far from having the same skills as the chef when he/she tries to chop onions for the first time in the real world.

A comparison between novice and professional soccer players conducted by Andersen & Aagaard (2000) shows this performance gap and rejects the cognitive premise of skepticism of doing. Their study examined two focus groups: one of retired professional soccer players who haven't played the game in more than a decade, and one of novice players. At the beginning of the experiment when both groups were asked to play a match, the two groups showed similar skill levels, but the retired players quickly showed radical improvement, while the first-timers progressed significantly slower. The reason for this phenomenon seems to have more to do with muscles structures than neurons.

The muscles of subjects in the first group, despite not being toned, had the potential to return to their old form by retaining some memory (reflected in the structure of muscle fibers) of the past; Hence, when retired players were in the field, their motor control already had an established reference point for how to implement certain techniques which the other group missed.

First-time players, on the other hand, had to follow the same procedure that their experienced counterparts went through at the beginning of their careers to shape their muscle structures for such memories in their muscles, a process which requires time and cannot be immediately manufactured through triggering some neurons.

This demonstrates that performing an action requires the muscles to learn alongside our neural system and both will get better at their performances over time because of the concrete and long-standing impacts of actions on a biological level. This cannot be reproduced without going through the actual process of doing them and even the most powerful VR technology cannot skip this process by only tampering with neurons. The fact that a powerful VR system might be able to delude us into thinking that we have just finished a marathon does not mean that it successfully circumvented everything that happens as a result of actually running a marathon. As the next chapter argues, the best and probably the only way for VR to simulate doing something is by allowing users to actually do them (with some accepted proximity).

Since skepticism of doing always involves physical actions, we can expand the above findings to argue that because any action relies on our muscles and the body, the characteristic of not being fully reproducible through neural manipulation will hold for them as well. So Nozick's premise that an action in VR can be reproduced only through neural manipulation is unfounded.

Nevertheless, it should be noted that the above counter argument does not reject the possibility of users making wrong judgments about VR. For instance, expecting an increased lung capacity from playing a walking simulator that does not involve any cardio exercises is a mistake similar to expecting a game of chess to improve your calves. The fact that the conclusion does not follow the premise is a fallacy created by users not the nature of VR. The possibility of judgment error which results in illusory perceptions is not a defining characteristic of VR, since many existing VR applications already utilize actions, but a pitfall that VR can stay away from by incorporating physical actions into its interaction.

At this point, one can ask: what if we imagine a VR technology capable enough to also physically manipulate the structure of our muscles as well? Here I would argue that this actually contradicts the accepted premise of the skeptics that VR is capable of allowing some type of shortcut. Since muscle manipulations are by definition concrete changes in the medium through which we do things, we expect all changes to have implications for our bodies and how we do things afterward; hence there is nothing left to be skeptic about.

3-3-2. Skepticism of Being

Skepticism of Being argues that, while in the real world every individual has the possibility to be a certain type of person in a given situation or behave in a certain manner, VR doesn't necessarily allow this to happen for its users (Nozick 1974, p. 47). An extreme case of this would be to watch a VR movie like *Dear Angelica (2017)*, where the users passively see through the eyes of a superhero without being necessarily confronted with a choice to be particularly courageous, compassionate, or heroic.

To argue against the skepticism of being, we should start by noting that it is virtually impossible to find instances of a fully passive VR experience in which users cannot exert any type of autonomy. Even watching a VR movie does not mean that users are completely unable to express their personality because at least they have probably decided to watch a VR movie instead of, for example, walking in a park.

Beyond the choice of using the technology itself, the interactive nature of VR is bound to offer its users additional opportunities to assert their personal preferences as the VR applications offer more choices. Even the most basic VR experience today lets individuals choose where to look, what to listen to, how long to look at what they see, what details to pay attention to, where to go next and etc. Obviously, in more sophisticated VR settings, these options can be more decisive in shaping the virtual experience.

A good example of this can be seen in the VR game called *TiltBrush* (2014). In addition to providing a normal painting platform, TiltBrush lets users paint in a 3D space and a sculpture-like fashion. They can then use their creations to play a game of Pictionary, where the affordances allow players to position teammates in specific angles, choose how subtle the visual hints should be, and how much risk they are willing to take, either by creating a more challenging image or showing off their drawing abilities to the other team. Admittedly, there are still significantly less affordances available to this player compared to the real world. However, this already rejects the premise of this category of skeptics that there is no legitimate way for VR users to express themselves.

We can think of numerous other VR cases that fall somewhere on the spectrum briefly outlined above while still acknowledging that providing more meaningful opportunities for VR users to exert their identity requires various design considerations. By admitting that such a spectrum exists we accept that it is possible to move toward creating a VR where users can increasingly express more personality, however, this is not a guarantee that such a goal can or will be fully realized and investigating the preconditions of that realization remains open to further investigations. The next chapter investigates the need for the bodily manifestation of such identities as a crucial and yet underrated precondition of expressing one's identity.

3-3-3. Skepticism of Reality

The skepticism of reality takes it to be self-evident that a human-made reality, a world no deeper or more complicated than what someone else can construct, is ultimately unsatisfying compared to the real world. Such skeptics might even agree that a VR experience can be temporarily pleasant despite its limitations, but once we start to substitute it with parts of our reality, it starts to fail the users. For example, the experience of walking in a virtual park can never encompass all the aspects of walking in a real one, although at first glance the virtual park might look bigger, greener, more colorful, etc.

Upon further analysis, there seem to be two deeper reasons for this dissatisfaction: first is the assertion that anything synthetic, by definition, lacks novelty since it is bound to be deterministic in as much as there is a finite set of possibilities already planned by the creator. So, regardless of what the participant does, the set of possibilities remains limited.

Second, users in VR are essentially in a facade that they cannot walk behind it or investigate, where the laws and structures governing their interactions are the result of arbitrary decisions made by designers. For instance, they would say: there is no real gravity in a modern VR flight simulator, it is just an arbitrary decision made by the creators to force the virtual plane to move towards what visually appears to be the ground but it does not mean that objects in the simulation have weights.

One response to the first category of this skepticism is to argue that even the material world itself might be deterministic and that given enough information it is theoretically possible to predict all outcomes of any real event or situation. In practice, however, we are far from achieving such knowledge about the world, while it is common to assume that such information about VR systems is present.

They would say VR is deterministic because, like any other content relying on a digital computer or any other machine, it is rooted in deterministic algorithms or mechanisms that dictate exactly what can and should happen at any given stage depending on the input it receives. This means that any VR application is essentially a big but finite-state machine, a computation model where at each moment in time the system is in a certain state waiting for new inputs, and once the algorithm finishes processing said inputs, it decides what new state should replace the current one and this cycle repeats for the new state.

For example, one of the most common actions in contemporary digital VR is a simple head rotation, where the user starts by seeing a certain image on the HMD - the current state of the machine- but as soon as the user starts turning his/her head to look at a different direction, the movement is translated by VR sensors as an input to the current state of the system. An algorithm created by developers processes both the input and the current state, probably alongside other sets of criteria, and eventually concludes that what was being displayed on HMD needs to be adjusted to show a slightly different image that gives the illusion of transition (see fig. 1.2). Obviously, any state machine describing an actual VR application, like *TiltBrush*, would have significantly more states, yet the working principle is similar.

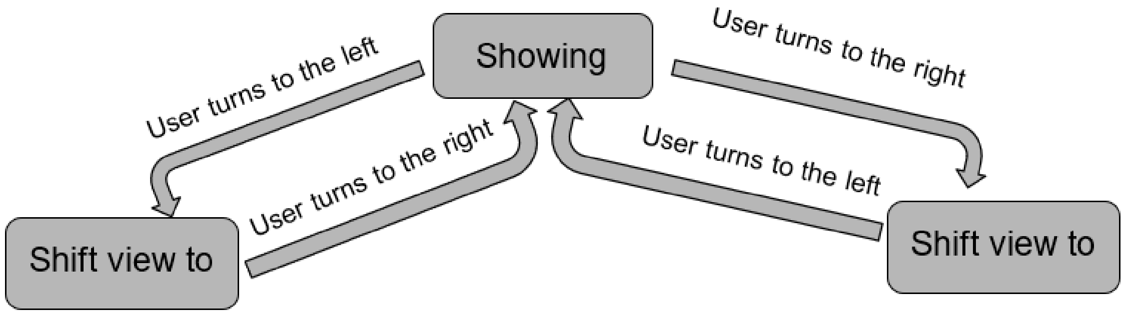

Fig. 9: A simplified state machine for head movement in VR

Before responding to this first category of criticism, we have to realize that confusing an underlying structure with what the structure can produce is a common misunderstanding. Possibilities and their realizations are far from being the same thing. In chess, there is a limited number of pieces and rules players must obey, however, the number of combinations these two sets can create is huge. There are more than 288 billion combinations possible after only four moves in chess and trying to brute force[8] all the possible first 40 moves would yield more combinations than 10^{86} which is the size of all electrons in the whole known universe (Stinson, 2012). As far as the criticism about the finite scenarios of a virtual world is concerned, we can see how a system with a very limited set of elements and rules can also generate a practically inexhaustible set of outcomes.

A typical VR application today, such as the *X-Plane 11 (2017)* flight simulator with thousands of rules, hundreds of cockpit control inputs and other random variables such as the weather results

[8] A common term in computer science where a code blindly tries every possible answer to a question. For example, trying every word in the Oxford dictionary to find the password of an account. The implication of the term here is to underline the blind nature of just trying out chess moves regardless of how smart or productive they are.

in a significantly higher number of unique scenarios compared to a simple game of chess and it will remain practically impossible to try them all. The high number of possible paths makes the interaction each user has with VR virtually unique since the probability of different users making an identical set of decisions is virtually zero. However, a practically inexhaustible set of outcomes is at best a necessary, but not sufficient precondition for the reality of VR only showing that they have this attribute in common.

Furthermore, the second point raised by the skeptics of reality about the superficial existence of what happens within VR seems to be based on a similar assumption that mimetic similarity to the real world counterpart makes something real. According to this view, for instance, an artificial tree is not a real tree because it is not similar enough to a living tree, for instance in terms of what it is made of, although they might look identical. Furthermore, it seems to advocate for arbitrary criteria for this similarity. For instance, it is true that we find it hard to believe that a virtual plane is being pulled toward a virtual ground by the same force of gravity that attracts real planes towards earth or that the same aerodynamic principles are at play when a virtual plane flies. However, it does not follow that the virtual *plane* does not exist or an event, that might not be called *flying* anymore, is not happening. For example, we can pose these very same challenges to a hypothetical physical plane that uses magnetic forces to stays in the air. Questioning whether that object should still be called a plane or what it does should still be called "flying", might be important discussions in their own rights, but they should not be confused with questioning the reality of that object or the fact that it floats in the air.

In the following section, I will argue that, while a virtual world does not have identical elements (governing laws, events, objects) as the physical world, it still has elements that are real and capable of shaping what goes on in the virtual world.

3-4. Virtual Realism

Virtual realism was a term first coined by Michael Heim in his 1998 book with the same name. Heim described the term as "the pragmatic interpretation of virtual reality as a functional non-representational phenomenon that gains ontological weight through its practical applications" (Heim 1998, p. 220). In the book, he argues that virtual entities are indeed real, functional, and even central to our future life. He concludes that the essence of VR can be described as follows: 1) virtual reality is about interactive simulation; 2) virtual reality often takes place within networks allowing communication through remote presence and adequate interface; and 3) virtual reality leads to an immersion into artificial worlds or environments which might augment our reality (Gorguette d'Argoeuves 2010, p. 90).

Virtual realism has been modified and expanded since Heim. As we will see later in this chapter, David Chalmers (Chalmers, 2017) defends the real existence of VR's digital elements. Philip Brey (Brey, 2003), also, borrows John Searl's notion of social reality to argue that human interactions can give a different legitimacy to the digital entities that Chalmers described. Both these arguments helped to shape virtual realism in its recent form which is outlined later.

The following section will first describe and then employ virtual realism to show how it addresses another type of skepticism aimed at VR, called fictionalism.

3-4-1. Skepticism vs Fictionalism

Before we move on to a more exhaustive definition of virtual realism, it is important to understand its context and the problem it was originally trying to address: virtual realism was initially a response to what is referred to as digital fictionalism. Fiction in this context stands at the direct opposite of reality and on the same side as skepticism of reality. However, there are important distinctions between the two, since not all the positions that were discussed before are also being held by fictionalists.

Some fictionalists accept that VR is real, since it consists of real rules. And these rules come from something outside the subject’s mind and exist in the outside world. For example, a VR flight simulator operates according to some real precepts, such as the fact that if the plane hits the ground without its landing gear, it will crash or wind can influence the speed of the plane. Similar rules can also be found in the real world, only in VR, the airplane, the trees, and the air (what the rules are about) are not real entities in the outside world, but fictional (only exist in the subject's imagination). To use VR is, therefore, to interact with real rules while imagining a fictional world (Juul 2005, Tavinor 2009).

It should be noted that when fictionalists say a dragon is fictional (read in a book or seen in a VR game), they are not saying that there are no symbols (words, images, etc.) in the outside world that represent that dragon. However, they claim that having a real physical airplane to represent itself is different from having a symbolic hint that amounts to an image, whatever the nature of that image might be, and that difference is why we have such a thing called fiction.

Another fictionalist framing of VR is the one proposed by Bateman (2011), who claims that VR is best described as systems of contriving contingency followed by acts of interpretation from which players can derive emotions such as success, happiness, sadness, etc. (Bateman 2011, p. 50). In this view, instead of emphasizing the role of imagination, like Juul and Tavinor, Bateman focuses on interpretation. To him, whether we are playing chess, talking to a friend's avatar in *Second Life* (2003), or piloting a plane in VR, we abide by certain parameters so as to enjoy the triumphant feeling of successfully navigating real rules to grasp the meaning in our actions.

Aarseth has taken this notion further to claim that the use of the term fiction, as something purely invented by imagination, will always be problematic (Aarseth 2007, p. 143). He points out that, in addition to rules, even something like the events that the user experiences inside VR and some of the constituting elements in those worlds are not just fictional.

Aarseth states that, while it seems obvious that virtual environments can include fictional elements that support their purpose, it is also clear that these elements are not as dominant in VR as they might be, for example, in a fictional novel. The interactive nature of virtual environments bring novel and real elements such as spatiality (how to implement spaces) into the picture (Aarseth 2007, p. 154).

This means that instead of the common notion that VR worlds are only fictional, we should start to see them as composites of entities that fall somewhere in the spectrum between real and fiction. Fictional elements like the background story we make up for a dragon hunter, in a hypothetical VR game, plus the virtual dragon we see in the game and the spatial representation of ourselves with regards to that dragon are examples of fictional, virtual and real elements respectively. This creates a network of real, virtual, and fictional elements that are constantly interacting with each other.

There seems to be a partial overlap between skeptics and fictionalists when it comes to their opinions on VR. As we have seen, there is little doubt about the reality of rules in fiction, and even skeptics of VR's reality have no reason to doubt the existence of such rules. However, they will add that in VR (much like in fiction), rules are arbitrary, superficial and with very limited impact, as opposed to the universality of the natural laws in the physical world.

As we will see in the next section, virtual realism attempts to dissolve the dichotomy of the arbitrary versus the universal set of rules by pointing out that not every physical world rule is as universal as gravity, nor is every interaction in VR based on superficial and artificial constructs.

3-4-2. Ontology of Virtual Realism

The original virtual realism argued that the virtual world involves virtual bodies (avatars), located in a virtual space, and performing virtual exchanges. Imagine, for instance, two users on the VR social media platform *Facebook Spaces,* where friends can talk and interact with each other and assume said users are having a casual discussion about something unrelated to the platform they are using (like updates on their families or their latest job anecdote).

Fig. 10: Facebook Spaces is a social media application that allows users to interact using VR (Franklin 2017)

In this case, it is easy to admit that a real discussion is taking place and that nothing about what the users say or hear is fictional. However, if in the same virtual environment, one of the participants hands over a family picture to another, this time it might be slightly harder to separate the “real” action of passing over photos performed by “real” bodies and the virtual document shared using a computer.

However, according to David Chalmers (2017), nothing about the above experience is fictional. It is true that we intuitively realize a mismatch between what happened for the avatars in this virtual environment and what happened in the physical world (aka no physical object was passed around), however, it is a cognitive error to get the physical world involved here.

He claims that something real has taken place for the virtual bodies residing in this virtual environment. There are virtual bodies that really inhabit virtual space, where they are really a few (virtual) meters apart. Actions performed within that virtual environment, such as picking up a gift box, require the use of the avatar’s body and cooperation between two virtual bodies, and there is nothing fictional about any of these actions.

It is important to note, however, that in a virtual environment the laws governing our actions - such as how one goes about picking something up or handing something over - can be different in nature compared to those in the physical world. Virtual rules may even create possibilities that are not available in the real world. For instance, picking up a physical object for most of us requires getting close to the object, then bending over and using our hands to grab it, etc. However, in a virtual environment, users might be able to do it through real telekinesis, because that object –and the virtual environment surrounding it– has the necessary properties that allowed such a movement to take place.

Moving on, we will discuss these underlying elements that virtual realism perceives as the real building blocks of any virtual environment- virtual objects, virtual properties and events, and virtual experiences- and demonstrate why they are real digital elements.

3-4-2. Virtual Objects

Virtual realism acknowledges that a virtual object is a phenomenon made possible by digital procedures, involving data structures and mathematical computations (in the form of digital bits that are made of material), used/executed by the central processing unit (CPU) alongside other processors that prepare the result to be presented via a peripheral output. These computational processes themselves rely on physical processes that boil down to tiny electron particles moving between atoms in a circuit.

Chalmers (2017) highlights the causal nature of these virtual objects by arguing for two distinct yet interrelated premises. First, those virtual objects are in fact digital objects with certain causal powers (to affect other virtual objects, to affect users, and so on). Second, those digital objects are the only ones with those causal powers.

According to the first premise, the computational processes and data structures that underlie a virtual object have many capabilities. They make our perception possible, they decide where and how all the objects in VR are located, and the way in which we can interact with them. In other words, there is a correspondence between the interactions of avatars, objects, etc. with the interaction of underlying data structures and computational processes. This underlying interaction is where the causal power lies, and acknowledging this power allows for divergence from some fictionalists, for whom the type of causal power an avatar - and other objects - have in VR is limited to the user's imagination. It should be noted that Chalmers is not rejecting the role and capabilities of the imagination, instead, he is pointing out the significance and reality of what is unfolding outside that enables our imagination to do what it does.

According to the second premise, what we perceive are the digital objects[9] and digital objects only. Thus, our perception is primarily rooted in the data structure and computational processes and not how they are represented. Such representation, which is usually in the form of images, videos, sounds, haptic feedback, etc. cannot replace the data structure as the root cause, because it cannot address how different points of view can result in different representations of the same object.

To better clarify this point, we can form an analogy from the physical world: when we look at a photograph of ourselves, most people will agree that it is their image and that they are the cause

[9] The ultimate physical underlying of virtual objects (including data structures and processes) is comprised of very small electrical circuits made by atoms in which electrons move between atoms and once they are aligned in specific ways we interpret the state of each circuit as a logical 0 or 1.

of what is seen in the picture, since the photo systematically depends on their features and they were appearing at the time that picture was taken. Even when we take into account all the potential distortions (some inevitable), such as bad lighting, odd camera angles, long distance, etc. it does not prevent us from concluding that the necessary condition of our picture is us. The same relationship exists between virtual objects and their representations. Here, the representations we perceive are of secondary value compared to the digital objects that are really responsible for making the representation possible.

This was also true of the *Facebook Space* example (Fig. 9) and the virtual object that was being exchanged. Each user sees a different representation of that object depending on where they are positioned. However, that does not mean that each user is seeing a different object. From an implementation point of view, programmers only need to include the position of the object into how object properties are being represented without having to generate and maintain multiple instances of the object. Indeed, it would be theoretically impossible to maintain fully separate objects that are behaving in a consistent manner without having one single source of information which would be the virtual object.

3-4-3. Virtual Events and Properties

This category might be the most appealing category for fictionalists, who would argue that even if virtual objects exist, it does not mean that virtual events are actually taking place outside our imagination. Fictionalists might claim that in a virtual world, a magical broomstick can fly, while in the real world, the physical broomstick does not have the capability to move by itself -never mind fly-, and indeed, no real object can move in the same way a virtual broomstick does. To put it simply, either the virtual broomstick is not real, or it is real, but what happens to it is not taking place in the outside world, hence what happens is fictional (Chalmers 2017, p. 10).

Virtual realism responds to this claim by reminding us that our current definition of flying is contingent on a host of different physical laws and dynamics, which don't necessarily exist in a virtual environment. Also, those laws do not need to be applied in the exact same way for virtual events to take place. Nevertheless, whether virtual flying is similar enough to physical flying for us to use the term "flying" or whether we should call it something else– while remaining a justified question– does not make the virtual flying (or whatever we should call it), as an event, any less real.

The virtual broomstick is a real digital entity in the virtual world, which requires its own definition of flying, just as spaceships require their own definition for flying in the physical world, which is different than flying an airplane, for example. In other words, the virtual broomstick can actually fly, the difference is that we should go to the data structures and processes to tell us what this flying entails.

A similar distinction between virtual and physical events has been put forward by fictionalists regarding virtual properties. For a property, like a color in a virtual world, fictionalists would argue that a non-virtual red is inherently different from a virtual red. In their opinion, there is a strong connection between redness and the object in the former that seems to exist only superficially in the latter.

Virtual realism follows the same contingency reasoning put forward in the case of events to defend the independent existence of virtual properties. In the case of defining a property like color, philosophers have traditionally been divided into two categories[10]. The functionalist view defined a property based on the effects it can cause. Consequently, redness is whatever causes the red experience for the observer. On the other hand, the primitivists considered redness as an intrinsic property of part or the whole object that causes red experiences for an observer under normal circumstances (such as normal light of day, an observer with no visual disabilities, etc.) and virtual colors can be understood in a way that complies with both of these views.

For functionalists, virtual red easily qualifies as red, since we already can reproduce it using an RGB monitor[11]. In general, such displays can already recreate the majority of our visible color gamut, but not all of it. Newer technologies such as ProPhoto RGB and Wide-gamut RGB are getting closer to fully recreate the visible color gamut (Susstrunk, 1999). In the meantime, our imperfect displays are capable enough to make the point for functionalists that the digital colors we have so far are all real colors.

For the primitivists, however, looking directly at digital objects by opening up the memory, for example, does not lead to experiencing redness. However, if we include looking through a functioning monitor screen as a "normal" precondition to experience redness, then we can argue for the reality of this virtual property. An object is virtually red when the digital object in charge of the color is allowed to produce reddish experience under conditions that are normal for virtual red. For today's VR this can entail looking through an HMD headset or a monitor screen.

The data structure corresponding to a virtual red rose really has attributes that eventually bring the reddish experience when viewed under these conditions. If and only if this characteristic of

[10] There are in fact numerous theories around the ontology of colors, with slight yet important variations, such as primitivism, eliminativism, and dispositionalism. However, for the purpose of this chapter, only two broader categories are considered. For further information please refer to https://plato.stanford.edu/entries/color

[11] Monitors where each pixel is comprised of a combination of red, green and blue colors.

the digital object is changed (by changing bits of information), it would create a different color[12]. (Chalmers 2017, p. 11).

Similar to underlying redness in the physical world, which requires the emission or reflection of light rays within a certain frequency range, the redness of a virtual object stems from certain numerical values in those data structures. Although this characterization oversimplifies the complexity of how computer software generates colors, the basic concept still holds. We can expand this functionalist understanding of virtual properties to more elaborate properties like squareness, by arguing that virtually square objects are objects that really have properties –such as binary bits of data to store length, width, color, etc.– that produce squarish experiences under conditions that are normal for virtual reality (Chalmers 2017, p. 12).

It should be noted that if we look at a more complicated property - such as the size of virtual objects[13] - the normal conditions through which we can perceive that property and reach an expected perception become more important. For example, it would be hard for users to accept that an in-game avatar of them is anywhere near their height, especially when they are looking at it through a 21-inch monitor screen. In the case of redness or squareness, a monitor screen might have been enough to observe the redness regardless of its dimensions, however, perceiving the right size appears to require more in order to be satisfied.

Conventional VR HMDs are particularly helpful in satisfying the perception requirements for the normal condition because they make it possible for us to experience things in life-size proportions. All spatial properties, in fact, seem to be able to benefit from the possibility of

[12] Assuming that all other variables remain unchanged

[13] Please note that this virtual property is again both functionally and primitively real because we can change some attributes of the virtual object that will result in a change in its size.

observing properties –such as size and distance– proportionally to our bodily dimensions, which make VR distinct in this regard. The next chapter will discuss the significance of it in more details.

3-4-4. Virtual Experiences

If somebody believes that virtual objects are not real in any sense of the word, it is justifiable to think of the perception of them as a form of hallucination or illusion. For such a person, the experience of seeing something in VR is similar to seeing something in the distance they initially thought to be an animal, but upon closer inspection proves to be just a rock. The image of the dog that the person had until that point, turned out to be an illusion in the sense that what was in their mind did not correspond with what was out in the world.

The VR equivalent of this illusion happens when a user seeing a virtual chair two feet away from them in a virtual room thinks that there is a physical chair close by in the physical world. Like the previous instance, this is not due to the illusory nature of the rock or the virtual chair, but due to a failure to distinguish between a virtual environment and the physical world.

To investigate this type of illusion, David Chalmers uses the analogy of a mirror and asks: is what we see in a mirror an illusion? Indeed, someone who has never seen a mirror before would probably be very confused in their first encounter with one. However, someone who is familiar with mirrors would have a vastly different experience. (Chalmers 2017, p 14; see fig. 10).

Our everyday driving experience suggests that virtually nobody is confused by how rear-view mirrors work. For instance, every driver manages to reach the conclusion that: [in my rearview mirror] all the cars appearing in front of me are in fact behind me moving in the same direction as me. Most of us can even make further conclusions by using our observation to calculate the distance from the cars seen in the mirror, their speed or which direction they are signaling to turn to, etc. Chalmers concludes that the example of mirrors shows that there are cases of illusion that can eventually be corrected as the user gets familiarized with them. Once we understand how rear-view mirrors work, virtually everything we take away from looking at them, like the position of other cars, their moving direction and their distance corresponds with the reality of cars on the street.

Fig. 11: A car that is in fact behind you appears to be a part of the scene in front of you

However, we have to also realize that not every potentially illusory instance will eventually run out of its illusory impact. The rubber-hand illusion (also known as the mirror-box experiment) is a good example of this phenomenon (fig. 11). This is an experiment where the subject places both of his/her arms on a table and sees one of the arms directly, while the other one is covered by a mirror that shows the first arm. Now if someone starts stroking or massaging the hidden arm while you look at the reflection, your brain will perceive these actions to be performed on the covered hand, so for instance, doctors can use it to help the tingling/itching of the phantom limb. This is a powerful example of participants being fully aware of the nature of the mirror used in the process but still cannot help reaching an illusory conclusion. In the fifth chapter, we will return to this phenomenon to show that once we take into account how the sense of ownership over our limbs is established, there is very little difference between owning your arm and owning a reflection of your hand and if the former is not an illusion maybe the latter is real as well.

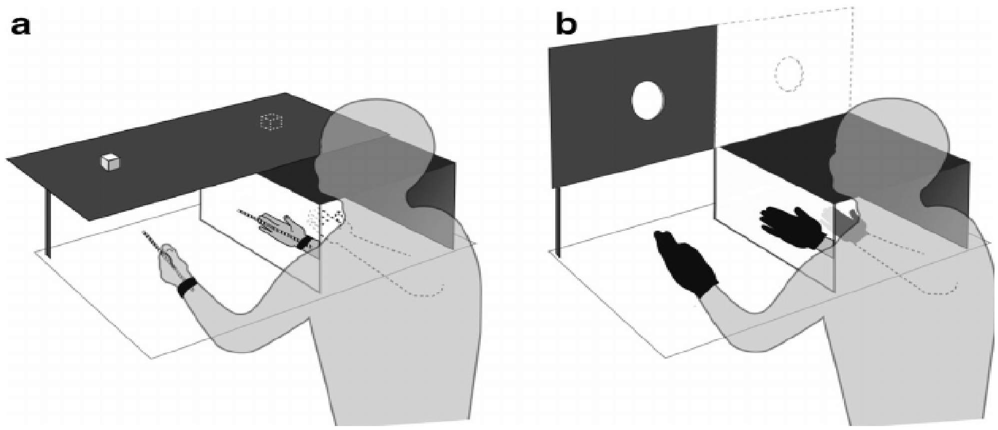

Fig. 12: Doctors use a mirror-box for patients who have had an arm amputated; this, for example, can allow the patients to scratch an itch on their phantom limb (Tsakiris & Haggard, 2005).

From this comparison between VR and mirrors, Chalmers claims that there are four interrelated factors involved in moving our experience between the illusory vs. non-illusory sides of the spectrum. *Knowledge* is the first factor that can have a substantial effect, but as the mirror-box example demonstrates, knowing in advance does not necessarily prevent the illusion. The second factor is *familiarity,* which helps us interpret what we are sensing. Both of these factors can contribute to *actions* that we might need to take, and these actions, in turn, shape the familiarity and add to our experience.

For example, parallel parking depends on the driver's familiarity with the dynamic of rear-view mirrors as well as the driver's ability to take actions according to what they see. Such actions, in turn, adjust our understanding of the sensory input.

The final factor is *naturalness*[14] (Chalmers 2017, p. 15). Naturalness describes our innate tendency to interpret the world in a way that remains consistent with our other preconceived notions. These notions either come from our biological limitations or the specific habits we develop since birth. For example, when it comes to mirrors, it is intuitively unnatural for babies to realize that something appearing in front of them is in fact a reflection of them and the stuff behind them. It's also unnatural in the sense that those images cannot be touched and interacted with, since the vast majority of what they see and grow accustomed to tangible objects.

We can expand the mirror analogy to videos as well. People who have no experience with videos might think what they see is an actual event unfolding right in front of their eyes, as was the case in the early years of cinema and the movie about the approaching train we discussed earlier. But as viewers became more aware of what a video is, they became less likely to be misled by their preconceived notions.

The final step is to stretch the analogy one more time to include VR as well. A naive VR user might be fooled by what they are seeing by making unfounded associations between the virtual and physical environment (like thinking a virtual chair is in a physical room), but once some (or all) of the four factors start to enter the equation, something similar to the mirror example will occur. A sophisticated user will become familiar with VR and will make judgments that are fully contingent on the virtual environment.

[14] In the next chapter, it will be argued that embodiment not only has many overlapping aspects with all the four factors that Chalmers mentions, but it is also in a sense a foundation upon which knowledge, familiarity, action, and naturalness are built.

3-5. Social Virtual Reality

Following the comparison between entities in the physical world and the virtual worlds, we should also notice another real entity that mainly relies on social constructs, subjective interpretations, and collective agreements. John Searle called this category “social reality” and described its characteristics in his theory of social ontology (Searle 1995).

Searle believed that entities can either exist wholly independently of human understanding and thought, or their existence might be fully or partially dependent on human thought. This idea led him to make a distinction between physical realities and social realities (Brey 2003, p. 271).

According to him, physical reality is genuinely objective and includes entities that exist regardless of our subjective interpretation. On the other hand, social realities are defined in the context of human institutions, practices, and artifacts. They pose a paradox in being at the same time "objective" (in the sense of being widely accepted and uncontroversial), and yet highly dependent on how humans collectively agree to understand them (Searle 1995, p. 131). A true statement about a “social reality” results in what he calls a “social fact” in the same way that true statements about physical realities are physical facts. For example, Mount Everest being the Earth’s highest mountain above sea level is a physical fact since height is an innate attribute of physical objects independent of human beliefs. On the other hand, statements such as Justin Trudeau is a married man or Elizabeth II is the head of the state in the United Kingdom are true social facts because if there were no human beings around, such concepts couldn’t exist and hence couldn’t be true.

One of the most famous social facts would be the fact that paper money has purchasing value. There is nothing intrinsic about green paper bills which dictate their application as some form of currency. Only when enough people accept its functionality and begin to use it that money becomes a social fact valid to use in commercial interactions.

As Philip Brey (2003) claimed, Searle's social ontology can explain why some entities can be subsumed into virtual environments while some cannot. Money and monetary transactions can be fully transferred into virtual reality and virtual money can be just as real as paper money, not because virtual money also exists in the form of data structures and processes, rather, because it can have the same status function as paper money. Similar to paper money, this function was derived from the conventions and objectives of human institutions or certain portions of it. Such entities, therefore, will be just as real once they are transferred to digital forms because they were never tied to a certain physical reality to begin with (Mooradian 2006, p. 678).

Finally, it is worth mentioning that just because social realities are fluid in nature and the social function of something like paper money was easily transferred to Bitcoin, it does not mean that similar transitions will take place for every social reality. All this argument entails is that the possibility exists. Whether or not we will see the day that virtual marriages, virtual conferences or virtual wars are as accepted in the same way as their non-virtual counterpart is not something inevitable and societies will have to make decisions that can always change their status in one way or another.

3-6. Value of Virtual Actions

After an ontological reflection on VR that resulted in identifying objects, properties and event as real constituting elements. This section begins discussing an epistemological question about the value of virtual experience and how value can be attributed to virtual actions.

When we think of common examples for what people value intrinsically and consider to be good by nature, what comes to mind are things like friendship, art, adventure, nature, compassion, etc. and many of them have either already been the focus of VR applications or are likely to be explored by it in the near future.

As virtual friendships, virtual romantic relations, virtual adventures, and virtual competitions are becoming more commonplace, the question of how to theorize the value of these experiences becomes more important. In the remainder of this chapter, I will use two cases, namely virtual martial arts and virtual sex, to investigate the questions of their value in comparison to their physical counterpart in order to find what exactly the determining factors in attributing values to them are.

The VR settings for virtual *martial arts* as described by Mooradian (2006) has two variations. First, we have a setting where a virtual avatar is controlled through a handheld controller as it moves in a 3D space and fights assailants while the user is being visually and auditory immersed. The second setting enhances the body interface so that the player is not simply an avatar in the space fighting by means of handheld controls and is able to use the exact corresponding body movements to strike and defend against opponents (Mooradian 2006, p. 680).

The settings for virtual *sex* as described by Rheingold (1991) are also twofold. Back in the early nineties, he envisioned an extension of computer-based pornography, which then existed only as digital versions of print pictures and videos, enabling people to look around and investigate content as an observer. For the second configuration, we can imagine that this extension would be further developed into a three dimensional, more immersive experiences. Also, through a bodysuit, more interactivity would be added and the simulation of physical contact and tactile sensations are also possible (Rheingold 1991, pp. 345).

Starting with the case of virtual martial arts via a controller, it appears that in this type of setting users might find the activity exciting and invigorating. However, the value of the experience would be lacking in a number of ways.

First, the exact execution of the techniques would be unreal. Even though they might appear to cause similar motions on a display, the strikes and blocks would likely not be done with the proper force and in the proper form. Here, the players will not be moving in the proper way even if their avatar appears to do so since the precise movements of the body and muscles are excluded to simplify the interaction. Second, the players' endurance would not be tested, as they would not have to exert much bodily force to execute any of the techniques. Third, the players would not have to take any damage as they would in a real match or experience the same bodily pain.

It appears that a lack of accuracy is the common root cause of all three disparities mentioned earlier. Crandall and Levich (1998), in their critique of virtual reality, argue that the accuracy of a simulation in terms of the actions and interactions are the most decisive factor to the value of a VR experience. For instance, having a martial arts VR simulator that punishes being kicked by an opponent through physical pain is a more accurate simulation compared to an example where the player only loses some imaginary points.

Now let us look at the more complex setting for virtual martial arts[15]. Imagine a VR system in which a body suit embedded with sensors and actuators captures every slight movement and recreate every relevant sensations, pressures, and tension. Here we cannot blame the simulation for leaving out essential and value-bearing aspects of the actions the same way it did in the previous setting. It seems that the accuracy of simulations, at least in the case of virtual martial arts, can allow for an experience that is admittedly a legitimate type of martial arts. In the next chapter, this notion of accuracy will be redefined in terms of creating an embodied experience.

Mooradian (2006) expanded the above analysis and claimed that even in the case of non-ideal virtual martial arts, there is still a direct connection between the partial accuracy of the simulation and the similarity of values associated with virtual actions. This means that even in a less accurate VR setting –where for example kicking requires the players to move their legs, but throwing a punch is still done by just pushing a button– the simulation would not be devoid of similar values, because there is still partial resemblance either in movements or calculated response or quick anticipation of the attacks, etc.

The example of virtual sex, as a case that contains emotional and social aspects alongside certain acts, signals a more complicated and flexible nature when it is brought to VR. Rheingold (1991) argued that unlike the virtual martial arts, here it is not immediately obvious that something is missing from the virtual sex as we go from the non-ideal VR settings to the ideal one. It appears that, in virtual sex, it is not possible to pinpoint a set of deciding factors, like specific acts or skills, as the preconditions for an action to constitute sex (Mooradian 2006, p. 686). Unlike the

[15] *TeslaSuit* (2015), *bHaptics TacSuit* (2017) and *NeoSensory exoskin* (2018) are some of the recent commercial products that are getting closer to realizing what such a hypothetical haptic suit might look like.

case of virtual martial arts, it is even harder to question the enjoyment that a user might feel from virtual sex.

Let's assume that we found participants of virtual sex who are enjoying the experience under ideal or non-ideal VR setting. The first thing to note is that their enjoyment cannot be defeated or criticized in the same way we analyzed virtual martial arts. Virtual sex does not fail by virtue of failing to incorporate skilled bodily movement. It doesn't matter whether the virtual touching and feelings are tightly correlated with skillful techniques in the area of sex. A lot of people might pursue sex (and virtual sex) with different goals in mind, and regardless of what an outside observer might say about them, it is hard to claim they are suffering any conceptual confusion about whether what they are doing is sex or not.

Based on our earlier discussion of social reality, we can see that virtual sex is in many ways also a social reality due to the significance of sex's social and cultural underlying. The fact that defining sex as certain universal acts seems so problematic is exactly because it can differ vastly between individuals and groups depending on how they collectively defined it.

The contrast between virtual sex and virtual martial arts shows that different physical actions can have vastly different intrinsic values that might or might not be maintained in VR. Consequently, it is not feasible to give general prescriptions for how the value of every activity is expected to be transferred between the virtual and non-virtual worlds. In the case of virtual martial arts, a criticism based on accuracy was plausible, by pointing out all the elements that VR experience was lacking in terms of physical techniques, endurance, risk, etc. which in the case of virtual sex was not possible.

Before we conclude this section, it should be noted that, the inability to attribute some values to a virtual experience does not mean people will not enjoy the virtual experience or that these experiences are devoid of any values. For example, precisely because the imagery is so exciting and great things appear to happen with little effort, some people might find virtual martial arts more enjoyable and valuable in the sense that they can perform timely and effective counterstrikes that are amusing to watch. However, such a feeling is probably different from what a martial arts athlete feels while performing those techniques. The athlete's experience involves more complex coordination and anticipation, plus control over individual muscles and the sense of physical exertion that are grossly simplified or completely absent in VR.

3-7. Conclusion

Establishing that elements such as objects, properties, and events are indeed real entities with digital underlying, allows us to start distinguishing the justified and unjustified beliefs that users form during interactions with these elements and their experience as a whole. It was demonstrated that not all beliefs about VR are illusions, and the illusory ones are not all the same. On the one hand, we sometimes interpret a virtual experience as an illusion due to lack of familiarity, knowledge, naturalness or actions. In such cases, we can expect the illusions to gradually disappear as the user becomes more adept in interacting with virtual environments.

On the other hand, there are instances like the mirror-box experiment (a type of body ownership phenomenon) that does not seem to be disappearing no matter how adept users are with the setting. In the fifth chapter, we will return to body-ownership phenomenon in VR and show that, as far as our neural system is concerned, there is little difference between how we register our hands to be a part of us and how we might take ownership over a virtual arm. While some might continue to call such phenomenon as a case of illusion in VR, the neurological similarities suggest a potential for significant impact on users as a result of such phenomenon which cannot be easily ignored.

Finally, a particular type of belief that is concerned about the value of virtual actions was discussed. By comparing virtual martial arts and virtual sex, it was demonstrated that there is a spectrum where on one side we have what is called *well-defined* activities composed of concrete identifiable actions. For such cases, we can rely on the concept of accuracy to help us evaluate how much the values attributed to the virtual experience resemble their non-virtual counterparts. On the other side of the spectrum, we have activities that are not as well-defined due to their highly subjective nature which makes defining accurate virtual simulation either problematic or impossible. This is not to say that virtual sex, for example, can never be on par with non-virtual sex, rather it is to say that accuracy in simulation is not the deciding factor.

If we accept that the question of value for well-defined activities boils down to the problem of accuracy in virtual simulations, then it is logical to ask: what this accuracy should look like and what are the steps involved in achieving it? The fourth chapter offers embodiment as the necessary frame to define accuracy and outlines physical and social embodiment as two preconditions that can bring an embodied VR experience. Finally, the last chapter takes one step further to outline some of the most important mechanisms of an embodied simulation and shows how different aspects of an embodied virtual experience can undermine each other and create tradeoffs where for example, social and physical embodiment have to be balanced against each other.

4. Embodied Virtual Reality

What disembodied realism misses is that, as embodied, imaginative creatures, we never were separated or divorced from reality in the first place. What has always made science possible is our embodiment, not our transcendence of it, and our imagination, not our avoidance of it (Lakoff, 1999, p. 41).

4-1. Introduction

The previous chapter ended with a relatively straightforward comparison between the value of virtual sex/martial arts and their physical-world counterparts to demonstrate how dissimilar such a relation could be from one activity to another. Probably the most obvious conclusion one could draw from these vastly different cases is that when it comes to attributing values of real-world actions to those that resemble them in VR, no general rule can be imagined.

The next and more relevant conclusion we can draw, however, is that in the case of well-defined activities such as virtual martial arts, an accurate VR simulation appears to be a goal that, if achieved, would warrant comparable values to the non-virtual activity.

Devising a definition for accuracy that applies to all well-defined activities, requires a holistic view of the body where movements, sensations, and all the skills involved in coordinate them within an environment are taken into account. As this chapter demonstrates, all human actions are inherently embodied, which is to say states of the body modify states of the mind. This means that simulating well-defined activities in VR, that are the focus of this chapter, is essentially a question of making those virtual activities embodied.

The chapter starts by investigating embodiment as a multi-faceted term that with philosophical origin, that has also become a central concept in describing the role of the body in fields such as cognitive science and neuroscience. There is no agreed-upon version of the term across disciplines, however, since the different meanings tend to overlap, this research extracts the commonalities that are applicable to the study of VR, forming a more balanced view between both the social and the physical dimensions as preconditions to a fully embodied VR experience.

By establishing what creates an embodied experience in the first place, we can then reflect on how VR technology might provide affordances to address it. Three types of affordances - namely motor, sensory and psycho-social - will be outlined for any VR application that aims at building accurate simulations. The chapter concludes with a return to the problem of the value of actions in VR, to argue that embodied simulations in the case of well-defined actions have the same instrumental value as their physical-world counterparts.

4-2. The Evolution of Cognitive Science

Traditionally, various branches of cognitive science, also known as cognitivist or classicist, had one core principle in common, which was to view the mind as a central processing unit using abstract symbols and representations as the input while the type of its connections to the outside world was of little theoretical importance (Hart 1996; Fodor 1983). Perceptual and motor systems, though reasonable objects of inquiry in their own rights, were not considered relevant to understanding the foundation of our cognitive processes (Clark, 1998). Instead, they were considered independent modules, expected to be analyzed separately as a topic of other fields of science such as orthopedics, optometry, and dermatology.

This view was most prevalent in cognitive psychology in the 1950s and 1960s when most theories of human thinking dealt with propositional forms of knowledge that were consumed by the processing center that is the brain. During the same time period, the field of artificial intelligence, aimed at recreating human intelligence by simulating the underlying structure of the brain, was also dominated by computational models of abstract symbol processing.

Hilary Putnam (1967) was a major contributor to this framing of the human mind, according to which our brain is essentially a giant state-machine that receives new inputs and decides what state to go to next based on a combination of the current state and the new input. Once the system transitions into this new state, it waits for new inputs and the same cycle is repeated with the new state as the new current one.

Additionally, the modularity hypothesis (Fodor, 1983) laid the basis for an even more centralized view of cognition. According to Fodor, cognition itself is not modular and it is performed exclusively by the brain. The brain's connections to the world, on the other hand, happen through separate, independent and modular units. For instance, perceptual or motor processing is done by encapsulated plug-in modules that provide highly limited forms of input and output to the brain (Wilson, 2002). All the important decisions are therefore calculated and conducted by a small part of the brain and then fed to the body for execution while our senses are creating brain-friendly translations from the outside world to the mind.

In the past three decades, there has been a parallel movement from within the cognitive sciences that proposes placing the role of the human body at the center of our cognition, instead of treating it as a simple translator (Clark, 1998; Wilson & Foglia, 2011). Research conducted with this goal in mind forms an emergent subfield of cognitive science that today is known as the embodied cognition framework.

Embodied cognition (EC) is still a young and growing framework and many more studies are needed before anything close to a complete picture of the mind-body dynamics is achieved. At this point in the evolution of this framework, its predictive capabilities are limited, however, it is gradually establishing the evidence to free the field of cognitive science from a brain-central view and move it toward investigating the entire body as a critical component of cognition (Shapiro, 2011; Varela et al., 2017).

Historically, research that fell into EC offered a host of distinct claims, some of which are more controversial than others (Mahon & Caramazza, 2008) depending on how the role of the body is balanced against the brain. As Wilson (2002) argues, one could find cases where EC doesn't have a full explanation yet. For instance, EC has yet to describe how we can lay plans for the future and think over what has happened in the past or how we can entertain counterfactuals to consider what might have happened if circumstances had been different, or how we can construct mental representations of situations we have never experienced, based purely on linguistic input from others[16].

Nevertheless, there are also well-established EC findings that over the past two decades have gathered robust empirical support (Chiel & Beer, 1997; Clark, 1997; Pfeifer & Scheier, 1999;

[16] For a comprehensive discussion of EC shortcomings please refer to Wilson (2002).

Wilson, 2004; Wilson & Foglia, 2011; Varela et al., 2017). This chapter will employ four of these well-established principles that are particularly relevant to simulating well-defined actions. First, EC asserts that cognition is *situated* (Clark, 1997; Spivey, 2007), meaning that all cognitive activities take place in the context of an environment and inherently involve perception and action. Second, cognition is *time-constrained* (Pfeifer & Scheier, 1999, Calvo & Gomila, 2008) and should be understood in terms of how it functions under the real-time pressures of interactions with the environment. Third, we offload cognitive work onto the environment due to our limited memory and attention span (Wilson, 2004; Gray et al., 2006), meaning that we exploit the environment to reduce the cognitive work we need to do. For instance, we write notes and keep calendars as aids to our memory and instead just remember where we have that information written down.

Fourth, action and perception are highly interconnected and can have an unmediated relationship where one directly influences the other without it necessarily entering conscious thought (Churchland, Ramachandran & Sjenowski, 1994; O'Regan, 1992; Pessoa, Thompson, & Noë, 1998). This notion also implies that bodily traits, features and how skillful we are at performing some tasks impact how we shape our cognitive processes through life and are reflected in our preferences, beliefs, and judgments.

4-3. Evidence

If being embodied is as fundamental as EC claims, we should expect it to be fully intertwined in every cognitive process, to the point where the behavioral impact might not be concisely detectable by a person. Thanks to advancements of modern neuroscience and brain imaging techniques such as fMRI[17], we can directly monitor the neural system and intercept changes long before they result in interceptable behavioral changes. In the following section, I will look at some of the most robust experimental evidence that supports EC's claims.

4-3-1. Neurological Evidence

When we talk about the effects of embodiment, it is important to notice that there are two ways of verifying the evidence of its effects. First, there is a neurological approach based on the Hebbian learning rule of synaptic plasticity. According to Donald Hebb's law - first articulated in his 1949 book *The Organization of Behavior* - two neuron cells (or systems of cells) that are repeatedly activated at the same time tend to become associated so that activity in one facilitates activity in the other (Hebb, 1949).

For instance, upon examining hand-manipulation-related neurons, Murata et al. (2000) showed that objects of similar size and shape[18] will activate the same region of the brain. Additional, there was also a more granular relationship within the activated area based on the specific type of manipulation such as fixating or grasping. This means that grasping a small sphere shaped object –be it an apple, tomato or any other similar object– relies on the same neural structures independent of what the object is. Additionally, since we are likely to have other senses involved in the process of grasping, such as the vision that tells us the object is red, the neurons responsible for detecting that color were also primed. According to Hebb's law, once these two

[17] Functional magnetic resonance imaging, which measures brain activity by detecting changes associated with blood flow. This technique relies on the fact that cerebral blood flow and neuronal activation are coupled.
[18] The detection, in this case, comes from haptic and proprioceptive feedback and not from visual stimuli

distinct structures are primed in this fashion frequently enough, they will become increasingly interconnected on the neural level (Allport, 1985). On a more abstract level, this implies that we are more likely to expect that seeing a red sphere should be accompanied by grasping it or vice versa, however, we should keep in mind that our neural system contains billions of such connections that are constantly changing as some deteriorate while new ones take shape.

The most important implication of this discovery is that the cognitive representation of an object is intrinsically tied to the way we use our bodies to interact with it. Therefore, these two are not separate domains pieced together by the mind and are directly bound together (Rizzolatti et al. 1988). As a result, a banana is not just an average length yellow fruit, rather it is an object that needs to be peeled in a certain way, be eaten from the top down, etc.

For the neural formations, the repetition is the governing factor and there is no preference about what object manipulations should look like. For example, if someone is accustomed to biting into a banana without peeling it first, as long as it that act is consistently repeated, neural structures related to that action will get interconnected to neurons in charge of visually identifying the banana.

It is not hard to imagine why the impact of such neural formations also extends to a virtual environment (VE), where users want to grasp a virtual object that appears to be yellow and the size and shape of a banana. However, if the act of reaching and grasping is not afforded in that virtual environment, the virtual experience cannot be fully embodied. If users are expected to perform a substituting gesture like pushing a button, in order to grasp at a virtual banana, it is true that new neural structures can be created, however, it does not comply with the existing neural dispositions that we bring into the virtual world.

In addition to the neural formations that are derived from motor activities, there are the *premotor*[19] neural structures that later studies have uncovered (Pellegrino et al., 1992; Fogassi et al., 1994). According to them, even if an observer is merely witnessing certain object manipulation movements of others on objects with familiar size and shape, his/her premotor neurons get triggered. However, if we take away the object and repeat the movements in front of the observer, the previous neuron firings will not happen again.

Neuroimaging studies also confirmed that in some cases even observing another person's actions without specific objects will cause the observer's neurons (called mirror neurons) responsible for executing that same action to get activated involuntarily (Gazzola & Keysers, 2009). The clearest instance of this phenomenon can be observed in the case of yawning or "contagious" laughter where the action of others triggers us to automatically repeat them.

These are some of the most consequential principles for the study of VR that neuroscience has discovered so far. However, this field is far from being able to outline a comprehensive model of the brain, meaning that what we know is subject to revisions and refinements. The fMRI technology, today's most powerful neural imaging tool, is an example of how limited our understanding of the neural system is. As it is currently used, the fMRI does not exactly measure neuronal activity (Poldrack, 2008). Each dot of light on the fMRI's screen -the voxel- represents blood flow in the region of approximately 80,000 neurons and more than 4 million synapses. Additionally, this dot of light is the average measurement of activity over one second in a single region, but neuronal signaling occurs a thousand times faster, in the realm of milliseconds.

[19] Premotor neurons' functionality is to prepare the body's muscles for the exact movements that we have decided to make.

However, as far as VR is concerned, the current state of EC research provides an opportunity for every VR application to re-evaluate and expand the bodily affordances provided for the users. For instance, all the physical skills and mental skills of a martial artist can be traced back to these highly specialized neural formations and it is impossible to gain those skills merely through audio-visual stimuli.

4-3-2. Behavioral Evidence

The second category of evidence comes from closely studying and monitoring subjects through their conscious and unconscious behavioral changes by questionnaires and implicit association tests. This type of evidence, at least on the surface, seems to work in a more straightforward fashion, where there is a consistently detectable impact by the bodily interactions on the cognitive perception. For example, researchers found that by priming individuals with a warm or cold beverage, they could influence whether the subject perceived people they just met as having a warm or cold personality respectively (Williams & Bargh, 2008).

Another discovery suggests that forcing subjects to sit upright allows them to feel prouder over their achievements or contracting the forehead muscles increase how hard subjects perceive their work on a task to be (Stepper & Strack, 1993). This demonstrates a tightly coupled relationship between what we used to understand as the bodily representations of a phenomenon and the underlying phenomenon itself.

Other studies showed that even our abstract problem-solving capabilities are influenced by body movements. For example, allowing the reader to make the appropriate facial expressions (happy, angry, sad, etc.) while they are reading a text improves their overall reading performances, while forcing them not to make the appropriate facial expressions can slow down, or even prevent them from correctly understanding the content of what they were reading (Havas et al. 2010).

Another group of studies has shown that memory retrieval is enhanced when body gestures are involved in encoding information to memory (Barsalou, 1999; Glenberg & Robertson, 2000; Scott et al, 2001). For instance, after reading a sheet of paper with character information, subjects who acted out those character traits were able to better recall it later, compared to individuals who tried to retain the information by re-reading or listening to it.

Another study indicated that even something as simple as taking a different spatial perspective can be improved by the presence of a surrogate body to shift our egocentric perspective into (Mainwaring et al., 2003; Tversky & Hard, 2009). Participants were asked to describe spatial relations between salient objects in a picture, and the presence of a person in the scene encouraged many respondents to take that person's spatial point of view as their own. It led them to describe the location of objects in the scene based on that figure's right or left, despite the cognitive difficulty of reversing left and right.

These findings are some of the most robust evidence to support that mental mappings of situations become intertwined with how they are reflected in the body and as a result, the way we encode our bodies in an experience becomes an integral part of that experience and it will not be the same experience if these embodied aspects are omitted. This integral relationship is consistent with how the neural assemblies are shaped. For example, if our sense of happiness is frequently accompanied by certain facial gestures, they gradually become one.

4-4. Different Notions of Embodiment

After a brief review of the types of evidence that gave rise to a body-oriented view of cognition and before we can begin talking about its concrete benefits for VR, we need to establish a definition that clarifies these findings. Typically, this is where the term *embodiment* comes into play, and in this research, I will also try to provide an adapted definition that applies to the specific case of VR.

First, however, we need to realize that embodiment –much like other complex concepts such as immersion or presence– has persistently resisted a single definition. Embodiment has also been used across different contexts and as the topic of inquiry in philosophy, neuroscience, psychology, cognitive science and artificial intelligence. This has made it harder to find a unifying definition for the concept although the goal of these attempts has been to explain the type of phenomenon described in the evidence section earlier.

From a philosophical perspective, embodiment has been part of a broader discussion on how one defines and experiences oneself. It emphasized the relevance of sensorimotor skills for general intelligence, the situatedness of cognition, and the role that the body has in determining the outcome of thought processes, in addition to the subjective experience of owning and using a body (Blanke & Metzinger 2009).

Embodiment was also used to acknowledge that bodies are constantly receiving a flow of information - including auditory, visual, tactile, proprioceptive, vestibular[20] and interceptive[21] - from the surroundings and the body itself which is more than any other object in the world. We

[20] The sensory system that provides the leading contribution to the sense of balance and spatial orientation
[21] The internal sensors that provide a sense of what our internal organs are feeling, like hunger.

also have unique internal access to it (de Vignemont 2011, p. 1). After all, it is only through this body that we can feel most sensations.

An intimate sense of ownership over the body is another aspect of what has been denoted by the term. We care for our bodies more than any other object, and our body is the only instrument of our will that requires no intermediary tool to command. The body is also overwhelmingly successful in completing the essential tasks we require of it, like picking up objects, taking us from one place to another, eating food and informing us about pains.

We feel a sense of ownership over our bodies both in the sense that we know it and feel it intimately and also we can control it to do things exactly as we want to (O'Shaughnessy 1980, p. 211). These are all different ways of attesting to the instinctual fact that there is something unique about experiencing the body as our own or, as Frederique de Vignemont puts it: we have a "non-conceptual intuitive awareness" (de Vignemont 2007, p. 431) of this ownership.

From a neuroscientific standpoint, the term has also been used to describe the phenomenon of the representation of the body in the brain, something that can be altered neurologically (Graziano & Botvinick, 2002). The assumption here is that without an internal representation of the body or a mental model of the relative positions of the head, torso, and limbs, we are unable to perform even the most trivial actions. Also, that model needs to be constantly maintained, according to the sensory feedback we receive, so it can continue to serve its purpose.

Inquiries into the dynamics of this internal representation fall into two scientific disciplines, namely psychology and neurophysiology. Psychologists emphasize the multisensory nature of body representation, and their work demonstrates that vision, touch, and proprioception are combined and cross-referenced with each other in the brain to shape a complex and dynamic model of the body. Neurophysiologists, on the other hand, focus on components of body representation rooted in proprioception and movement control (Hobson & Friston, 2012). Over time, these two disciplines have found common ground, as psychology has turned towards exploring the spatial coordinate systems that organize the representation of the body and the control of our movements, while neurophysiologists now also investigate audio-visual, proprioception and haptics since they can get integrated into same neural assemblies (Hobson, 2015).

Artificial intelligence is yet another discipline that used the term. Here, embodiment is used to point out the intelligent machines' need to have some sort of a body. This body should be closely connected to the robot's central processing unit and be utilized to perform actions. Also, the processing unit should constantly track the body and use that information to adjust itself to better receive the inputs it requires to make the right decisions (Dreyfus 1992). This also connected AI to the field of robotics, where embodiment is substantially simplified to refer to a distinction in artificial forms of intelligence contrasting virtual agents and robots that have a real physical representation to those that do not (Foster, 2007; Wainer et al., 2006).

Finally, embodiment has also been used in the context of video game theory to refer to the digitally created representation of the users, also known as an avatar. The term in this context refers to a visual presentation of the body as a contributor to the sense of being present in a virtual space (Slater, Spanlang, & Corominas, 2010). Dovey and Kennedy (2006) also used the term to refer to the sensorial representation in the game-world that impact the subject and allow it to be re-embodies it that space. As the remainder of this chapter argues, although this last view is a legitimate part of embodiment in VR, only defining embodiment in VR as the existence of such representation might paint an incomplete picture. First, because this definition does not offer any boundary on how similar the representation of the physical body needs to be, and second, because it undermines the psycho-social functions of our body, which we - knowingly or unknowingly- use to convey meaning to ourselves and others around us.

The next section will first categorize four common aspects of the term as the guiding formulas to define embodied experience in VR. However, it should be noted that a constantly evolving definition of the term in relation to VR will remain inevitable as it is currently the case in all other disciplines mentioned earlier (Wilde, 1999; Glenberg, 2010; Meteyard et al., 2012).

4-5. Framing Embodiment for VR

In addition to being a topic of interest across different disciplines, there have also been different combinations of the term within those disciplines, among which are: situated embodiment (Zlatev, 1997), mechanistic embodiment (Sharkey & Ziemke, 2001), phenomenal embodiment (Sharkey & Ziemke, 2001), natural embodiment and structural embodiment (Ziemke, 1999), naturalistic embodiment (Zlatev, 2001), and social embodiment (Barsalou et al., 2003). All these definitions overlap in some regards while diverging in others.

Tom Ziemke (2003) compiled a review of these terms and extracted six broader notions that might be intended when one of the above terms is used: 1) structural coupling between agent and environment, 2) historical embodiment as the result of a history of structural coupling, 3) physical embodiment, 4) social embodiment 5) organismoid embodiment (i.e. organisms such as humanoid robots), and 6) organismic embodiment of autopoietic[22], living systems.

[22] Refers to any system capable of reproducing and maintaining itself.

Drawing on the work of Ziemke, this thesis selects the first four notions from the above list because they are the most applicable options to VR. Out of these four, physical and social embodiment have the most concrete implication for the design of any VR application, while the structural and historical coupling should be taken into account to fully understand how far the extent of social and physical implications can go.

4-5-1. Physical Embodiment

Physical embodiment is probably the most common interpretation of embodiment. According to which there needs to be a tangible and physical instantiation –like a physical body– for the embodiment to be achieved. This means, for example, that all living creatures are embodied because they have physical bodies. However, scholars who originally introduced this definition (Dautenhahn et al., 2002; Quick et al., 1999) would not consider something like a software system to ever be embodied, although it resides in a computer machine. This means that just occupying physical space, or virtual space for that matter, would not be the same as being embodied.

To theorize this distinction, Riegler (2002) asserted that, while just occupying space is not enough, once a system becomes meaningfully connected to its environment, probably through some type of sensors and actuators, it is no longer just occupying space and has become part of the environment and serves a purpose which makes it embodied. For instance, a simple automatic plant watering system that allows water to reach the plant once the soil gets dry would, according to this view, qualify as embodied. It should be noted that this particular example has an important characteristic. The software of this system is placed within a body through which it interacts with the environment, but the purpose that the interaction serves for the plants is relevant here since it contributes to the ecosystem around it.

The problem with this definition is that it still leaves us with the vague criteria of meaningful interaction. A simple RC toy car, for example, occupies space and might have a couple of sensors like speed limits and actuators like wheels and lights. It can be argued that even a wooden chair has some extremely simple actuator/actuator. A typical chair has four legs that make it stand at a certain distance from the floor, much like what an extremely simple sensor, like a thermostat would do. Obviously, these two examples meet some of the criteria established so far and even if we conclude that these are examples of full embodiment, a more specific account should connect this notion to how humans are embodied and what that human interaction with the environment should look like.

An account that bridges this gap and gives a useful interpretation of the meaningful interaction in Riegler's account comes from George Lakoff (1999). Lakoff notes that as a result of having a body like the one we have, humans have developed a metaphorical relationship between the structure of concepts they formed and their bodies. Having this metaphorical relation to the body is the determining factor to reach embodiment. Lakoff demonstrates that the concept of "grasping an idea", for instance, is grounded in the bodily experience/activity of grasping physical objects. This perspective dismisses the possibility of a chair being embodied in a way that humans are embodied since some degree of intelligence is needed. For a software system or a robot, however, this remains an open discussion which is beyond the scope of this thesis[23].

[23] For further information please refer to Collins (2000).

In the case of VR, however, the question is slightly different. On the one hand, since humans are the users of VR and they already are embodied beings due to their long biological evolution, the burden falls on any technology –in this case VR– that tries to simulate, change or expand bodily actions to be customized according to this predisposition. In Lakoff's view, having hand allowed us to develop and expand the concept of grasping which is now an affordance we come to expect from everything we interact with. Consequently, humans respond better to a virtual body that gives them familiar affordances like grasping hands, extending arms, bending legs or rotating wrists.

On the other hand, much like what happened with the physical body, it is imaginable that through time we would develop new metaphorical relationships with a virtual body that is not like ours. As a result, this view does not preclude the possibility of being embodied in a different virtual body, but we should be mindful of the effort required to shape new metaphorical relations to and the potential conflicts they might cause for users who are accustomed to human-like bodies.

To generalize, an embodied virtual simulation (of well-defined actions) needs to start with allowing virtual actions that are to some degree similar to how we are used to performing them and perceiving ourselves while doing them in the physical world. In terms of input interfaces, for instance, we have limbs with certain affordances –like having hands and legs that bend in different directions– which we use alongside sensory stimuli to discover our surroundings in ways that a hand-held motion-tracked controller with a couple of buttons cannot simulate. Since it fails to do so, it fails to comply with our physical embodied predisposition to perform efficiently in a virtual environment.

The complementary component is that we also can use our senses to direct what we are doing and VR relies on the idea of the avatars to simulate this aspect. It is true that every avatar tries to reflect our motor control to some degree. For instance, most avatars tend to reflect spatial movements, by moving their point of view accordingly, while many of them do not reflect changes in body gestures or facial expressions. In fact, many recent VR games such as *Job Simulator (2016), Beat Saber (2018), Space Pirate Trainer (2016), Silicon Valley (2017),* and *Fallout 4 VR (2017)* mostly skip the representation of the body and rely only on the first-person (floating head) point-of-view, where motion tracked controllers signal where a generic looking hand or a weapon would show up, while the rest of the body is missing.

In such cases, the first-person point of view is an accurate simulation of how we are used to seeing the world, however, the lack of visual stimuli from the body parts is one of the missing components for embodiment. Admittedly many such shortcomings are due to technical complexities of tracking full body movements and are expected to be resolved in the future, however, the goal must not be mistaken with achieving just a visual signpost for the body.

It is true that we see and hear our bodies do what we decide to, and that VR to some degree has managed to recreate this, but we are also aware of what we do through tactile, proprioceptive, vestibular and interoceptive inputs, which are all stimuli that VR still cannot provide in its interface, nor can it reflect them in its virtual avatars. Similar to how what we see in VR changes as we move, mechanisms of feedback around other actions need to be created. For instance, when we pick up a virtual object, the weight that our hand/arm senses (through its proprioceptive sensors) determines how hard our grip should be and how the rest of the body should be positioned to be able to carry this weight. At the same time, the haptic sense determines if there is enough friction in our grip or if the temperature is within certain limits that wouldn't cause pain. These were just a few examples of all the feedbacks involved in performing actions.

In addition to the sensory feedback that users themselves need to receive in order to carry out actions, there is also and interpersonal aspect to such feedback. There is a range of usually subtle and yet vital role that these feedbacks can play in conveying information between people which brings us to the social aspect of embodiment.

4-5-2. Social Embodiment

As Barsalou et al. (2003) explain, states of the body, such as postures, limb movement, facial expressions, and body language - which manifests itself during social interactions - play a central role in social information processing. This processing includes both how we decide to express our current state or intention and our identity or attitude through the body long before any verbal communication or even conscious thinking gets involved.

Social embodiment adds a new dimension to the physical embodiment by reminding us to take into account the following three facts about the function of the body (Ziemke 2003): first, when we receive social stimuli, in addition to reaching a certain cognitive state, we simultaneously express that cognition through certain bodily states. For example, being embarrassed in public is not only a matter of mental realization of being embarrassed, it is also accompanied by refusing to make eye contacts, trying to occupy less space, trying not to be noticed, etc. Such bodily manifestations are tied to the state of embarrassment, and while somebody might manage to conceal it or present it differently, the fact that embarrassment goes beyond a mere state of mind remains. According to the neurological principles we have discussed earlier, in a neural system, the manifestations will become interconnected with the mental state to a point that it is impossible to distinguish one from the other and triggering one is to trigger the other.

Second, perceiving the bodily states of others can trigger bodily mimicry in us, which can subsequently bring about a cognitive state of mind for the observer (Dautenhahn, 1997; Seger, Stone & Keenan, 2004). Repeating the body language of others is a nonverbal way to communicate how much we like the people we are interacting with. For example, the synchronicity of the crowd at rock concerts or parades automatically gives participants a feeling of belonging which may not be consciously realized by them, but that does not prevent people from participating in it. According to Dautenhahn (1997), participants go directly from intercepting the gestures to repeating them, and then to the corresponding mental state without realizing it. They would only be aware of how safe they felt if they paused their activity for a moment and intentionally paid attention to their condition.

This brings us to the last point: bodily states do not need to be reflected in conscious thinking in order to have subsequent impacts. For example, forcing a smile on someone's face by asking them to horizontally hold a pen with their lips will increase how funny they perceive a cartoon while preventing a smile will cause the opposite effect (Stepper & Strack, 1993). This shows that even subjects who are conscious of their artificial enforced body gesture cannot escape the implicit impact that they create.

The social aspect of the embodiment brings additional requirements to any VR setting that wants to encompass social embodiment. First, VR should allow multiple users to exist and interact in the same virtual environment, these interactions should start with seeing where they are placed and hearing what they are saying via their avatars and go further to reflect them in a more detailed way where subtle movements, gestures, and expressions are visible. Users should be able to change how they appear to each other in terms of skin color, body shape, clothing, makeup, and facial expressions. Second, the input interface through which these capabilities are afforded to the user, needs to closely simulate the original body controls (Cabral et al., 2005). For instance, although pushing a button can be used to manifest a happy facial expression to others, for the user that is not a bodily expression neurologically associated with happiness, which will interfere with the full experience of the user.

Physical and social embodiment as described here has been gradually gaining momentum in scholarly works in the past two decades (Ijsselsteijn et al., 1998, 2000, 2001, Leea et al., 2006, Slater et al., 2016a, 2016b, 2017a, 2017b), however, this chapter emphasizes two lesser-known aspects of embodiment, namely the structural and historical coupling, that can put the physical and social aspects into some perspective for future VR applications.

4-5-3. Embodiment as Structural Coupling

An illuminating interpretation of the meaningful interaction criterion that Riegler suggested earlier is the notion of embodiment as structural coupling which originated from Maturana and Varela's (1980) work on the biology of cognition. Quick et al. (2000) expanded this notion to also apply to non-biological systems and claimed that a system[24] is embodied only when it is structurally coupled to the environment it is operating in. Structural coupling is achieved when, at any given time, a subset of the states of the system are caused by the environment around it

[24] Humans are a type of system in this definition.

while at the same time, a subset of states of the environment are caused by the system within it (Quick et al., 2000, p. 7). Also, the corresponding states between system and the environment are said to have formed a channel.

For instance, in our earlier case of a plant-watering system, structural coupling requires the system to be constantly aware of the moisture level of the soil. As a result we can say that the state of the system is impacted by the one of many states of its environment. On the other hand, if the amount of water in the soil is provided by the system so the system's state in terms of moisture is determined by the system. Obviously, this was just one example of numerous channels that can be established between the states of the system and states of the environment. Another channel can be established if the system starts to gets its electricity from the plant or starts to monitor and provide other nutrients that the plant needs.

Critics of this view like Riegler (2002), on the other hand, have argued that being structurally coupled ends up being a low requirement that renders any system to be structurally coupled with its environment to some degree. For example, a simple piece of rock lying in a garden is also structurally coupled with its environment since it will inevitably affect how the sunlight or the wind reaches its surroundings while a nearby flower (part of the rock's environment) can have the same influence on the rock.

One way to reconcile Riegler's criticism with the original definition is to view structural coupling as a relative idea that forms a spectrum where, for example, a piece of rock is less structurally coupled compared to our hypothetical plant-watering system. The plant-watering system has established more channels that connect its states to the states of its environment while it still is influenced by the wind and sunlight as the piece of rock was. In addition to establishing new channels, increasing the bandwidth of existing channels will also increase structural coupling (Quick et al., 2000). Channel bandwidth, in this context, refers to how closely the aforementioned states reflect one another. For example, if the plant-watering system places multiple sensors in different areas to monitor the plant's moisture level, it achieved a higher bandwidth compared to when there was only one sensor.

Now, if we turn to virtual environments and ask how the user can be structurally coupled with that environment, a couple of responses come to mind. First, structural coupling encourages a constant mutual interaction between users and virtual environment in a variety of channels with higher bandwidths. As VR provides more sensorimotor inputs to users, it establishes new channels of interaction that impact user's internal states. Reflecting users physical and social states in VR, such as body movements and facial expressions, creates a channel through which user impacts the virtual environment. Increasing the fidelity of sensory inputs, such as higher image resolution, or improving the tracking capabilities of VR can also increase the channel bandwidth and increase structural coupling.

Second, user actions can also be a great source of influence on virtual environments since it compels VEs to reflect the results of these actions. This makes the idea of treating VR users as sheer observers problematic. This can be a criticism of the exploratory VR applications such as *Google Expedition Tours (2014),* where users are placed in different geographical locations and get to only move around and look at objects. One could argue that even the most trivial controls we are afforded as observers in VR in terms of where to move or what to look at, still allow for some degree of interaction with the environment. This is a legitimate argument for some degree of structural coupling in a relatively passive VR application and confirms the need to recognize a spectrum for structural coupling where basic interactions can put a virtual tour into a superior position compared to, for example, watching a movie from a predetermined point of view.

Before concluding this section, there is an important distinction we can make between different types of structural couplings. When we think of biological systems, it is hard to think about cases of structural coupling without realizing that many of the existing channels have been gradually evolved through a long period of time to adapt that organism to its environment and increase its chance of survival. In VR, however, this evolution is more time constrained with and more limited in its scope. In what comes next, I will first discuss the role of history and then show how it can be translated to apply to the relationship between VR users and their virtual environment.

For instance, regardless of how necessary haptics feedback might be for a user, it is not logical to expect users to establish this sensory channel without VR already providing the required feedback for it. However, expecting users to adapt to a structural coupling would need more affordances from the virtual environment. In particular, allowing users to manipulate a virtual environment without having a way of maintaining the results of this interaction makes it hard to say a meaningful change has taken place as a result of this coupling. For instance, moving a virtual chair that immediately goes back to its original position, in most contexts, is a useless virtual act. If we take this logic a bit further, moving a virtual chair that does not return to its original position, but also does not have any further impact down the line to the user or to the virtual environment is also meaningless. Being aware of the down-the-line impacts of actions brings us to the final aspect of embodiment, namely embodiment as historical coupling.

4-5-4. Embodiment as Historical Coupling

In order to complete the picture drawn by structural coupling and point out the origin of structural coupling, some researchers proposed history as a complementary criteria that can explain the root cause of embodiment. Varela et al. (1991) observed that cognitive systems became structurally coupled to their environment due to a long process of agent-environment adaptation which forces one or both sides to change. On the systems side, this resulted in establishing new channels to interact more efficiently with the environment. For instance, the simple light-sensitive spot on the skin of some ancestral creature gave it some tiny survival advantage by perhaps allowing it to evade a predator or move more efficiently toward food. After a long period of time this evolved into the visual sense that many animals have today (Lamb, 2011).

Environments also have to change as new channels were being established. The burrowing behavior of some marine animals 530 million years ago, manage to break down organic material in the seafloor and release stored carbon dioxide into the waters which then gradually made its way into the atmosphere and led to a 100-million-year long period of global warming (Lenton et al., 2015).

Riegler (2002) tried to include the role of adaptation in creating structural coupling and claimed a system to be embodied when we see the evidence of co-adaptation between that system and its environment. An easy way to detect historical coupling is to test whether the agent has gained any competency from being in the environment. This notion is similar to the biological view of evolution; however, we should note that the time scale required for biological evolution is significantly longer than what we have available in VR's historical couplings.

Riegler's framing of historical coupling extends that of structural coupling, since it implies that having a structural coupling that lasts over a certain amount of time could result in historical coupling if signs of change in the agent can be identified. Take the way we treated televisions for example. TVs provided a new way for us to know about the world around us. In a sense, they established a new channel between viewers and the world and this channel gradually started to change viewers. They arranged their homes around it, scheduled their days according to its programs and started to think about the world based on the information it provided. These were all instances of us adapting and hence becoming historically coupled with our environment through an instance of structural coupling.

Looking at today's VR applications, some general patterns of historical coupling can be detected. Most VR applications retain the impact that users' decisions make on the virtual environment for a period of time. A trivial example of this is allowing users to move virtual objects around. However, more significant examples can be found where VR provides users with the opportunity to adapt to their environment as they spend time in VR. Many VR games adopt a point-and-click movement mechanism which at first might be unintuitive, but over time users can adapt to it and move on to enjoy other aspects of the game.

Whether it is something simple like learning how to move in VR using the controllers or navigating complex tasks such as painting in 3D, they all need to actively or passively encourage users to reshape their existing perception and behaviors on a personal and social level. The next chapter will return to this notion of adapting to show some of the underlying structures that govern our adaptation to a virtual environment.

4-6. VR's Potential for Embodiment

As it has been previously demonstrated, all four notions of embodiment can be utilized to ease the virtual experience into being more embodied, however, in order to complete our discussion we need to answer one final question: If embodiment, as outlined here, is to be achieved in contemporary VR technology, what are the affordances VR needs to provide?

By looking back at the definitions - and given the nature of digital technology – this research puts forward three categories originally extracted from Costa et al. (2013) which can encompass many of the embodiment requirements discussed so far. These affordances include sensory stimuli, motor control, and psycho-social.

4-6-1. Sensory Stimuli

First, an ideal VR experience will need to provide a full sensory embodiment, which refers to the degree to which the users can leverage their senses in a virtual environment. Also, this definition is not limited to the traditional five senses and includes proprioception, thermoception (temperature), nociception (pain) and equilibrioception (balance). Understandably, this adds technical complexities that are subjects of inquiry in the field of human-computer interaction and outside the focus of this thesis, however the fact that all these senses have a role to play in an embodied experience, cannot be ignored.

The body of research regarding different senses and their impact on VR users, while growing significantly in the past two decades, is not evenly distributed among the senses. Visual sensory stimulation has been investigated the most, which is justifiable due to the preference our mind has towards this sense, in fact, cases of lacking modality correlations between vision and other senses usually result in a higher emphasis on vision. For example, if we see a lawn mower in the VR in front of us, but hear the sound is coming from behind us, our first response is to force the sound to match our vision and register it as coming from somewhere in front of us instead of ever attempting to question our vision (Guttman, Gilroy & Blake, 2005).

Visual stimulation research covers topics such as the impact of visual scale - i.e. how big objects appear- (Downing et al., 2001; Czerwinski, Tan, & Robertson, 2002), imagery dimension (how 2D and 3D images affect us) (Kober, Kurzmann, & Neuper, 2012), and imagery fidelity (how to visual details and photo-realism impact us) (Goldstein 2007).

Next, we have the study of auditory stimulation which nowadays is concentrated on action-driven sounds that originate from potentially moving sources and is commonly used in existing VR applications that allow users to spatially pinpoint the exact source of a sound. The research into the fidelity of such dynamic sounds constitutes a majority of research in sound stimulation (Murphy & Pitt, 2001; Grimshaw, Lindley, & Nacke, 2008).

Haptic feedbacks are probably the fastest emerging subfield in VR, and simplified cases -such as vibrations in the controller - have been around for more than two decades (Benali-Khoudja et al., 2004). The more advanced research looks into how feedback forces can improve our task performance (Bailenson & Yee, 2007; Reiley et al., 2008), one example being haptic feedback helping novice surgeons to decrease inconsistencies in applying pressure during surgical cuts in a simulator.

Smell and taste are the two remaining senses that have been underrepresented in scholarly work due to technical complexities involved in their simulation. Dinh et al. (1999) conducted one of the first VR experiments that stimulated scent, where they evaluated the effects of smell and taste on memory by using coffee among other stimuli. The results showed that the presence of scent helps to recognize objects faster comparatively due to the higher object engagement it creates for users. Another study conducted by Tortell et al. (2007) confirmed these findings. The olfactory stimulus also has been shown to induce certain feelings –like joy or calmness– in multiple studies (Carlin, Hoffman, & Weghorst, 1997; Hoffman et al., 2003; Baños et al., 2013, 2014).

In addition to the five basic senses, there are other more subtle senses such as our ability to detect heat, cold, itch, skin tension, pains and hunger that VR research has not investigated usually due to technical complexity. As a result, we cannot know the degree of embodiment we can expect VR to achieve via channels that only utilize the main five senses until a more complete picture emerges.

4-6-2. Motor Control

Traditionally, motor affordance is provided using constrictive interfaces like gamepads and joysticks, but VR has pushed that into a significantly greater degree of freedom, involving crouching, bending, head movements such as pitching[25], yawing[26]. This increase of motor freedom is complemented by the fact that in some cases they are afforded in ways that our bodies are already adapted to. For instance, to see the surroundings, users only need to turn their heads which how it is done in the physical world. The goal of motor affordance in VR is to provide the same possibility with regards to all our movements.

[25] Rotating around the horizontal axis.
[26] Rotating around the vertical axis.

Just because the outcome of any movement can be broken down into a set of three-dimensional transitions in an XYZ coordinate system, we should not undermine the complex processes that generate the vast range of movements we are capable of. Executing any action heavily depends on the creation, maintenance and moment-by-moment reactivation of neural mappings that tells us how to appropriately program/execute our movements in the specific situations in which we find ourselves.

Also, we constantly balance the feedback we receive from the world as the movement is taking place against our previous expertise. For instance, even though we might be quite experienced at picking up coffee mugs, we continue to take proprioceptive and haptic feedback that tell us how heavy or hot the cup is into account

Although the range of natural and artificial movements are theoretically infinite, in practice the research on the motor affordances of VR is rather limited. As Boletsis (2017) describes, the scholarly work can be categorized into four groups: motion-based research (which involves walking-in-place[27], redirected walking[28], gesture-based[29], arm-swinging[30] and reorientation[31]), room scale-based studies (which tracks subjects as they walk around a room), controller-based research (which either uses traditional game controllers or the human-joystick method that extracts input from subjects' head movements as they are standing or seated in a chair-based [32]

[27] The user performs virtual locomotion by walking in place, i.e., using step-like movements while remaining stationary.
[28] The user walks freely inside a limited physical space while being able to explore unlimited virtual environment.
[29] The user makes gestures to direct virtual movement. The various gestures such as tap, push and flying.
[30] Users swing their arms while remaining stationary, and their arm movements are translated into VR motion.
[31] The user walks freely inside a limited physical space while being able to explore unlimited virtual environments by modifying the rotational gain of the users, so they physically turn around when they meet the boundaries of the physical space
[32] The user sits on a stool chair, which acts as an input device, and the stool rotation and tilt are translated into VR forward/backward and turning motions.

system), and teleportation-based research, where in order to move, users just point to a place and get relocated immediately.

Walking-in-place and controller/joystick-based locomotion are the most studied techniques (Bozgeyikli et al., 2016; Langbehn et al., 2015; Skopp et al., 2014) and we can distinguish two different types of interfaces. Physical interaction of the walk-in-place method uses our familiar ways of moving and interacting –such as walking, grasping, picking, and etc. – and is more in line with what physical embodiment advocates.

On the other hand, control/joystick-based locomotion employs an artificial motor control that might allow for a less physically intense experience, with the user being stationary and relying on a hand controller to trigger movements instead, which can be cognitively intense and is known to lead to VR sickness (Fernandes & Feiner 2016).

VR teleportation techniques are not studied as much as the previous methods, although they are the most dominant locomotion techniques in commercial VR games (Boletsis, 2017). As most of the evidence in the next chapter will show, room-scale based motor controls are the least compromising - and hence the most compliant category - for physical and social embodied since it allows for a limited and highly controlled amount of natural, closely tracked movements, that are complemented with physical objects to add rich sensory stimuli such as haptic and tactile feedback.

4-6-3. Psycho-social affordances

Finally, we have what Costa et al. (2013) called the psycho-social affordance, which refers to the capability of VR to allow users to express their personal and group identity. This can be provided through a wide range of communication methods we constantly employ to convey information to others, ranging from our appearances and our actions to how we talk and etc.

Research shows that people put considerable effort into customizing their avatars (Ducheneaut et al., 2009) while they try to realize some aspects of their “ideal” selves through the avatar which then can increase their self-esteem (Bessiere, Seay, & Kiesler, 2007; Dunn & Guadagno, 2012). Users also modify their behavior to match the avatar they created (Yee & Bailenson, 2007), for example, the ideal self for a user might entail an avatar with a mysterious face covered by their hair, which in turn encourages the VR user to engage less in discussions and navigate situations in more subtle ways.

There is also a host of studies focused on the social dynamics of large or small groups of people in a shared virtual environment and one approach has been to investigate how avatar’s verbal and non-verbal methods of communication are employed by participants to achieve certain goals (Allwood & Schroeder 2000; Abelin, Axelsson & Schroeder 2001). During their studies, they monitored who dominates the group in a task scenario that requires coordinating others while subjects were given certain non-verbal communication advantage. Their findings showed that the degree of freedom in interacting with a virtual environment was the determining factor in who will assume the role of coordinating others. Slater et al. (2000) have expanded this finding by claiming that even individuals who usually do not tend to take leadership roles will do so once given the more flexible VR interface (Slater et al., 2000).

Other studies also showed that both in small and large groups, the majority of users follow the social conventions of the real world such as keeping their distance from others, turning to face their conversation partners keeping more distance from strangers and valuable objects, etc. (Pargman 2000; Schroeder 1999).

Also, it was demonstrated that not all the features of one's virtual representation have the same significance for the users. Hirose et al. (1999) have discovered that more visible parts of the avatar like weight, height, nose size and eye shapes are the most common characteristics to customize, while very few people will go through the trouble of customizing what is not immediately visible to others, like the ears.

The psycho-social affordance appears to cover a broad category of dynamics that don't exactly fit into the scope of the motor and sensory affordances discussed earlier, however, in many regards has to rely on them to function. For instance, there is a significant performative aspect to the way we do even trivial things in different cultures. Frustration about having to wait in a long line to get the daily coffee can be communicated in many non-verbal methods such as frequently looking at our watches, crossing the arms, exhaling deeply, etc. and we highly rely on the motor and sensory affordances to implement them.

4-7. A Reflection on Value

This chapter started by putting forward the idea that an embodied VR experience will allow well-defined virtual activities to maintain the values attributed to such actions in a non-virtual world. Now we will return to that discussion in light of the physical and social embodiment we outlined earlier, starting with a reflection on the concept of value and a distinction between instrumental versus intrinsic value. This distinction is used to narrow down my claim and argue that the instrumental values of embodied VR activities are on par with conventional non-virtual ones.

Let's refer to the value theory to distinguish between instrumental and intrinsic values (Zimmerman et al., 2019). Instrumental[33] value is that which we attribute to actions, people, ideas, objects, and properties, because they lead to an achievable result, regardless of how good or bad said result might be. For instance, money is supposed to be instrumentally good due to its function of achieving things, but not intrinsically good or bad, since it might or might not lead to good/bad ends.

On the other hand, the intrinsic value of something is said to be the value that that thing has "in itself," or "for its own sake," or "as such," or "in its own right". As one of the oldest questions that philosophers tried to answer, there is a large scholarly work around what values fall into this category or whether or not this category even exist which is outside the scope of this thesis especially since this chapter's argument only targets the instrumental value of actions.

If we return to the case of virtual martial arts, it seems that all the instrumental values we might attribute to the non-virtual martial arts can be transferred to its virtual counterpart, as long as the virtual martial arts is physically and socially embodied. For instance, martial arts as a sport with the instrumental value of promoting physical fitness relies on motor control and sensorimotor

[33] The *Intrinsic* vs. *Instrumental* distinction appears to be the most relevant framing for the value theory in VR compared to other consequentialist terms such as "*utility"* that are usually used in relation to ethics. However, if one has a utilitarian interpretation of actions which defines actions to be exactly the consequences they bring about (de Lazari-Radek & Singer, 2017), then this chapter's claim would be that once VR technology becomes embodied enough, it will be able to recreate actions with the same utilitarian values.

coordination which are skills acquired through repetition and practice. A physically embodied virtual martial arts will result in promoting the same proficiencies and hence bring the same instrumental values as martial arts. Proficiencies such as muscle control, muscular endurance, pain tolerance, sensorimotor coordination and other body-related techniques practiced in martial arts, fall under the requirements for physical embodiment. The mental skills such as anticipating an attack, planning counterattacks or analyzing the opponent are examples of structural couplings that users need to acquire as they try to improve their virtual experience and all these changes are instances of historical coupling that can be formed through time.

On the other hand, martial arts as a way of promoting mental health which, for example, encourages respect for others and the environment can be simulated in a socially embodied virtual experience. If there are any physical manifestations involved in a martial arts code of ethics like manners, courtesy, respect or consideration for others, the psycho-social affordances of VR can ensures that users are provided with ways to express them.

4-8. Conclusion

The third chapter reflected on what is real in a virtual environment and argued that in addition to the essentially digital elements such as objects, properties and events, there is a very real and dynamic social aspect to anything that takes place in VR. The chapter then concluded by discussing the value of virtual activities and how comparable they are to their non-virtual counterparts. By juxtaposing virtual martial arts and virtual sex, it appeared that in the case of virtual martial arts there was a direct relation between the accuracy of the simulation and how comparable the value of virtual activity was with the non-virtual counterpart.

In this chapter, the idea of accurate simulation, particularly for well-defined actions, was expanded and embodiment as the criterion to evaluate this notion accuracy was put forward. An account of embodiment that fully applies to virtual environments, should not be limited to just the physical actions, and must capture all the implications of having a body. This means that an embodied VR should include the physical and the social aspects of experiencing the world through human bodies. As EC research suggests, we develop cognitive ties to the body where we not only perceive and interact with the world through the body, we also interpret the world in relation to our bodies. Consequently, VR applications have to allow their users to utilize their body in ways that are

In order to outline what VR should provide to allow for the social and physical embodiment, this chapter offered three types of affordances that if VR provides, it can move towards fully utilizing all our bodily functionalities. Sensory stimuli allow users to fully perceive what takes place in a virtual environment and their interaction with the environment as they perform different actions. Motor controls are the various muscle movements that are conducted by any part of the body and make actions possible. Finally, psycho-social affordances that allow expression of our cognitive state were introduced as an indispensable aspect of an embodied experience which is usually undermined in VR design.

This chapter argued that by employing all three affordances, virtual experiences have the necessary toolset to tackle the problem of accurate simulation in VR. The instrumental value of well-defined activities –which is the outcomes expected from performing them– that in the case of martial arts could be physical fitness or mental health can be achieved through an exact replication of actions through motor controls and sensory stimulation. The personal and interpersonal aspects of a martial arts experience such as expressing respect towards others or showing mental peace are also elements that the psycho-social affordance of VR can help to bring about.

As we will see in the next chapter, sensory stimuli, motor control and psycho-social expression are broad categories that can overlap and influence each other. One particular area of research where the dynamics of these affordances has been studied the most is the body-ownership phenomenon in VR. By measuring how successfully these affordances can make an avatar incorporated into our bodies, researchers have tried to find rules to reach the most effective combination of these affordances in a non-ideal VR settings. In the next chapter, the impact of these affordances on each other will be discussed and the principles to best utilize them are extracted.

5. From Avatars to Body Ownership

One need not be a chamber to be haunted,
One need not be a house;
The brain has corridors surpassing material place.
- Emily Dickinson

5-1. Introduction

In the third chapter, we have reflected on what is "real" in a virtual environment and argued that VR is constituted of real objects, events and properties. In the chapter that followed, this thesis delved into how valuable VR experiences can be, a multifaceted topic that resists broad judgment. By framing the question of value in terms of embodiment, it was possible to argue that a combination of physical and social definitions of embodiment for VR can act as a more comprehensive set of criteria to consider in order to achieve accurate simulations.

The concept of embodiment served as a valuable lens, through which it was possible to identify what we desire VR to imitate from the non-virtual world. In the present chapter, however, we will take another route, pointing out the flexibilities that allow us to deviate from non-virtual embodiment and still achieve embodiment in VR. These flexibilities are rooted in the neural structures that were discussed previously, but this time they will be centered around the parts of that neural system that tells us where our body starts and ends, also known as the body schema, which underlies our sense of body-ownership and as we discussed in the previous chapter, our embodiment relies on this relation of ownership towards non-virtual or virtual bodies to exist.

To demonstrate the plasticity of our body schema, the chapter starts by responding to a simple, yet significant question about the limitations of embodiment in VR, known as the body-specificity hypothesis. According to the body-specificity hypothesis (Casasanto, 2009), an immediate consequence of embodied cognition is that people with different bodies who then interact with the environment in systematically different ways are bound to develop systematically different perceptions and concepts. As a result, VR - or any other platform for that matter - is inherently incapable of creating embodied experiences that are on par with what we experience through our unique bodies which makes virtual embodiments inferior to real-world embodied experiences.

Particularly regarding our sense of body-ownership, this hypothesis casts doubt on the possibility of feeling ownership towards any virtual representation that differs from the physical body we are adapted to. Before giving any response to this criticism, this chapter first outlines how the neural structures responsible for the sense of body-ownership are shaped, maintained and possibly changed.

As the studies discussed in this chapter will show, although the body-specificity and its consequences are indeed at play, the underlying mechanism behind body-specificity and body ownership appears to remain susceptible to change and certain considerations can significantly accelerate the speed of this change. The current body of research on the preconditions of body-ownership support two general principles that can contribute to the incorporation of virtual/non-virtual objects into our body schema: first, there needs to be a sensory signal correspondence between different stimuli, particularly the correlation between audio-visual and visuo-tactile is influential (Slater et al. 2008, 2009; Kilteni et al. 2013). Second, sensorimotor contingency needs to be in place to assure sensed body movements correlate with what audiovisual, haptic and proprioceptive feedbacks are signaling (Slater et al., 2009, von Zadow et al. 2013, Linkenauger et al. 2013).

Since academic experiments that have fully employed these principles are scarce, the chapter includes a delineation of three emerging VR applications - namely: body transformation, body-swap empathy and implicit learning where the above principles have been implemented to varying degrees and early results have indicated significant behavioral implications that can warrant further academic research into the topic.

The chapter then concludes by revisiting the body-specificity hypothesis to propose an interpretation that recognizes some legitimate concerns posed by this theory. Gender-based sensitivity disparity to stimuli, top-down nature of body ownership, and social biases like self-objectification are instances where VR experience has to be personalized to circumvent challenges imposed by this hypothesis. Meanwhile, the sensory correlation measures that this chapter discusses can offset some of the negative impact that body-specificity impose and can act as an intermediary step until highly customizable VR applications become feasible.

5-2. The Body-Specificity Hypothesis

Once we admit that embodied cognition means our thoughts are rooted in neural structures that are impacted by bodily experiences, it is only logical to expect that any individual must think differently to some degree, since we all have unique bodies. In other words, if concepts and word meanings are constituted in part by people's perceptions and actions, then different bodies that interact with their environments in systematically different ways, should form correspondingly different mental representations. Daniel Casasanto (2009) called this the body-specificity hypothesis. He goes on further to offer some evidence for his theory, by pointing out that people usually have a better fluency in using one hand over the other - also known as handedness - which he also believes can influence our judgments about abstract ideas, like value, intelligence, and honesty.

This hypothesis was supported through a series of experiments (Casasanto and Boroditsky, 2008; Casasanto, 2009; Casasanto and Dijkstra, 2010), where participants were asked which of two products to buy, which of two job applicants to hire, or which of two alien creatures looked more trustworthy. Right-handers routinely chose the product, person or creature they saw on the right side of the page, while left-handers preferred the one on the left. These kinds of preferences have been found in children as young as 5 years old (Casasanto, 2009). The experiment concluded that when everything else is similar, people tend to prefer the things that they encounter on the same side as their dominant hand.

Casasanto has directly associated the underlying cause of this phenomenon with the role of the fluency within an embodied experience. People prefer things that are easier to be perceived and interacted with, so right-handers interact with their environment more easily on the right than on the left, coming to associate “good” with the right side and “bad” with the left.

However, there is another crucial finding in Casasanto’s later research that shows this fluency is not set in stone and can be changed with little effort. Right-handed people who have had their right hands permanently handicapped or paralyzed and therefore rely on their left hand, start to associate “good” with the left side. More interestingly, the same transition will happen for right-handed individuals whose right hand is temporarily handicapped in a laboratory setting. Casasanto and Chrysikou (2011) demonstrated this in two separate experiments where individuals were made to wear ski gloves on their dominant hand. After only a few minutes of fumbling with it, right-handed subjects started to make decisions that resembled those of their left-handed counterparts.

5-3. Body Ownership and Avatars

While body-specificity theory puts forward a serious argument for the unique formation of mental representations, in doing so we have also discovered that the underlying plasticity of those representations allows a technology like VR to turn us into its adept users. This adaptation takes place through our sense of body ownership, which as the following neurological evidence shows, is in no way limited to our physical body and can go further to include tools and virtual avatars and objects.

To understand why body-specificity does not necessarily prevent our sense of body/avatar ownership, we must first see how this ownership is shaped and in order to do so, we must break down the fundamentals of the neural relationship between our body and external objects, including virtual ones.

When we play the drums, ride a bicycle, hammer a nail, or wear glasses, we extend our body structure through external objects and tools. Our instinctive ability to rapidly incorporate such objects and learn how to use these tools provides a clue to the remarkable plasticity of our brain in reflecting changes in our body and encoding the space where it resides in a way that keeps our interactions consistent.

Compelling observational evidence, coupled with neurological monitoring, indicates that the brain's representation of the body can be changed and extended[34] (Iriki et al, 1996; Ishibashi et al. 2000; Maravita et al. 2004; Yamamoto et al. 2001). For us to act efficiently in our environments, our brain needs to not only localize any object of interest in our extra-personal space, but also hold a constantly updated status of our body shape and posture maintained mainly through the unconscious integration of successive sensory, proprioceptive, vestibular and haptic signals, known as the *body schema*[35] (Maravita et al. 2003). This incorporation is what creates the subjective sense of body ownership.

The studies also show that our neural system allows for a malleable body schema, which might seem unnecessary since to us our bodies do not usually undergo rapid and visible changes and appear to be durable and permanent. However, a significant number of studies reviewed by Makin et al. (2008) revealed that what we traditionally considered to be the boundaries between our body and the environment are temporary constructs.

As was discovered with the case of the rubber-hand illusion, it only takes a few minutes of watching a fake rubber hand being stroked and tapped in precise synchrony with one's own unseen hand for an individual to start experiencing the rubber hand as their own. Drawing on this phenomenon, there is now a growing number of studies that seek to create VR equivalents of this phenomenon.

For example, Ijsselsteijn et al. (2006) have shown that recreating just the visual aspect of the rubber hand experiment in VR has the same type of effects, but to a lesser extent when the tactile

[34] To see a full review of these studies please refer to Maravita et al. (2003).
[35] Not to be confused with the body image which consists of perceptions, attitudes, and beliefs concerning one's body. In contrast, body schema consists of sensory-motor capacities that control movement and posture.

aspect is missing. Won et al. (2015) also discovered that subjects will quickly adapt to having a third hand that is controlled by combining the movements of the left and right hand. In another study, Steptoe et al. (2013) have depicted that subjects were able to quickly learn how to control a virtual tail that followed their hips movements.

How we behave in relation to physical extensions of our bodies is a good starting point to understand the relationship between our bodies and a virtual avatar. Research shows that similar to the case of tools, our avatar neither replaces our bodies nor do we mistake it for parts or the physical body; rather, a "good" avatar becomes integrated into our body schema (González-Franco et al. 2010; Lenggenhager, 2007; Perez-Marcos, 2009) from the neural level to the conscious thought.

A clear example of this phenomenon was observed in an experiment conducted by Yee and Bailenson (2009) where subjects were randomly assigned shorter or taller avatars compared to the virtual opponent they were supposed to play a game with. After spending one minute in the virtual environment where they could also see themselves and the other player through a mirror, subjects were asked to play the *ultimatum game*[36]. Results showed that taller avatars played the game more confidently and were less likely to accept unfair offers made by the virtual opponent. Fox and Bailenson (2009) later conducted a similar experiment where instead of avatar's height, the facial attractiveness of the avatars was the variable. Their results also showed that subjects who were given more attractive faces were less likely to accept unfair offers.

[36] An experimental economics game proposed by Forsythe et al. (1994) in which two parties interact anonymously and only once, so reciprocation is not an issue in the game, the first player proposes how to divide a sum of money with the second party. If the second player rejects this division, neither gets anything. If the second accepts, the first gets her demand and the second gets the rest.

Now the question shifts to what constitutes a “good” avatar? The current body of research into this topic shows that a combination of visual and tactile feedback, alongside the motor, proprioceptive and vestibular stimuli, play the most significant role in incorporating the avatar into the body schema. If these inputs are governed by visuo-tactile, visuo-proprioceptive, visuo-vestibular and visuo-motor synchronicity, then necessary –but not sufficient– preconditions for the sense of ownership are present (Tsakiris and Haggard, 2005). It is important to note that it is significantly complicated to talk about “sufficient” conditions of body-ownership - much like any other multifaceted phenomenon - given that there is even evidence showing that one can fail to feel a sense of ownership over one’s physical body or its parts and move toward various types of body objectifications under extreme conditions of pain and suffering (Ataria & Gallagher, 2015). A similar phenomenon can also happen to a lesser degree as a coping mechanism against social norms which we will come back to at the end of this chapter. This is why the different types of synchronicity discussed here are just contributing factors within a broader and more complicated cognitive mechanism.

Visuo-tactile correlations (the first discovered principle thanks to the rubber-hand experiment) in a VR setting refers to providing passive tactile stimulation on a user’s hidden physical limb, while at the same time synchronous visual stimulation from the virtual counterpart limb is demonstrated (Slater et al., 2008). This would be like witnessing your avatar’s right hand touching a flower and simultaneously having the tactile sensations of the soft surface at the exact same spot in one’s real hand. A more sophisticated case would include, for example, different textures, temperature variation, rigidness, etc.

Visuo-proprioceptive correlations during passive or active movements have also been found to accelerate the incorporation of the avatar into the body schema (Dummer, Picot-Annand, Neal, and Moore, 2009; Tsakiris, Prabhu, and Haggard, 2006; Walsh, Moseley, Taylor, and Gandevia, 2011). Proprioceptive signals are sent from muscle receptors to indicate their relative position with regard to other receptors in the rest of the body, a correlation between those signals and our vision then contribute to incorporating an avatar into our body schema. For instance, once we raise our right hand, proprioceptive signals automatically inform the body schema about the change, which doesn't amount to an exact position estimate yet. Having a virtual avatar make the visual corresponding gesture is what completes the picture in the body schema. This also confirms why for the proprioceptive sensors, non-relative[37] attributes such as the size, shape and length of the virtual hand that do not have to exactly match their physical counterparts.

Proprioceptive sensors are agnostic to non-relative features. A similar principle should be followed with regards to our vestibular and visual sense as well, our vestibular system is responsible for the sense of balance primarily sensed through the head which basically detects the direction of the gravity. Visuo-vestibular correlation requires what we see to conform to our sense of balance.

Movements seem to also be a contributing factor, especially when they are coupled with other senses. Visuo-motor (VM) synchronicity requires visual cues from avatar to match the actual body movements. In this case, experiments usually limit the movements to smaller body parts such as fingers and hands to minimize the impact of other correlations (Sanchez-Vives et al., 2010). Also, the time synchronicity between the two stimuli becomes more crucial and microsecond delays can cause the ownership phenomenon to not take place any more.

[37] Non-relative proprioceptive features are the body characteristics that we are incapable of measuring through only the proprioceptive signals. For instance, we are incapable of determining the shape of our own arm only via the signals that our muscles receptors generate about how contracted they are. However, it is clear that once we get other senses such as visual or haptic involved, we will be able to determine these features.

In the studies discussed so far, visual input were a common element due to the primacy of vision over other senses. It has been consistently shown that vision usually plays a dominant role over touch and proprioception (Ernst and Banks, 2002). For example, even a non-informative vision of body parts can improve the tactile perception by improving the spatial resolution of touch (Haggard, Taylor-Clarke, and Kennett, 2003; Kennett, Taylor-Clarke, and Haggard, 2001). For example, it was shown that looking at a picture of a rubber arm would help subjects identify where they are being stroked on their real hand compared to when a different object or a dark surface was displayed in front of them. However, some studies that tried to entirely leave the vision out of the experiment discovered that other combinations - such as proprioception and active motor control - can still create a sense of body ownership (Tsakiris and Haggard, 2005; Tsakiris et al. 2006). In one such experiment, subjects' fingers were moved and stroked without them being able to see it happening on a rubber finger, nevertheless, being able to actively move the finger and only see it at its final locations was shown to have a positive impact, but to a lesser degree compared to previous cases.

Unlike previous studies that focused on ownership over parts of the body, there are also a few experiments that sought to investigate the full body ownership phenomenon (Petkova and Ehrsson, 2008; Slater, Spanlang, Sanchez-Vives, and Blanke, 2010). They have discovered that the first-person point of view overwhelmingly surpasses the 3rd person point of view of a full body in bringing a sense of ownership (Petkova, Khoshnevis, and Ehrsson, 2011).

Lastly, the morphological similarities to one's body have been shown to influence body-ownership (Tsakiris et al., 2009; Tsakiris and Haggard, 2005). For instance, Tsakiris et al. (2010) showed that subjects were unable to feel ownership over a hand that appeared to be made out of wood. However, other physical aspects of the body parts, for instance, the accuracy in shape and color of the hand in the rubber hand experiment did not impact the sense of ownership as much (Longo et al., 2009; Kilteni et al., 2015).

The findings discussed so far portray a nuanced and unfinished picture of what can and cannot be incorporated into the body schema. They showed that there is a list of semi-independent coupled factors (visuo-motor, visuo-tactile, visuo-proprioceptive, and visuo-vestibular) and morphological similarities that operate side by side to produce in us a sense of ownership, however, these groupings are made to simplify the examinations and everyday life is full of significantly more complex correlations.

5-4. Prospective Applications

After discussing body ownership as a phenomenon, outlining some of the contributing factors and the principles governing them, the remainder of this chapter is going to highlight three VR applications where these correlations, knowingly or unknowingly, have been utilized and caused unparalleled behavioral impacts that not only confirms the principles discussed earlier in actions, it also attests to the legitimacy of VR as a newly discovered source of influence capable of creating unprecedented change in users.

5-4-1. Transforming the Body

As newer studies suggest, one characteristic of the avatars that our cognitive capabilities seem to be very lenient about is their perceived size (Lloyd, 2007; Banakou et al. 2013; Tajadura-Jimenez et al., 2017). Using a VR setting that provided arms, legs and head tracking through the

HMD and mapped it to the avatar, Banakou et al. (2013) embodied adults in the virtual body of a 4-year-old child. They repeated the same experiment, but now in the body of an adult shrunken down to the size of the child. The results showed that inducing the illusion of ownership over a child's body in adults influences the adult-child categorizations of self-versus others. This was determined by having the participants complete an Implicit Association Test[38] (IAT) (Schnabel, Asendorpf and Greenwald, 2008) at the end of both conditions while subjects were still in the virtual environment.

The IAT questionnaire paired child or adult imagery with "self" and "other" categories and the results showed that participants in the child condition responded faster when the "self" was paired with child-related images compared to when the "self" category was paired with adult-related images. On the other hand, participants in the adult condition had faster response times when the "self" category was paired with adult imagery compared to when it was paired with the child imagery.

Furthermore, it was discovered that, although both groups started to overestimate the size of all the objects in their vicinity, those in the child's body would overestimate the object sizes to be almost twice the size estimated by subjects in the adult body. Changes in the perception of object sizes resulting from changes in the size of the owned body were in line with previous findings showing that adults overestimate object sizes when embodied in a small doll-sized body and underestimate them when embodied in a giant body (Pena, Hancock and Merola, 2009). However, what makes this experiment interesting is that not only size accounted for this change

[38] A method for measuring the strengths of associations between concepts in an indirect way. In this method, the user's response time in associating a target category with positive and negative valence words is calculated and it is expected that the shorter the time is the stronger that association should be.

in perception, but also the shape of the body (child vs. adult appearance) exaggerated the result, which signals that the topic of body size can enter into the semantics of what it means to be a child vs. a child-sized adult.

The most important outcome witnessed in the studies surrounding the body-transformation phenomenon is that we can confirm a distinction between the bottom-up and top-down factors of body-ownership (Tsakiris, 2010). Body shape and body size are both bottom-up visual building blocks playing a role in the final phenomenon that can be improved by motor, haptic or proprioceptive correlations, however, as Slater et al. (2010) point out there is also evidence that confirms a top-down mechanism is at play. Top-down factors such as the point of view through which we are receiving the correlated stimuli seem to independently impact our tendency to accept an external object as our own. In the same study, Slater et al. (2010) demonstrate a case where the first-person point of view can, to some degree, override the negative impact of delayed visuo-tactile correlation which is a bottom-up factor.

Another top-down factor seems to also have entered the equation. When subjects took ownership of what they recognized as a child's body. A construct (social, biological, etc.) around how a child must perceive the size of objects formed by their own beliefs entered the picture and resulted in an exaggerated size estimation of the objects in the case of being a child compared to being a small adult while the body size was the same. This is one of the clearest demonstrations of an external factor, in this case, some type of preexisting conception of a child's view, that managed to act as a top-down factor that influences and even override the bottom-up aspects of the body-ownership.

Another characteristic that our body schema can easily incorporate is our skin color. Peck et al. (2013) have investigated the incorporation of virtual bodies with different skin colors in terms of implicit racial biases. They have designed an experiment based on the skin color of avatars as it was seen from the first- person point of view. Subjects were given an implicit racial bias test 3 days before the experiment and then another one immediately afterward. The experiment included 60 light-skinned female undergraduates who were given virtual avatars with either dark skin, purple skin, or without a body and the results showed that participants who were given the dark-skinned body showed the highest decrease in implicit racial bias compared to the other two groups. Similar to the previous case, this study signals that VR can act as a powerful practical tool to change the negative interpersonal attitudes.

In another related study by Kilteni et al. (2013), 36 Caucasian subjects were given a light-skin formally dressed avatar vs. a dark-skinned casually dressed one and were asked to play a West-African Djembe hand drum. The VR setting provided visuo-motor and visuo-tactile synchronicity by placing a real drum in front of them. The results showed that users with the second avatar expressed higher performativity and motion expressions while playing.

Subjects were also given a questionnaire which showed that the difference in clothing did not correlate with the body ownership they felt, meaning that subjects with both outfits managed to feel ownership to the same degree, while the skin color ended up being the determining factor. This not only confirms that pre-existing social constructs influence our willingness to take ownership of a body, but also that the impacts of these constructs are not necessarily limited to unconscious (implicit) biases. Virtual body ownership can easily enter in the realm of the semantics of actions where personal, social, political, cultural and ideological beliefs become serious factors that can change the outcome of virtual experiences.

5-4-2. Body-Swap Empathy

Inspired by the VR's potential to literally and figuratively show the world through someone else's eyes there has been an artistic effort to build an empathy promoter VR tool called *The Machine to Be Another* (TMTBA) (Bertrand et al. 2014). Although there haven't been many scientific research conducted to qualify its impact yet, the fact that it adopts all the visuo-motor, visuo-tactile and visuo-proprioceptive measures makes it a distinguished experiment. Also, the fact that it utilizes a human instructor makes its setting flexible and technologically feasible.

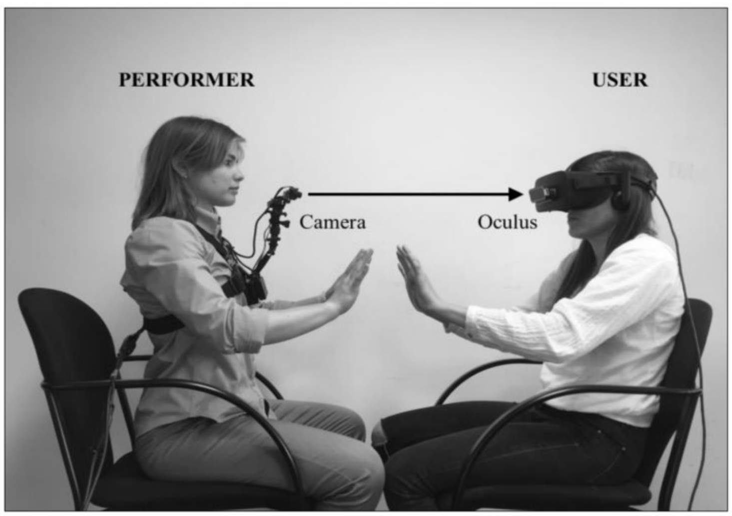

Fig. 13: An example of the body swap variation of TMTBA (Ventura et al., 2018)

TMTBA is designed to let users see themselves in the body of another person in real time by capturing what that person sees through a video camera and feeding it to the user. Even though the concept can be implemented via different technological means, the most relevant one to this chapter is the Body Swap in which two users swap perspectives using VR headsets and cameras while receiving directions by an instructor to move their limbs and their heads slowly and to collaborate with each other in order to synchronize their movements. This coordinated effort brings visuo-motor, visuo-motor, visuo-proprioceptive and visuo-vestibular correlations.

In addition to swapping subjects' perspectives by following all the synchronicity principles, the body swap also presents real narratives from different individuals acting as performers. Over a 5-year period, the group has presented several performances from asylum seekers in a detention center in Israel, an Iraq veteran in the USA, an African migrant in Spain and victims of police brutality in Brazil (Bertrand et al. 2018). These narratives are performed by the individuals themselves, drawing on their personal embodied experience on topics ranging from social stigmas to stories of forgiveness. The use of real people and their lived experiences is possibly the main conceptual edge of this artistic work.

At the final stage of the experiment (usually after 10 min of physical interaction exploring movements as well as interacting with physical objects and with mirrors) the user and the performer are placed face to face to interact physically with each other. Finally, the experiment also allows the performer and user to meet physically, immediately after the VR experiment, something that would not have taken place in everyday life.

Although there hasn't been published research with the version of TMTBA described here, Petkova and Ehrsson's (2008) work can be a great case to show the significance of similar exercises. They have found that using TMTBA - even without narrations – it is remarkably easy to move a human center of awareness from one body to another so that for example, one would protect a body they didn't own as if it was theirs when a knife threat was perceived. Ventura et al. (2018) also confirmed that the more synchronicity principles are combined (in this case, visuo-tactile and visuo-motor compared to just visuo-motor correlation), the stronger the emotional responses became. Future research can shed light on different ways that this sense of empathy is being expressed and how it can be measured.

5-4-3. Implicit Learning

When it comes to virtual reality's potential for education, a common misunderstanding is to solely focus on its technical aspects. As Fowler (2015) points out, the emphasis has always been placed on how photorealistic VR graphics are, how high the screen refresh rate is, or whether there is surround sound, while not enough attention is paid to the pedagogical aspects of VR. In particular, Fowler argued that any educational VR application should be primarily analyzed in relation to three criteria: first, how the VR experience advances explanation; second, how is it deepening understanding, and third, how is it taking account of the wider social context involved in learning. No VR-based system should be able to escape demonstrating how it is satisfying these three conditions, before being accepted as a teaching tool.

Slater (2017) agrees with Fowler's premise that technicalities of VR should not take the spotlight from its potentialities. However, he takes an entirely different approach that dissolves the need to satisfy the three conditions. Slater claims that since the aim is learning, we can think of implicit ways of teaching that still result in transferring the knowledge, while it might not be clear how these conditions are being met.

Implicit learning has been defined by Arthur Reber (1965, 1967) as the process by which knowledge about the rule-governed complexities of the stimulus environment is acquired independently of conscious attempts to do so[39]. Implicit learning produces a tacit knowledge base that is abstract and representative of the structure of the environment; such knowledge is optimally acquired independently of conscious efforts to learn; and ultimately it can be used

[39] To see a review of the studies supporting the possibility of implicit learning, please refer to Reber (1989).

implicitly to solve problems and make accurate decisions about novel stimulus circumstances (Seger, 1994; Shanks and St. John, 1994).

For instance, Reber (1967) used implicit learning to teach participants an artificial grammar that was too complicated to backtrack. In his experiment, subjects were exposed to multiple grammatically correct words called “stimulus”. The grammar used in creating these strings of letters came from what is called a schematic diagram (see Fig. 13). By starting from the input state of the diagram and following different arrows while writing down letters on each arrow, we can produce an infinite number of grammatically correct stimuli. However, just by just looking at the output strings, an observer is not able to tell if it is a randomly generated string or a grammatically correct one. Reber’s study showed that after some practice, subjects became increasingly adept at processing and memorizing strings, whereas a control group working with random letter strings showed no such improvement. Furthermore, after this neutral learning task, subjects were able to use what they had comprehended of the rules of the grammar to discriminate between new letter strings that conformed to the grammatical constraints and letter strings that violated one or more of the rules of the grammar.

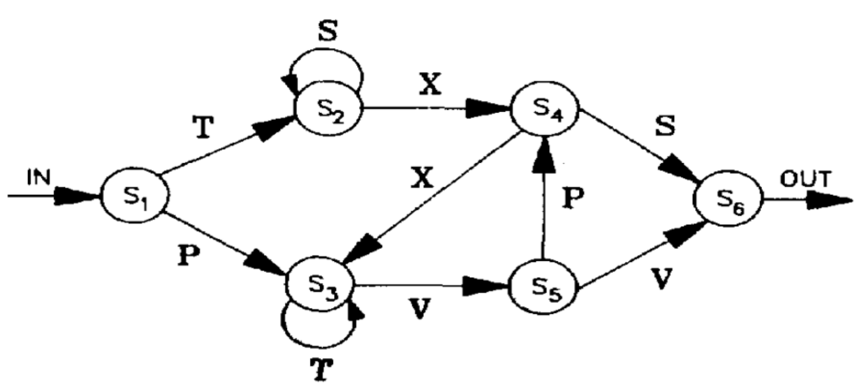

Fig 14. An example of the schematic diagram used to generate a stimulus. Stimuli are generated by following any path of arrows leading from the initial S1 to the terminal S6 which can create strings such as TXXTVPXVV, TSXXTVPXVPS, etc. (Reber, 1989)

A meta-analysis of implicit learning in amnesic patients showed that people with amnesia or autism do as well as others on implicit learning exercises (Kessels & de Haan, 2003). This finding suggests that implicit learning employs a communication methods that does not have the difficulties and behavioral rigidity that are problematic for such patients (Foti et al., 2015). Another implication is that implicit learning engages memory functions in a non-traditional way, since explicit learning have consistently failed to leave long-lasting impacts on such patients.

There is also a sizeable body of research into implicit learning of motor skills in disciplines that rely on those skills, such as in surgery (Masters et al., 2008), where it was shown that learning by observation and without explicit verbal instruction produced outstanding results, particularly useful in the multi-tasking environment of a surgical operation. In another study by Vine et al. (2012), it has been shown that the gaze strategies required to perform minimally invasive teleoperation through a robotic arm and a camera can be implicitly learned in VR (Wilson et al. 2011). Snyder et al. (2011) have done a comparison between proficiencies in laparoscopic and endoscopic surgical training taught through protocol training vs implicit learning in a VR simulation and demonstrated that the medical students in the second group demonstrated higher proficiency.

A few non-medical experiments also tried to integrate implicit learning into VR. A study by Bailenson et al. (2008) has shown that implicit learning of motor tasks involved in martial arts through VR can be accomplished. Their study allowed subjects to observe their avatar through a mirror, where participants would see themselves beside a Tai Chi teacher and were supposed to follow the instructor's movements for a period of time without knowing where each technique started or ended. The results showed that not only were they able to repeat the movements more accurately compared to users who watched the master on a screen, subjects were also better at identifying and breaking down the techniques.

Another successful case of using VR in implicit learning has been its application in rehabilitating patients with psychiatric disabilities to improve their interpersonal skills. Bell and Weinstein (2011) showed that VR can improve patients' job interview skills by allowing them to take part in a simulated job interview where they can roam a virtual room where two people are conducting an interview, and then assume the interviewee role themselves.

Another study that overlaps with VR exposure therapy helped shy subjects to overcome their fear of talking to people of the opposite gender. Pan et al. (2012) conducted an experiment where males who have been socially anxious about meeting women learned to reduce their anxiety after having casual conversations about mundane topics with a virtual woman that would occasionally insert anxiety-inducing triggers in the discussion without letting the conversation become too uncomfortable. During the experiment, there was no explicit attempt to influence the participants in any direction, but subjects were given the opportunity to have the experience and also look at a recorded version of the interaction from a third person point of view, which seemed to have been a contributing factor.

All of the VR applications discussed so far, were employing visuo-motor, visuo-tactile, visuo-proprioceptive and visuo-vestibular correlations as general methods that tended to improve the sense of body ownership in any virtual experiment. However, once we start to take into account the highly individualized formation of body ownership with respect to biological and social factors, these general correlation measures might not be as successful for everyone.

5-5. Body-specificity Challenges for VR

Before ending this chapter, it is important to mention that there are several challenges regarding the multisensory and sensorimotor affordances that future explorations of VR must consider. This brings us back to the body-specificity, but with a different understanding of the legitimate challenges it can impose.

What will be discussed here comes from an understanding of the body-specificity that is not as concerned with the needs of an individual, as much as it tries to advocate for addressing the intermediary shortcomings of VR that undermine broader groups of users. An ideal VR application might be optimized to take into consideration all the sensorimotor capabilities of individuals, however, that seems to be an out of reach goal for the foreseeable future. In the meantime, however, small considerations that take into account biological disparities and their implications can bring tremendous benefits to the users.

The most obvious and yet significant instances of this disparity can be found in the fact that heavyweight, oversized and ill-fitting VR equipment has long contributed to marginalizing women and the elderly (Park et al. 2004; Felnhofer et al. 2012), and even though this particular issue might be addressed with technological advancements, the tendency to knowingly or unknowingly overlook the bodily differences between genders or ethnic groups remains an issue.

Another good demonstration of this disparity is reflected in the fact that female users tend to be more susceptible to simulator sickness than their male counterparts (Lombard and Ditton, 1997; Nicovich, Boller, & Cornwell, 2005). One of the possible explanations for such side effect is that women generally have a wider field of vision than men. This makes female users more sensitive to cues shown in the peripheral areas of the eye compared to male players who are unable to see such inputs and have an easier time dismissing them. Any peripheral changes can give female users the impression of constant motion in the virtual environments which can cause motion sickness and headaches. This shows that VR applications designed for the male field of vision simply overwhelm female users by having too many visual cues while underutilizing their wider field of vision. Czerwinski et al. (2002) have demonstrated that providing a wider field of vision can indeed decrease this performance gap without being able to completely close it.

Another case was discovered by Slater et al. (1998). While investigating the sense of presence and the impact of body movement in a virtual environment, they found that men reported higher levels of presence than women in a complex task which required the subjects to remember and count virtual cues, while in less physically complicated tasks, the performance was the opposite. This is another case where setting visuo-motor requirements based on the falsely assumed bodily capability can completely undermine the targeted goal of a VR experience.

Other disparities of senses can be found within both the male or female population. Individuals who tend to use certain senses more often will have brains that allocate more resources to that modality and will be more sensitive to that type of stimuli (Cotman and Berchtold, 2002). For instance, gymnasts usually have a better proprioceptive ability that allows them to identify more accurately where their limbs are, even with their eyes closed. The same consideration should be taken into account when specialized VR applications are being tailored for certain groups, such as surgeons, people with physical disabilities, different age groups and etc.

Second, Slater's research advocates for congruent multisensory inputs which undeniably adds technical complexities to VR that not attainable yet. However, excluding the more technically challenging sensory inputs might not always be an option due to the impact they have on the perception of other senses. Excluding vestibular or proprioceptive signals, or providing them in an a delayed or ambiguous way that violates the correlation principle can cause the user to reject the inputs from the VE altogether as erroneous or react to such a mismatch in the form of simulator sickness (Akiduki et al., 2003).

For example, if visual signals indicate that the body is moving while the vestibular signal indicates we are standing still, a sense of dizziness and vertigo can be created. In these situations, the brain's first response is to solve the incongruity by determining which subset of inputs has the highest probability of being correct and which ones to ignore as a result. In order to do so, other stimuli - whether VR has planned for them or not - are employed. In our case, tactile and proprioceptive sensations are considered and if they signal that subject is, for example, seated, the scales are tipped towards a static position (Stoffregen et al., 1999). The significant consequence of this corrective behavior is that excluding inputs can cause the dismissal of other inputs that are actually being provided. This is particularly important for the implicit learning of motor skills that heavily rely on congruent sensorimotor inputs.

Another challenge that primarily impacts empathy in VR is that objectification can replace empathy. As we have discussed earlier, it is possible for VR users to shape their behavior to conform to their virtual representation, which means they infer their own attitudes and beliefs by observing their external behavior (appearance, shape, face, etc.), in the same way, we would infer the attitudes of others by observing them[40]. However, not all observable characteristics impact us in the same way, and some might contribute to creating distance from what was intended to be an empathetic bond by tapping into users' psycho-social vulnerabilities.

[40] This phenomenon is also known as Proteus effect (Bem, 1972)

One of the clearest instances of this phenomenon was reported by Fox et al. (2013) upon examining the impacts of a sexualized female avatar on female participants. Objectification theory claims that: "the cultural milieu of sexual objectification functions to socialize girls and women, at some level, to treat themselves as objects to be looked at and evaluated'' (Fredrickson and Roberts, 1997, p. 177). Fox's findings corroborated this hypothesis and showed that women are more at risk of being negatively affected by self-objectification and sexual myth acceptance when they are embodied in a sexualized avatar that looks like them compared to sexualized avatars that don't resemble them. For instance, as subjects' sexualized avatars started to resemble the participants (in terms of face, body shape and clothing), the participants became more likely to blame rape victims.

Another study conducted by Riva (2011) showed that obese participants were more susceptible to show dissatisfaction with their body image as they were given more overweight avatars. Meanwhile, non-obese participants showed no signs of changes in their attitudes towards their virtual body. This implies that the individuals who have been under more pressure from society to conform to certain norms, became more sensitive to deviation from that norm. This implies that for users with such backgrounds, taking ownership over an overweight avatar will be impeded in a way that is unique to some users while for others it is not an issue.

5-6. Conclusion

Body-ownership as one of the most important manifestations of embodiment, allows us to take a deeper look at the dynamics of psycho-social, motor and sensory affordances that VR provides. Body-ownership sheds light on the role of correlated inputs such as visuo-motor, visuo-tactile, visuo-vestibular and visuo-proprioceptive for VR users. Humans are biologically tuned to expect such sensorimotor correlations from their body and tend to incorporate external objects that provide these data in a correlated manner into their body schema as well.

Proponents of body-specificity hypothesis, on the other hand, question the universality of the above techniques since biological traits and behavioral patterns can create a highly specific relations to the physical or virtual body that differs between users. Biological traits, such as sensitivity to visual stimuli, varies between genders which should be reflected in how VR applications simulate these inputs. Similarly, other biological differences that might stem from gender, ethnicity, age or physical abilities would require special considerations to keep body-ownership attainable.

In addition to biological traits, social factors can also have a significant influence on our sense of ownership towards a virtual body. Social stigmas that target people based on their visible physical attributes such as gender, ethnicity, body type, height or age make these individuals more susceptible to body alienation. The pressure that individuals feel to distance themselves from what society deems unacceptable can manifest itself as self-objectification in women or body-dissatisfaction in overweight individuals. This also confirms that the impact of social realities, in this case social stigmas, can easily transcend the physical world and enter into the virtual realm.

The challenges posed by body-specificity hypothesis, are a reminder that virtual embodiment will remain a multifaceted phenomenon where VR affordances can operate independently and have the potential to contribute to or stand in the way of an embodied virtual experience. Such a complex system with many unknown elements plus the tradeoffs involved in building customized and expensive VR applications versus generic and less effective ones, are all the more reasons for future applications to try to strike a balance where all affordances are utilized to make up for what they had to overlook to make their design feasible and commercially viable.

6. Conclusion and Further Discussions

This thesis started by asking: To what extent is VR, and our experience inside it, real? Historically, this has been a broad recurring question usually posed by the critics of VR that questions its ontological nature while also casting doubt on the legitimacy of its impression on users on an epistemological level. The ontological dimension of this question challenges the objective presence of virtual environments (and their constituting components) as concrete real entities that exist in the outside world, while the epistemological aspect focuses on the users, their subjective experience, and the types of beliefs and expectations that are justified to have about virtual experiences. The third chapter of this thesis provided an alternative ontological account of VR as a real digital phenomenon, while the fourth chapter analyzed the validity of our judgments about the value of virtual actions at an epistemological level.

As the history of simulating techniques suggests, virtual reality, in all its forms, has been followed by questions about its illusory nature and inauthentic impressions, which the third chapter categorized and responded to. The skepticism of reality was an ontological question based on a comparison between VR and the real world, and it was argued that the lack of similarity, if in fact such a difference existed, does not conclude that VR is unreal.

Skepticism of doing was an epistemological question, which claimed since VR can only give an illusion of performing actions, without having to actually do them, the idea of doing something in VR will be meaningless. Here it was argued that while VR users can make judgment errors about their VR experience, the important issue with this skepticism was the implied cognitive assumption about the role of our neural system. Neural manipulation is only part of our cognitive faculty and the rest of the body such as muscles and receptors involved in performing actions retain an impact that cannot be simulated through neural manipulation.

Skepticism of being was another epistemological skepticism that claimed VR users cannot express their personality in a meaningful way. The counterargument provided in the third chapter pointed at the broad spectrum of ways that users continue to express their personal choices even when a VR application is treating them as passive observers. However, the role that VR can play to extend these options is something that social embodiment discussed in the third chapter, argues for.

After responding to the skepticisms of VR, an alternative account regarding the ontological underlying of VR was put forward. In contrast to the fictionalists' understanding of VR, which considers fictional constructs of the mind as the driving engine behind VR, the chapter argued for virtual realism where the building blocks of a virtual environment (objects, properties, and events) are fundamentally digital entities that really exist in the outside world in the form of binary data structures and digital processes.

In contrast to the philosophical idealism that regards reality as something that is determined within the human mind and accepts VR to be real when it appears real enough to the mind, virtual realism lends itself to a view of the world where VR is placed in a complex system of interrelated parts outside the mind and alongside non-digital elements. In this view, we should move past the question of whether VR is real or not, and start to analyze it in terms of its real causal structures, the patterns of interactions between such elements, the governing internal and external rules that dictate our method of interaction with VR, and the concrete impact of this interaction on the users.

To make the ontological discussion of VR more comprehensive, the third chapter also introduced social realities to the list of elements with real causal powers surrounding VR. If we accept John Searle's argument that collective intentionality can create new realities, then virtual environments are not exempt from participating in this collective process. Much like the non-virtual world, social realities are created in VR either because a recognized authority has endorsed their status, like online banking, or because they were accepted in a non-authoritative manner by the user community, as it was the case with Bitcoin. In addition to creating new social realities, social realities that were originally created outside VR can also impact and enter VR. For instance, as we saw in the fifth chapter, the beauty standards of an avatar can reflect the beauty standards of the outside world.

We have to extend the boundaries of discussion around VR to take both physical and social realities into account. This approach was followed in the fourth chapter, where physical realities such as cognitive predispositions of the users, the behavior of virtual elements and methods of interaction that are afforded to users are discussed. The last chapter also follows this comprehensive approach by reflecting on the impact of design biases and social stigmas on a virtual experience as instances of existing social realities that impact users even inside the virtual environment.

Once we established the nature of reality in VR, we can turn to the epistemological aspect of our main question. Asking if we can have real experiences in VR seems to carry an implicit comparison with our experiences in the non-virtual world and this thesis used this comparison to argue that an embodied simulation can have the same instrumental value as the non-virtual counterpart. For example, the values we attribute to an activity like martial arts seem to be rooted in the physical and mental skills acquired in the process and a virtual simulation that can accurately reproduce these skills can be said to have the same instrumental values.

The case of martial arts was picked as a case that represented a category of activities that are defined in terms of a specific set of actions. Using well-defined activities, as rare as they might be in real life, narrows down the scope of the experience that VR should simulate since we can pinpoint building blocks like hand movements and body gestures and ask what an accurate simulation of each action should look like in VR. Next, martial arts was contrasted with sex as an experience that refuses a universal definition in terms of particular actions. Accepting this distinction does not mean that virtual sex is not possible, rather it signals that virtual sex does not rely on an accurate simulation, as heavily as virtual martial arts does for it to be simulated. These two cases suggest that there is a spectrum of well-defined activities and as we move towards the more well-defined cases, an accurate simulation will have more influence on the experience and more of a determining factor in attributing values to a virtual experience.

After establishing the role of accuracy in virtual simulations, the fourth chapter argued that a comprehensive notion of accuracy is an embodied one and then outlined the necessary requirements that VR should provide in order to make an embodied virtual experience possible. Many of the current VR applications that try to bring a non-virtual activity into VR, create simulations that heavily rely on audiovisual stimuli and hand gestures. By providing such limited multimodal stimuli and some physical interaction, these applications hope to fully simulate the impressions of the original experience.

However, what this approach fails to see is that human cognition is an embodied phenomenon in which our senses collaborate with the rest of the body to accurately receive and interpret these stimuli. Providing sensory stimuli, without taking into account the crucial role of the body, pushes VR toward becoming a disembodied medium that misunderstands the function of the body, while expects the mind to fully carry on and function in its full potential. Although it is unlikely for humans with such a long history of cognitive evolution to have fully disembodied experiences, it is still true that not every VR application lends itself to an embodied experience to the same degree. This is all the more reason why VR should take advantage of any discovered cognitive principle and affordance that can make a simulation more embodied.

Embodiment, as a response to the mind/body dualism, has been discussed with regards to virtual environments before (Stone, 1992; Penny, 1993; Romanyshyn, 1994; Boyd-Davis et al., 1996), mainly to caution users of a future where Cartesian duality is reinforced by ignoring the body. For instance, Stone (1992) claimed that in VR the experimental body will be replaced with an avatar-like representation which Michael Heim later called a temporary distraction. Heim recounted users' first impression of their avatars thus: "Invariably, the user stands in place a few moments ..., takes in the surroundings, and then pats torso and buttocks with their hands as if to secure a firm landing and return presence in the primary body" (Heim 1995; p. 68).

At the same time, a minority of researchers have tried to devise an embodied version of VR that is actively trying to go beyond creating a mere visual representation of body (Murray & Sixsmith, 1999; Maus, 1992; Biocca 1997; Costa et al. 2013). Even though these studies gave rise to different visions of embodied VR, what they had in common was the acknowledgment that the body plays a constituent role in every experience and not just a casual one (Shapiro, 2011). In other words, there cannot be cognition without the body whether the environment surrounding us is virtual or non-virtual.

Since the early discussions of embodiment and VR and thanks to fMRI measurements, cognitive neuroscience has made considerable progress which provided the neurological evidence for the role of the body in cognition. These discoveries gradually created a research framework called *Embodied Cognition (EC)* which, despite not being a predictive framework yet, can inform our analysis of embodied VR. According to EC guidelines, our experience as embodied beings involves more than just having a body that executes actions and provides sensory feedback to the brain. In particular, this thesis compiled four different notions of embodiment drawn from EC guidelines that could help define how an embodied VR should look like.

Physical embodiment, social embodiment, embodiment as structural coupling, and embodiment as historical coupling are four notions that were originally devised to explain the relationship between biological systems and their surroundings, but this thesis applied them to the relationship between VR users and a virtual environment. The physical and social embodiment have the most concrete implications for VR, while structural and historical coupling should be considered when the physical and psycho-social affordances are being implemented in VR.

While the full implications of the physical embodiment for VR are being gradually discovered through experimental research, one of the best established ones claims that sensory affordances of VR should provide stimuli to the whole body. These inputs should reflect the events that are unfolding in the VE as much as they should reflect the state of the body itself in VE. It is true that we normally see parts of our physical body in our everyday life, which helps us be more aware of it, but we also rely on audio, haptic, proprioceptive and vestibular feedback to corroborate what we see. Sometimes, we even have to use such feedback to compensate for the lack of other stimuli. In this view, the physical body itself can also be an ultimate representation, as we can see in some augmented reality applications where the user's body is placed in an environment that is a mixture of virtual and physical entities.

Proprioceptive and vestibular signals play a particularly important role in our physical embodiment, which is sometimes overlooked. VR can engage these senses through how users physically interact with a virtual environment. Motor control affordances that engage our muscles and require movements in limbs and torso and allow actions like reaching, grasping, bending, crouching, and rotating, provide the most intuitive way of getting proprioceptive and vestibular senses involved (Sanchez-Vives & Slater, 2005; Slater et al., 2010). Other EC findings also suggest that in addition to incorporating more inputs like proprioceptive, tactile and vestibular, providing these inputs in a correlated manner can create the most successful outcomes (Kilteni et al., 2015; Samad et al., 2015; Talsma, 2015).

We rely so much on these correlations, that in some cases, the correlation we are trained to expect between multiple senses can temporarily override the input of individual senses. For example, when the source of a sound is seen in front of us while the sound detected by the ears appears to come from behind, our first reaction is to force the sound to conform to the visual stimuli (Guttman, Gilroy & Blake, 2005). On the other hand, the rubber-hand experience suggests that tactile feedback can override the interpretation of visual inputs because although the subjects see that the rubber-hand is being attacked, their response is to treat that attack as if it was targeting their real hand (Ijsselsteijn et al., 2006).

The fourth chapter also drew attention to the social functions of the body, which is ignored in most VR applications. Social embodiment implies that VR applications should allow users to modify and manipulate their virtual representation so that it expresses their personal and social identity. Studies show that users make considerable efforts to customize certain aspects of their avatars and then behave according to what they created if they are given the chance (Ducheneaut et al, 2009; Yee & Bailenson, 2007). However, comprehensive social embodiment means our avatar should provide psycho-social affordances that allow the user to control their facial expressions, body gestures and other forms of bodily expressions that we are socio-culturally trained to use to communicate with others in our everyday life.

After outlining sensory stimuli, motor control and psycho-social affordances as the preconditions of an embodied VR, the fifth chapter turned to body-ownership phenomenon as a heavily embodied phenomenon where how these affordances interact can be analyzed. Next, the contributing factors that make body-ownership possible were also balanced against the body-specificity hypothesis to question how universal an embodied virtual experience can be. According to the body-specifity hypothesis, if human cognition is as dependent on the body as EC claims, each individual should have unique cognitive capabilities. However, the body-ownership phenomenon is a good indication that, by providing certain correlated stimuli, many of these predispositions are prone to rapid changes.

It was already known that body schema –the neurological structure that maintains the state and boundaries of the body– is malleable (Iriki et al, 1996; Ishibashi et al. 2000; Maravita et al., 2004; Yamamoto et al., 2001). For instance, the original rubber-hand experiment (Botvinick & Cohen, 1998) was the first controlled case that demonstrated subjects can be primed to treat a rubber hand as their own. Recent studies (Won et al., 2015; Steptoe et al., 2013) have shown that the phenomenon is reproducible in a virtual environment where a virtual hand was successfully incorporated into subjects' body schema. More recent findings seem to support the vital role of corresponding multimodal stimuli accompanied by motor movements. Although the most successful results were reported in the case of visuo-tactile correlation (Ijsselsteijn et al., 2006), likely due to the primacy of our visual sense (Ernst & Banks, 2002), visuo-motor and visuo-proprioceptive and visuo-vestibular correlations are not far behind (Tsakiris, Prabhu, and Haggard, 2006; Sanchez-Vives et al., 2010; Gandevia, 2011).

Based on EC's premise that all our bodily capabilities are crucial in human cognition, it is clear that more research is needed before we can arrive at a comprehensive model in which all the permutations of sensorimotor correlations are mapped out. Future VR research can also benefit from studying senses outside the big-five category, where muscle tension, balance, acceleration, temperature, and pain alongside internal senses such as thirst and hunger are studied. Additionally, future research should expand its analysis beyond only one pair of stimuli to see, for example, how the combination of visuo-tactile inputs plus proprioceptive feedbacks would impact the sense of body ownership. Given the holistic nature of embodied phenomena as it was seen in the body-ownership case, adding a new stimulus can significantly improve or impair the whole virtual experience. For example, an uncorrelated audio input can interfere with correlated visuo-tactile stimuli and undermine the body-ownership that could happen without the sound. This holistic characteristic is a potential source of complication as VR moves toward getting more senses involved.

After having outlined the visuo-motor, visuo-tactile, visuo-proprioceptive, and visuo-vestibular correlations as body-ownership's main contributing factors, the fifth chapter also outlined body-transformation, empathy induction and implicit learning as three lesser-known applications where these correlation techniques are heavily utilized and early results are promising. Body transformation's goal is to provide users with the experience of owning a body different than their own in terms of size, age, race, and gender. This appears to be an area where the body-schema is most flexible and shows rapid change. For instance, after spending a few minutes receiving correlated visuo-motor inputs from an avatar with a different skin color, IAT results showed decreased unconscious bias in subjects (Lloyd, 2007; Pena, Hancock & Merola, 2009; Peck et al., 2013). Banakou et al. (2013) conducted a similar study on avatars with smaller sizes which managed to impact a user's perception of size and distance in VR.

The common change brought about by body-transformation can be described as a type of increased sensitivity toward the real people who resembled the avatar. This attitude change pushes the subjects' attitudes to resemble those who have those bodily characteristics in the physical world. A decrease in unconscious racial bias can be explained through this attitude change. This chapter also drew attention to a social factor at play in Banakou et al.'s (2013) study. How subjects' identified with a small avatar varied according to whether the avatar appeared to be a baby or a very short adult. This suggests that the social construct of what it is like to be a child played a role in estimating the size of surrounding virtual objects.

The next application, interconnected with body transformation, was empathy induction through putting users in the circumstances of another. *The Machine To Be Another* was an example where visuo-proprioceptive and visuo-tactile correlations were artificially enforced by a third person. The early results showed that subjects experienced strong emotional reactions such as anxiety, fear, weird sensation and some even felt highly uncomfortable by being put into someone else's body (Ventura et al., 2018). This study shows that performing an experience, instead of just hearing or seeing it, can elicit stronger responses from users. TMTBA offers a novel way to ensure sensorimotor correlation with significantly less technological complexity which can be easily adapted for creating various VR applications. Even though this is a relatively new VR application with few scientifically documented results, the fact that it satisfies multiple correlation requirements is a promising aspect of this application.

The last application outlined in this thesis was the implicit learning simulations that focused on non-verbal and non-instruction-based training of motor skills. For instance, studies showed that through observation and practice, the multi-tasking skills required in certain types of surgery can be better internalized by students (Gockel et al., 2008; Garcia et al. 2009; Snyder et al., 2011). Additionally, since implicit learning does not rely on traditional communication methods and memory functions, it is particularly valuable in educating subjects with amnesia or autism who cannot memorize instructions or are unable to follow verbal instructions (Kessels and de Haan, 2003).

As it was mentioned in the opening remarks of the fifth chapter, body-specificity is a legitimate potential challenge to the universality of VR simulations, which is consistent with the claims of the EC framework. However, the flexibility of our cognitive processes, reflected in the role of correlated stimuli, is the technique that this chapter offered to partially alleviate the negative impacts of our body-specific tendencies for VR. At the same time, it is crucial to maintain realistic expectations of how much body-ownership techniques can be successful. This is why the last chapter concluded by drawing attention to biological and social disparities in users that require extra considerations from VR designers and that users cannot be expected to simply cope with.

The difference in visual sensitivity and muscle capabilities across genders and age groups is one of the most consequential disparities that any VR application should take into account and make adjustments to. Nicovich et al. (2005) demonstrated that female VR users are more susceptible to be overwhelmed by visual cues and perform poorly at their tasks. This means that providing identical stimuli can put female participants at a disadvantage point because the design unconsciously favors less visual sensitivity.

In addition to the biological distinctions, social pressures can also increase the targeted group's sensitivity toward their bodies to the point that correlation principles can bring the opposite outcome. Body alienation experienced by obese VR users (Riva, 2011) or the self-objectification witnessed in female users (Fox et al., 2013), demonstrate that cultural and social norms play a role in our virtual experience and should be taken into account. These factors change a user's threshold of identification with or alienation from a virtual avatars in ways that is unique to particular groups of society. For instance, the stigma around being overweight or how a sexualized appearance might justify certain treatments by society obstructs a correlated multisensory stimuli from bringing the successful body-ownership effect that it would have otherwise.

The role of such social and biological factors brings us back to the idea of thinking about VR as a web of interrelated parts. In the complex web of physical and social realities that make up a virtual experience, numerous elements with real causal powers might be ignored or remain hidden until a new discovery or a novel approach sheds light on a new causal relation between elements and trigger a reevaluation of the whole system. Embodiment, as described in this thesis, anticipates the discovery of new social and physical realities that might come to the fore and rearrange the web of interacting elements. In the meantime, the VR affordances specified in this thesis, can provide a relatively comprehensive toolkit to accommodate for what we know so far about embodiment.

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