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Avatar Creation Therapy for children

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"χαλεπὰ τὰ καλά"

Abstract

Today, more and more multimedia platforms offer users the possibility of creating their own virtual representation. This function is called 'avatar configuration' and allows for a certain connection between the user and his or her stand-in within the virtual environment. Although the video game industry has devoted a great deal of interest over the years to the development of virtual reality platforms and avatar configuration, other sectors are also slowly beginning to invest in the research and development of these tools, particularly the field of healthcare. The aim of this thesis is to assess the potential of this tool in the therapeutic field for analysing patient behaviour and resolving possible disorders. The target of this project is children who are going through the transition from childhood to adolescence. Furthermore, the application developed, available both in immersive and non-immersive reality, allows the patient to explore the island and modify their avatar as they wish, assisted by a specialist who will guide them through the therapeutic process.

Acknowledgments

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Chapter 1

Introduction

The use of computer science and multimedia applications for therapeutic purposes is constantly increasing, in particular the use of Virtual Reality, VR, is increasingly insistent. This growth is due to the possible benefits that these technologies can offer to patients, who are able to immerse themselves in simulations of real-life episodes to overcome their problems. However it is important to keep in mind that during the experience it is possible to enter a state of anxiety or difficulty, so the presence of a therapist during the journey within the virtual environment is crucial. This thesis, in particular, aims to be an effective tool for therapists in order to facilitate analysis regarding the identity of patients and trying to know in depth the issues that can be caused by a poor consideration of their image in real life. The goal of the project is to allow patients to create their own avatar within a virtual reality environment.

The thesis is divided into five chapters: in the first chapter, the objectives of the project are presented and an introduction on how hardware technologies are used for the various levels of virtual reality in the clinical setting; thus it is possible to provide a clear view of the project and in particular the characteristics of the relationship between virtual reality and mental health. The second chapter aims to explain what virtual reality is, how it has evolved, how it is used today in various fields of work, and the role of avatar configuration in this field. The third chapter focuses more on the analysis of the technologies used for the development of the project. The fourth defines avatar configuration, the main platforms that allow this feature and the functionalities present in the main configurators to date are analysed. The fifth is concerned with the development and thus the description of the various phases that led to the realisation of the project in its immersive and non-immersive version. Finally, the sixth deals with the analysis of the data collected through tests carried out on the application by a sample of users.

1.1   About the project

The purpose of virtual reality is to enable patients to overcome their ailments by immersing in the virtual world; this requires the assistance of a therapist. Patients must feel in a non-judgmental and trusting space in which they can express themselves in total freedom, thus the relationship between patients and therapists is of crucial importance. In addition, clinicians should be able to support the patients in any moments of anxiety and uncontrolled emotion that may occur during therapy. The project is currently aimed at children who are going through the transition from childhood to adolescence and may perceive therapy as a source of discomfort. The goal is to offer a virtual reality platform that makes the therapeutic experience enjoyable, yet effective. This method of psychoanalytic pathway allows patients to control their avatar and modify it, according to their preferences, while exploring the virtual world; the choices made will determine the avatar's identity and will be an important source of information for the therapist. Furthermore, the project does not only have a therapeutic but also an analytical purpose with regard to the tools used: in fact, the use of a virtual reality platform aims to understand what the user's feelings are when dealing with this type of therapy, and how efficient the use of these tools is compared to the methods already used for identity disorder therapies.

1.2   What is Virtual Reality Therapy

The therapist's task is to reclaim the patient's unconscious content, to bring it to a conscious level and to rework it. Copious theoretical models have developed over time in an attempt to resolve psychic conflicts and each of them provides its own key to reading and resolving conflicts. For example, a classic approach used in psychotherapy is the narrative method which, by its very definition, is a model that exploits mental images associated with memory. The advent of virtual reality has led to a revisiting of classical psychotherapeutic models because virtual reality can no longer allow the narration of episodes, but above all its concrete visualization, within a space "protected". It would also allow the representation of alternative possibilities, those that have not been experienced. The cathartic effect would therefore no longer derive from the narration of events alone, but from the reliving, with all the sensory organs, a traumatic event. Virtual reality can allow not only to face critical events, but above all the possibility to live them in a virtual reality "protected" in the presence of the psychotherapist or reassuring people. The use of virtual reality in psychotherapy is known as Virtual Reality Therapy, VRT. It is important not to confuse this concept with teletherapy which is a talk therapy performed remotely. Different is virtual reality therapy that relies on virtual world and the support of a licensed therapist. This method plays an important role

in therapy, it consists of experiential and technological factors that can lead to a radical change within the experience that the subject makes of himself. Within a psychotherapy path, virtual reality can represent a support of relative importance especially because it offers the patient to actively participate in the awareness of thoughts, emotions and behaviors that it puts in place in certain situations. More specifically, a system of virtual reality enable us to send to electronic computer input signals, which means information about action of patient are collected, and output signal will be returned inside of virtual world. Based on the output tools used it's possible to distinguish different types of virtual reality, in fact VRT can be more or less immersive, three different typologies can be distinguished: non-immersive, semi-immersive and fully immersive. When we call about virtual reality exposure therapy(see fig. 1.1), VRET, we intend an immersive virtual experience inside in a 3D environment not unlike the real world, it is usually used with headset. VRET has proven useful to treat patients suffering from phobias but not only, in fact, according a research in JMIR Serious Games[14], it has a very positive success rate when used to enhance cognitive behavioral therapy for those suffering Post Traumatic Stress Disorder. Despite the fact that VRT is a fairly recent tool, it has quickly proved to be valid thanks to its characteristic of allowing the patient to actively participate in the recognition and awareness of thoughts, emotions and behaviors of their own, in the situation.

Figure 1.1: Virtual Reality Exposure Therapy

1.2.1   Use cases for the Virtual Reality Therapy

Virtual reality therapy provides platforms for real-time assessment of a patient's behavioural, emotional, cognitive and physical responses in a virtual environment[10]. Today, it is mostly used experimentally, thus not only for therapy but also to assess its real effectiveness. Below some case studies are presented in which virtual reality has been used for a better understanding of a range of psychiatric symptoms.

Anxiety Disorder

In this context, the use of VR for various types of phobias is discussed, which are one of the most common psychiatric disorders. The treatment used and indicated by international guidelines is exposure therapy and thanks to the use of virtual reality, especially immersive, it is possible to follow this therapy in which patients are exposed to their fear to try to overcome it by learning that the feared events will not happen.

Social Anxiety Disorder

A use case in which several research has been done over the years concerns social anxiety and anxiety about speaking in public. According to several experiments[10], allowing the user to directly control the avatar and speak during conversations in VR showed an improvement in this type of fear, despite the fact that participants rated the conversation as scarier in a virtual environment.

Post-traumatic Stress Disorder

It has been noted that prolonged exposure to imaginal stimuli related to a traumatic situation of the patients can trigger anxiety attacks and other emotional processes causing they to abandon or not undergo the therapy. To overcome this problem, many studies have tried to analyze post-traumatic stress disorder treatment with the use of VRET. Many tests have compared VRET and prolonged imaginal exposure in American soldiers and veterans, within virtual reality the user was immersed in environments that reminded Iran and Afghanistan. The tests revealed that both treatments were effective, but prolonged exposure gave more convincing results for therapies ranging from 3 to 6 months. Further studies have revealed how VRET can reduce the desire to commit suicide post-treatment and it lowers the desire to use antidepressants.

Body image disturbance

The use of virtual reality therapy for this type of disorder is quite common. The body image disturbance is often related to food problems, in particular many studies focus on binge eating[29]: in fact these studies show that VRT for body image

disorders is successful in females with binge eating. Potential results were provided for physical appearance disorders for obesity patients[7]: therapy consists in making the patient relive past experiences with the assistance of a psychotherapist with the aim of correcting and interpreting these situations correctly.

Eating Disorders

The use of VR has also been tested for eating disorders, such as anorexia and bulimia nervosa, demonstrating that if patients are exposed to virtual eating stimuli they will have similar emotional, cognitive and behavioural responses to real-life ones that often relate to a sense of dissatisfaction with their bodies.

1.2.2 Potential disease

While virtual reality is increasing in therapeutic use, few companies are actually investing on this platform. This is due to several elements, in fact, for the use of these technologies it is important to have a smart device or a computer and often a fast internet connection is also required, although this type of technology is very popular nowadays it is not always easy to have these tools available, furthermore, when dealing with immersive augmented reality software, it is necessary to have a headset, which is known to generate a problem known as 'VR sickness': i.e. negative effects that develop after prolonged use or non-use of the visor, such as headaches, burning eyes, nausea, dizziness, a sense of confusion. This is mainly due to the contrast between what the eyes perceive and what the body perceives. Thanks to the quality of the visors on the market today and the content that is produced in pursuit of a closer approximation between the real and the simulation, virtual reality sickness has definitely decreased, so much so that many people can use the visor for more than half an hour without complaining of any symptoms. Importantly, psychological therapy through virtual reality has been studied for several years, but the fields of application are still limited. The explanation is partly found in the skepticism that many still have towards this "new" technology, the economic factor could also be an obstacle but in reality the cost of the headsets currently on the market is decreasing a lot and is significantly expanding the offer of applications in virtual reality.

1.2.3 VRT: future challenges

The continued development of virtual reality tools will make these technologies increasingly accessible and affordable. It will be important to understand whether this growth will be followed by an increase in the use of Virtual Reality Therapy. Certainly, a strongly evolving topic is the resolution of 'VR-sickness'. Another very important aspect is the acceptability of this method of treatment by doctors and

patients. DBy decreasing eye contact, there are many clinicians who still believe that the use of VTR and particularly VRET can compromise the effectiveness of therapy and the relationship with the therapist. However, several studies claim that the therapeutic relationship is not altered with the help of these technologies[26] [32].

1.3 The representation of one's own identity

1.3.1 Identity

With the concept of identity refers to the construction of one's internal world, the set of basic values, the self-image, but not only that, it influences the way individuals move, speak, express themselves: postures, body attitudes, sensations. Identity only grows through relationships with other individuals, understanding their diversity allows users to grasp the differences and thus understand themselves. Identity can be enriched during development by opening perspectives and potentialities of life, or by closing oneself in limited spheres that impoverish the person, take away meaning, trigger conflict with other identities and other people. One of the most important components of identity is gender: the masculine and the feminine, being women and being men; which is the basis of difficulties and imbalances in our culture, of imbalances between the living conditions of women and those of men. It is possible to explain identity concept in more exhaustive way introducing the concept of self.

Self

Everyone is different from everyone else, so it can be defined that everyone has a self. Latter usually provides a sense of coherence, connection between what an individual was yesterday and who he is today. However, the self is constantly changing by being subject to the passage of time and going through different social situations. It is also important to note that the ego acts as both subject and object, so in the course of life it learns about itself. According to Carl Rogers[2] it is important to distinguish the real Self from the ideal one: the real Self is all that individuals feel to represent, that they have achieved by them own strength and that they can actually achieve;whereas the ideal self means all that we aspire to, that which we want to achieve but are not sure we can achieve. They can be congruent or inconsistent, the first leads to the feeling of self-realization and fulfillment, instead in the second case it is possible to have a positive or negative inconsistency between the real and ideal Self. Some people may have an image of the ideal Self too pessimistic, others too optimistic, these states can lead to inner conflicts that can lead to sadness, anxiety, or even depression. Overall each individual has an ideal and real self, this

dualism is a very important concept to understand the meaning of avatar creation in the therapeutic field.

1.3.2   Personality disorders in children and adolescents

According to a famous book by Paulina Kernberg et al. "Personality disorders in children and adolescents" [20] historically personality disorders have received less attention from clinicians and researchers than other psychiatric disorders such as depression and schizophrenia, mainly because at first glance the impact of personality disorders may be less conspicuous. Despite this, studies of personality disorders in adults are increasingly increasing, and the growth of interest in these types of disorders has certainly been encouraged by the new edition of the DSM, the Diagnostic and Statistical Manual of mental disorders, and one of the most widely used diagnostic tools for mental disorders by clinicians, psychiatrists and psychologists worldwide. Although the changes in the DSM have encouraged clinical interest and research on personality disorders in adults, they have not had a similar impact on the study of the onset and course of personality disorders in children and adolescents, as clinicians tend to be reluctant to diagnose personality disorders in children and adolescents because such a label could have negative effects on the child's self-concept. Although many problems that arise at the pre-school level are resolved with time, it is not true that all children's problems are transient. Given the complexity of development, it is well known that there is some predictability of adult psychopathology starting in childhood.

1.3.3   Virtual Identity

The creation of an identity within a virtual world can be very useful in the therapeutic field. In fact, it is important to analyze what drives individuals to represent their identities in virtual worlds and what drives them to create avatars in a particular way and what kind of relationship exists with their real self. In different virtual environments identities are more fluid and people have the opportunity to have new experiences that in real life would be difficult or even impossible to live. The research of Vasalou and Joinson demonstrate [31] how avatars created on blogging, gaming or dating sites differ from each other by highlighting different characteristics of themselves to look appropriately more interesting, or try to communicate distinctive traits of one's character or body. This shows that depending on the type of virtual world and the purpose different strategies of representing the self are implemented. There are three features that are sought after in the construction of the avatar are: the representation of an ideal self, so that users create an avatar that resembles their real appearance, but with idealized features; to have a non-conventional look; or create an avatar that follows a popular trend or the style of famous character. The choice to create an avatar with a certain

appearance can have multiple reasons. Among the most common reasons there is the intention of wanting to hide what is believed to be an aesthetic defect, instead some do it to feel belonging to something, others to become someone who can not be in real life because of fear or to replicate unreachable fantasies. In conclusion what may seem like a simple game, namely the creation of an avatar by a user in a given virtual context and its behavior within it, can sometimes suggest a lot of information related to that particular real person and his way of seeing the real self and the ideal one.

1.4   Virtual reality as a useful support for therapy

VRT proves to be a tool with great potential, it could be of great help for patients of all ages and a potential excellent support for different types of problems. Optimism about the future use of this technology is confirmed by the increasing use, year by year, of virtual reality in therapy and especially by market estimates in the coming years which, as shown in the figure 1.2[28], describe a logarithmic increase in VRT. Nowadays there are some limitations that affect the economic aspect and the 'VR sickness' but the sudden development that is investing these technologies allows to see in the near future the resolution of these problems and a massive use of VR in the field therapeutic. Within virtual environments it is very important the role that the avatar creation plays, which allows to observe and analyze differences with the real world and user behavior within platforms where users are allowed to identify themselves freely.

1.5   Research question

Although the concepts of the real and virtual self succeed in providing a general idea of why people tend to explore various identities in order to deal with different situations, further research is needed in particular on the age group of interest of the project. Indeed, previous studies in this field on avatar creation are limited and mainly concern adults. To fill this gap, the behavioural patterns of the participants and their motivations in creating a given virtual representation were examined using a child avatar configurator. Therefore, the research questions of this thesis are:

- Can the user create his or her own avatar in a simple manner?

- How does the user prefer to make changes to their avatar?

- How involved does the user feel in the virtual experience?

- Is the user satisfied with the result?
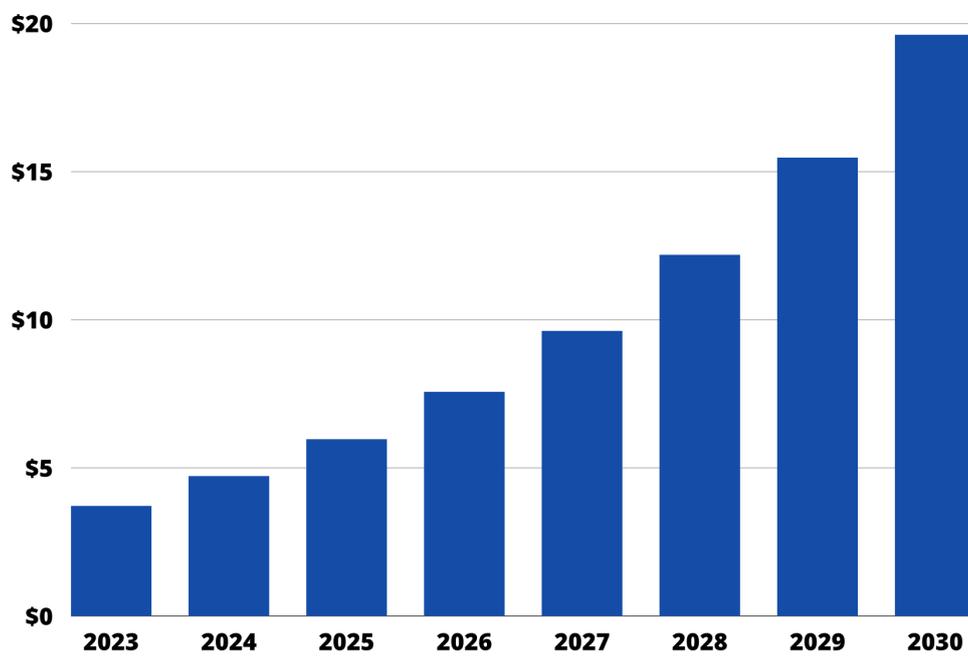
Figure 1.2: Augmented and Virtual reality in health care market, 2021 to 2030

Chapter 2

Background

Virtual reality is a computer-simulated reality in which the user can move and perform actions. This technology is used in various fields and can be employed with different technologies. With the development of virtual reality, the importance of creating avatars has increased, whose role is to generate a virtual representation of the user. The purpose of the second chapter is to provide a more detailed view of virtual reality, to explain what are currently the most common use cases, the technologies used, existing typologies and also what relationship exists with the avatar creation.

2.1   Introduction to Virtual Reality

Virtual Reality aims to offer an interface that simulates a real environment through the use of software and hardware elements with the objective of giving the user the illusion of being inside a real space. Users can perform several actions, depending on the purpose for which the platform was developed. The aim of Virtual Reality is to involve all the senses in order to make the experience as realistic as possible, allowing one to fully immerse oneself in a non-real environment. In many experiences of virtual reality users may be able to explore the world around us, see and touch objects or use them to create more, or they may interact with some elements within this world, it is possible to also perceive sounds and recognize which direction they come from. The world of virtual reality is constantly evolving; In fact, in many areas it is used on an experimental basis because there is uncertainty about its real effectiveness. Indeed, there are several problems associated with the use of these technologies, one of the best known being 'motion sickness', i.e. the feeling of discomfort such as dizziness, disorientation or nausea that may affect a subject during or immediately after using a Head Mounted Display. This sensation is very common in humans and is similar to the feeling of motion sickness or seasickness and depends very much on the hardware equipment being used. Another concept to

make more realistic the experience inside an virtual environment is the immersion. It depends on the level of efficiency of the technologies made available for the Virtual Reality System, therefore it is an objective and measurable factor. The level of immersion includes many components[5]:

- Field of regard (FOR), is the extent of the observable world that the user sees at any given time;

- Field of view (FOV), is the total area of the visual field around the user;

- Display size;

- Display resolution;

- Head-based rendering, visualization of images that depend on the physical location and orientation of the user's head;

- Lighting, must be as realistic as possible;

- Frame rate;

- Refresh rate;

- Stereoscopy, it describes how each of the two eyes visualizes different images allowing the brain to process them and create a third resulting image that provides a further insight into depth.

If efficient software and hardware technologies are used, it is possible to achieve a high degree of immersion but unfortunately this element alone is not enough to determine the success of the virtual reality experience, in fact it is very important to take into account the level of presence. It is a subjective factor and depends on individual psychological response to a VR system, so the degree of presence can be different for each user even for the same Virtual Reality system and the same users could have different degree of presence with the same system at different time, so it depends on personal factors.

Overall, the level of immersion within a virtual reality environment depends on how much the senses are involved, the input or output devices (HMD, VR gloves, controllers, wands...) have this precise goal. Human vision involves brain more, the second most important sense is hearing instead the other senses play a minor role. The graph describes how the five human senses contribute to virtual reality[24].

2.2   Types of Virtual Reality

It is possible to distinguish different typologies of Virtual Reality according to technologies used. The supply of hardware and software elements but also the type
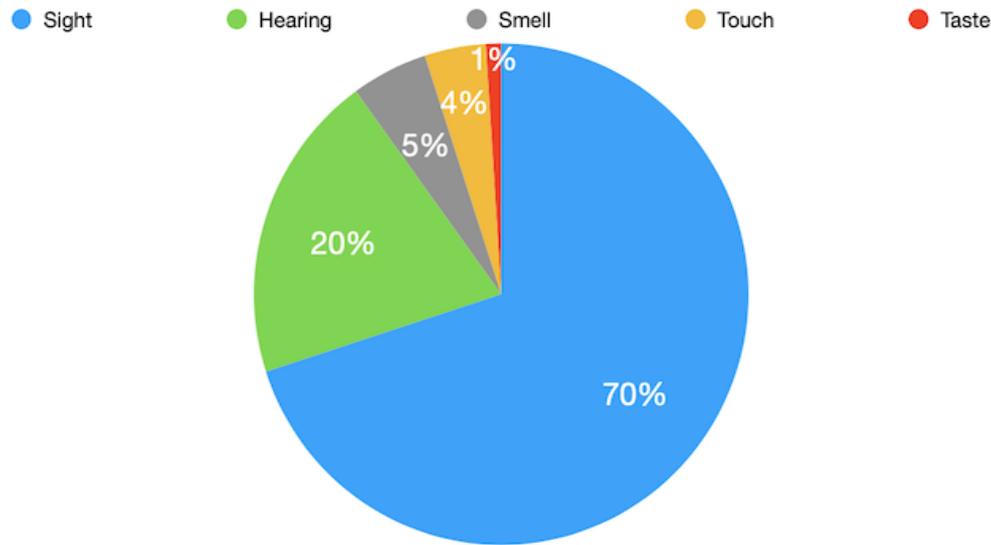
Figure 2.1: Impact of senses on the human brain

of interaction deployed determine the level of immersion allowing to define three types of virtual reality experience.

2.2.1 Non-immersive system

This is the most cost-effective system for providing virtual reality simulations, as the virtual world is displayed on the screen and does not need any other devices, thus allowing the user to remain fully aware and in control of the physical environment. Non-immersive virtual reality systems rely on a computer or game console, a display and input devices such as keyboards, mice and controllers. A video game is a good example of a non-immersive VR experience.

2.2.2 Semi-immersive system

It is a hybrid between a fully immersive system and a non-immersive system, in fact it includes a desktop virtual reality system and additional devices, which give users the perception of being in a different reality, but allows them to remain connected to the real world around them. An example of semi-immersive virtual reality are the various commercially available simulators. They often consist of a large concave screen, a projection system and a monitor. Again, high-level computer graphics are used. From an economic point of view, the use of semi-immersive simulation might be more advantageous than full simulation.

Figure 2.2: Non-immersive Virtual Reality

Figure 2.3: Semi-immersive Virtual Reality

2.2.3 Fully-immersive system

To achieve this level of immersion in VR, the use of a protective glove[1] or controllers and a Head-Mounted Display(HMD)[2] is usually required so that the user's head movements can be tracked and simulated within the virtual experience. In this type of approach, the auditory and visual involvement of the user is ensured and as little external stimulation as possible is sought to make the experience fully immersive. There are various examples of immersive virtual reality, especially in the field of video games. A different type of fully immersive virtual reality is that provided by CAVE (Cave Automatic Virtual Environment), it is a semi-immersive virtual reality environment, consisting of a cube-shaped room and face-facing video projectors.

Figure 2.4: Immersive Virtual Reality

Hardware components for virtual reality

Virtual reality, to convey the feeling of complete immersion to the user, must involve the senses as much as possible. To achieve this, it is important to use certain hardware components:

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[1]Is an input device similar to a glove worn on the hand that contains various electronic sensors that monitor the hand's movements and transform them into a form of input.

[2]Is a screen mounted on the viewer's head through a helmet.

- **Head Mounted Display:** is a headset that is worn on the head and provides viewing of the virtual world in three dimensions. Its goal is to provide a visual experience close to the real view.

- **Headphones:** must provide spatial audio that matches the images projected. Often HMDs have headphones implemented within them.

- **Tracking systems:** have the task of measuring the coordinates and orientation of the user. This information is used to determine how to view the virtual environment so that it really looks inside it. Tracking devices are usually present within the HMD and input devices such as controllers.

- **Input devices:** are used to communicate user actions within the virtual world. One of the most common input devices is the wand, a hand-held joystick with several buttons. It has a functionality similar to that of the mouse, but being equipped with trackers allows you to grab objects, to rotate them, to move them in depth. Input devices are also used to simulate the feeling of touch. And there are different types beyond the wand, for example the VR glove. is a complex system that allows to trace the position and the orientation of the hand and fingers generating a greater sense of immersion within the virtual world.

The table 2.1 illustrates the differences between the three types of virtual reality technology described.

Table 2.1: Comparison among the different types of virtual reality

	Immersive	Semi-Immersive	Non-immersive
Resolution	Medium	High/Medium	High
Immersion	Full	Partial	None
Cost	High/Medium	High/Medium	Low
Number of user	One	One/Multiple	One/Multiple
User-friendliness	High	Medium	High/Medium

2.3 Evolution of Virtual Reality

Although virtual reality is a rather modern technology, its history involves much of the previous century. Its evolution has allowed the use of this technology in many scientific fields and nowadays the use of virtual reality tools is increasingly widespread. One of the most popular virtual reality devices is the virtual reality headset, there are different types and once worn, it allows one to immerse oneself

in a simulated three-dimensional reality using the concept of stereopsis[3]. The first studies concerning this phenomenon date back to 1838 with Charles Wheatstone, his research led to the creation of the steropscope and showed that the brain combines two images of the same object taken from two different angles to create the feeling of depth.

2.3.1 The beginning of Virtual Reality

The first reference to the modern concept of virtual reality comes from the cinematographer Morton Heiling, he invented Sensorama [4] and five short films to display inside it. This machine not only allowed to see in 3d the images in motion but also generated smells, wind, sounds, colors, vibrations. Heiling later invented the "Telesphere Mask" which is the first prototype of head-mounted display, in fact it was a television set for individual use that provided stereo sounds, three-dimensional images and a complete peripheral vision. Later the evolution of virtual reality involved the military field with the invention of the "Headsight" that enabled motion tracking and a first flight simulator for the Air Force. In 1968 Ivan Sutherland created the so called 'The Sword of Damocles'[5], although Heiling invented the "Thelesphere Mask", this is considered the first head-mounted display system for immersive simulation applications, in fact it was connected to computer and not to telecamera.

2.3.2 The rise: 1970-1990

Over the next two decades, many companies began investing in research and production of VR products. In 1975 Myron Kreuger created Videoplace, an artificial reality laboratory that allows the user to perform actions without using virtual reality devices. Later in 1979 with Howlett was born a new type of optical system: the Large Expanse, Extra Perspective (LEEP). This creation permitted to obtain stereoscopic image and a field of view creating a realistic sense of space. LEEP laid the foundation for the development of modern virtual reality tools, later NASA studied its VR system to help astronauts and the result led to the creation of the Virtual Interface Environment Workstation (VIEW): a tool consisting of HMD and gloves to involve haptic interaction and ensure a better virtual reality experience.

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[3]Visual ability of humans to perceive the depth of space through binocular mechanisms, the eyes.

[4]the first immersive machine that aimed to include in a realistic way all the senses in order to offer the viewer an engaging activity.

[5]It was named this way because of its shape: in fact the headset was so heavy to wear that it had to be hung from the ceiling.

Figure 2.5: Sensorama

In the second half of 1980, Jaron Lanier helped popularize the term Virtual Reality, he is one of pioneers of this technology and founder of the company VPL Research[6].

2.3.3 Toward the 2000s

In the 1990s, the largest gaming companies began producing the first commercial virtual reality products. Virtuality group launched 'Virtualiy', it was the first widely available multiplayer VR product and also in those years the CAVE was created, the first cube-shaped immersive room. At the end of the 20th century Linden Lab was founded to Philip Rosedale, the goal of this project was to develop hardware to achieve a 360 degree immersion capability within a virtual reality experience. This led to the creation of a computer game where users could participate in games focused on collaboration and socialization with other players in a 3d online environment and following the birth of Second Life, where users creating their own avatar could interact with other users in a virtual world online.

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[6]It was one of the most companies to product and to sell VR products

Figure 2.6: CAVE

2.3.4 Today

In 2010, Palmer Luckey, founder of Oculus VR, created the first Oculus Rift. This head-mounted display was only able to track the rotation of the head, however it enjoyed a field of view of 90 degrees and a greater visual quality of the images that allowed to reduce the distortion. Oculus VR later adopted a display for its future devices that helped reduce the lag and smear of VR headsets created by a gaming company called Valve. Today, many companies deal with VR and have their own dedicated research groups, including: Amazon, Facebook, Sony, Google, Microsoft and many others. Of course, VR is widely used in games and entertainment, but also thanks to the optimal performance that modern equipment provides, many other industries are increasingly showing interest in adopting virtual reality within their businesses.

2.4 Virtual Reality applications

The presence of virtual reality is increasingly widespread. Today, there are many areas in which investment is being made in the development of this technology; below are the different types of use.

Figure 2.7: Prototype of the Oculus Rift

Figure 2.8: Modern Oculus Rift

2.4.1 Tourism

The largest tourism companies have found virtual reality to be an excellent solution to improve the services they offer, as clients can visit the world's major cities remotely. This service allows customers to facilitate their travel decisions. They

can also choose hotels, attractions to visit and much more by immersing themselves in virtual reality guided tours.

2.4.2   Architecture and Design

Virtual reality gives architects the opportunity to evaluate their projects in more detail before they can be realized in real life: in fact it is possible to design a three-dimensional construction through the dedicated software and then, using the virtual reality, dive inside it. This functionality can be very useful not only for the architect but also for customers, who, for example, can visit their future home virtually before it is built. A fundamental element in this field is the Building Information Modeling, BIM. It is a method that serves to carry out in optimal way the phases of planning, construction and management of the structures through the use of a dedicated software, which, moreover, allows to collect all the relevant data of a construction. The use of this method and VR have allowed a strong innovation in the field of architecture and design by introducing many benefits such as the optimization of costs and working time, detect errors before starting the realization of the project, reduce redesign costs. In conclusion, the role of virtual reality is not only to view the final work before it is built, but it is an excellent support for every phase of the project in order to avoid mistakes before they are committed in reality.

2.4.3   Education

The use of virtual reality has allowed the introduction of new learning methodologies with the aim of increasing students' interest in acquiring new knowledge. An interesting feature is to allow the learning of abstract concepts within interactive environments. To ensure that virtual reality can be an effective tool, the role of educators is important, who must be able to use but also develop creative activities that increase the student's involvement. An interesting feature is to allow the learning of abstract concepts within interactive environments. To ensure that VR can be an effective tool, the role of educators is important, who must be able to use but also develop creative activities that increase the student's involvement. Much research continues to be done to understand the real effectiveness of virtual reality in learning, in particular, a study[22] shows how this technology can increase students' interest in learning new concepts but at the same time the user could be enchanted by the exposure within the virtual environment distracting him from learning new notions.

2.4.4 Automotive

In recent years, in order to increase the quality of services and improve the products offered, the automotive industries are increasingly using VR. One of the most important uses concerns the autonomous driving ensuring total safety, to ensure this service the vehicle is controlled through software tests. These have the task of capturing and processing as much information as possible while driving in order to improve the quality of service. Virtual reality allows test software to be used within virtual environments, avoiding tests in reality, so that, at the same time, many tests can be carried out and more accurate data can be guaranteed. Scenario reconstruction is used for different needs such as for training purposes, in fact the virtual reality can be used to learn to drive a vehicle in total safety or to determine what happened during an accident.

2.4.5 Events

VR events allow users to meet other people virtually to do or see different things. Some companies offer the possibility to see different sporting events live through the use of headsets, they also allow to see the game from different perspectives, look at the statistics in real time and other features to entertain. They can be organized meetings or conferences or simply meet people in virtual places that exist in reality.
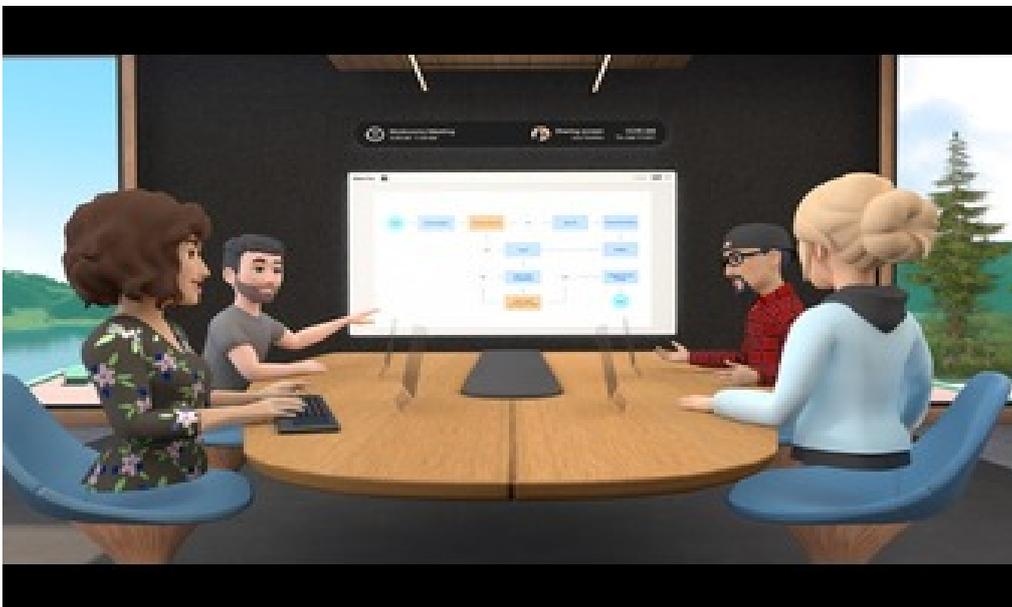

Figure 2.9: Meetings in virtual reality

2.4.6   Health

The period of the pandemic revealed many limitations in the field of health, but at the same time made it possible to experiment with virtual reality as an alternative system to existing ones.

Telemedicine

Telemedicine describes medical services that enable patients to be assisted at a distance. The doctor can consult the patient without being in the same place by telephone communication, video call or other electronic means. With the use of VR it is possible to simulate the visit within a three-dimensional virtual clinic allowing doctors to consult with other colleagues from different parts of the world in conference to offer a more precise assessment of the problem, moreover it could also reduce the need for many specialists within each hospital. Unfortunately, telemedicine, taking place at a distance, tends to reduce the quality of communication between patient and doctor, so it cannot completely replace the traditional types of examination. An example is the Epazz Slims[3], they consist of nano cameras and motion sensors with the purpose of reconstructing the patient's body in 3d. This project aims to create a virtual reality environment that allows a complete medical examination with full sensory involvement. Telemedicine has become more widespread after the pandemic and its use can be beneficial, in fact it could be useful for several reasons: for those who are afraid to enter a hospital or a clinic; for those who live in areas far from a medical facility; enable greater collaboration between doctors in different parts of the world; finally can reduce the likelihood of infection between patients and doctors.

Clinical Care

A health clinic consists of a group of doctors and nurses who provide health services. Virtual reality can be a useful real-time tool for different services.

- **Orthopedics**, virtual reality is mainly used for the planning and pre-operation training phase. Existing applications concern arthroscopic simulators, fully immersive operative simulations for trauma management, arthroplasty, tactile bone perforation simulators and reconstruction simulations[16]. Orthopedics can have great advantages with the use of virtual reality because it allows to practice orthopedic surgery without the direct involvement of patients. Several studies claim that this technology is useful to train new experts in this field and how it improves performance.

- **Obstretics**, The use of a virtual environment cannot be considered a pharmacological technique, but can be used to improve pregnancy by teaching how to better manage pain during labour. This type of experience reduces

anxiety and all those emotions that can be harmful to the mother but also to the unborn child.

- **Paedistrics**, an example of a virtual reality application in this area is KindVR. It allows children to immerse themselves in a virtual environment while being vaccinated, so the aim is to distract the patient to perform a treatment that can cause pain. Success is subjective but the perception of pain can be altered by changing the characteristics of the virtual world according to the sensations of the child.

- **Neurology**, in particular in the field of sports was created the application Eye-Sync, allows athletes to recover from a concussion. Once worn the headset collects data based on eye movements through an eye tracking system, this allows you to understand user progress.

- **Dentistry**, several applications have been developed to simplify operations in this area, for example virtual reality is used to relieve pain during dental operations. Another field of application concerns maxilofacial surgery to reduce the complexity of operations and provide effective therapeutic results[18].

Physical health

Physical state affects a person's health. Virtual reality is used to try to change the habits of sedentary people, encouraging users to exercise in a fun and innovative way. There are several games that use immersive reality to achieve this. Supernatural is an addictive game with four training modes, each of which allows the user to achieve a desired goal in an original way, such as burning calories or improving flexibility. Another type of fitness game is Bodycombat VR, which allows one to train using certain martial arts techniques. In these types of games there are usually virtual instructors to guide the user to the correct execution of the exercise.

Veterinary

Virtual reality is not only used as a support tool for the care of humans, but also for animals. The introduction of immersive environments and even avatars makes it possible to analyse large amounts of data to understand the health, sociality and emotionality of animals. Proof of this is the experiment done on a farm in Moscow called RusMoloko: the breeders have made their cows wear VR headsets, created specifically for their structural characteristics, in order to reduce stress and anxiety, the images projected in the viewer represented meadows and fresh grass. This experiment led the cows to produce more milk.

Mental Health

Mental health affects the quality of life, it determines the way people deal with anxiety, problems, the unexpected, the relationship with other people. Mental health is of great importance at all stages of lives, from birth to old age. The use of virtual reality allows the patient to face a specific experience, in a controlled manner, in order to overcome the problem. In particular, immersive virtual reality is used to treat specific phobias. It tries to involve as much as possible the sight, the hearing and the touch in order to make the user feel immersed in the simulation. Therapists have complete control of the platform so they can start or stop the virtual session whenever they see fit. A great advantage of this type of therapy is everything that happens is within the virtual world, so it can not cause any harm to either the patient or the therapist. In addition, virtual reality can be quite attractive, especially for younger patients, and this can be a great advantage for a more relaxed approach to therapy.

2.4.7 Entertainment

The entertainment industry is the one that has invested the most in virtual reality, especially in the world of video games has had a great success, soon in this field were released the first headsets for virtual reality. To date, there are many types of game consoles that support HMD and other technologies to ensure the best VR experience possible. In the cinema, virtual reality is used to allow the user to observe the environment at 360 degrees and also this technology to participate in musical concerts.

2.5 The relationship between avatar creation and virtual reality

The momentum of VR technologies is constantly growing for several reasons. The available hardware and software devices are increasingly accessible and powerful, in addition the impact of simulated reality environments is giving encouraging results in various sectors, from games to medicine, from science to tourism (see figure 2.10 [27]). This allows companies to evaluate with greater interest the use of these technologies and invest in research in this field.
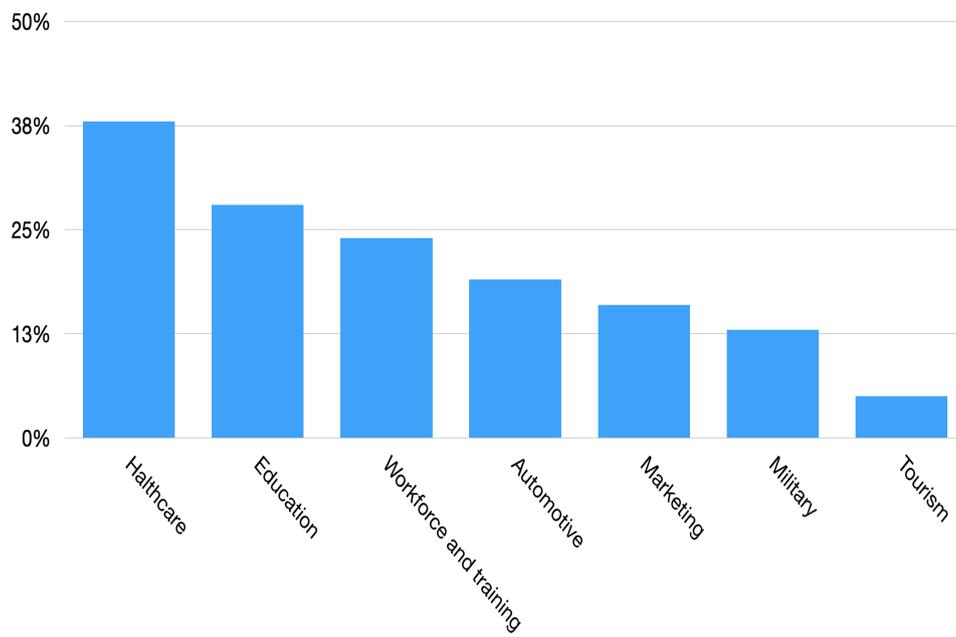
Figure 2.10: Sectors with the highest use of VR

Chapter 3

Avatar configuration

Nowadays, most virtual reality platforms belong to the gaming world, especially online multiplayer games. Usually the first step, before starting to play, is to create a personal virtual character who will have the task of impersonating the user in the game, more commonly called an 'Avatar', this term has its roots in Hinduism, it is derived from a word in Sanskrit that indicates one of the ten incarnations of the god Visnu. Generally, an avatar can be a two-dimensional, three-dimensional or imaginary representation; it can be created with preset models from a dedicated platform or an original representation through special software.

3.1 Overview of current avatar configurators

Nowadays, avatar configuration is increasingly present in every sector. The vast majority of tools used for virtual character customisation provide the user with similar functionalities. Specifically, modifications are usually divided into three or four sections: head, body, clothes and accessories; this allows to focus on the changes affecting that section.

3.1.1 Avatar configuration in the world of video game

As mentioned earlier, the field where this practice is most widespread is the world of gaming. Not only video games, but especially the industries that produce game consoles allow users to create them own virtual stand-in: this has proven to be an effective tool in bringing users closer to the gaming platform, facilitating the creation of an active and long-lasting community, but not only that, in fact the creation of an avatar allows to be recognisable within the platform by other players. Playstation is the only company that has not developed a real avatar configurator, in fact the user is only able to choose an image that can represent him or her. The other major competing companies, on the other hand, have focused heavily on this feature, they are Xbox and Nintendo.

- Both use cartoon-style graphics, Xbox allows users to begin creation by selecting one of the pre-configured avatars provided, once chosen it is possible to change the appearance. From the point of view of functionality, it allows a fairly complete customisation of both the body and the face: in fact various aspects of the physique can be modified, it is possible to change the eyes, eyelashes, eyebrows, ears, mouth, nose, chin, but not only that, in fact it also gives attention to the look by allowing users to choose the haircut, make-up, fingernails and type of clothing desired. A different feature compared to many other configurators is the ability to equip the wheelchair and other object for people with disabilities or for sick people, making the platform as inclusive as possible.
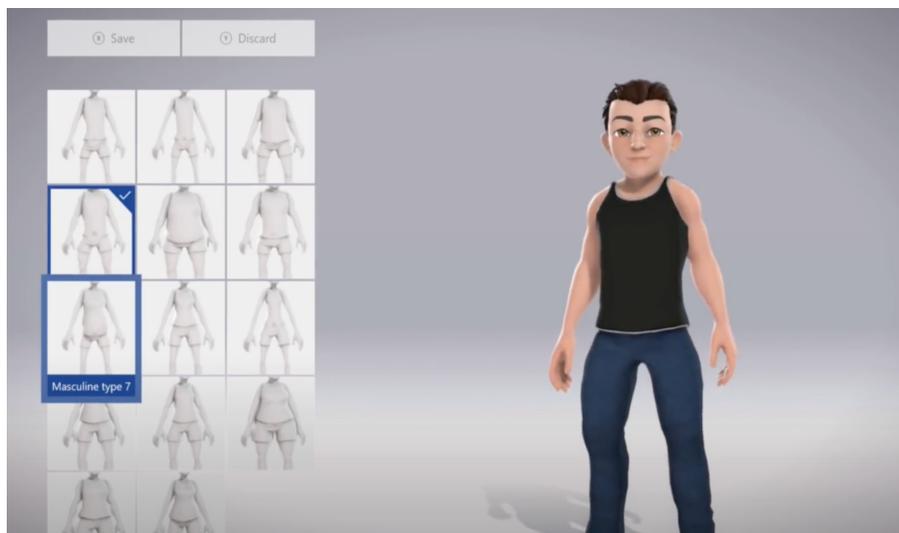
Figure 3.1: Xbox avatar creation

- The avatar in the Nintendo universe is called Mii, it is one of the most famous configurators within the world of video games. The tools of customization are quite similar to those of the Xbox, One of the most obvious differences is the use of more minimalist graphics for the look of the Mii and a more immersive interface that also makes the customization part of the avatar a main aspect of the platform.

Most games, especially in the online mode, provide the ability to create an avatar. In particular, some of these have given great attention to the avatar configuration:

- One of the most complete is The Sims, which is a life simulator and allows users to take care of the appearance and health of the avatar during the different stages of the game, the novelty compared to the other configurators is that the focus of the configurator is not only on the modification of various
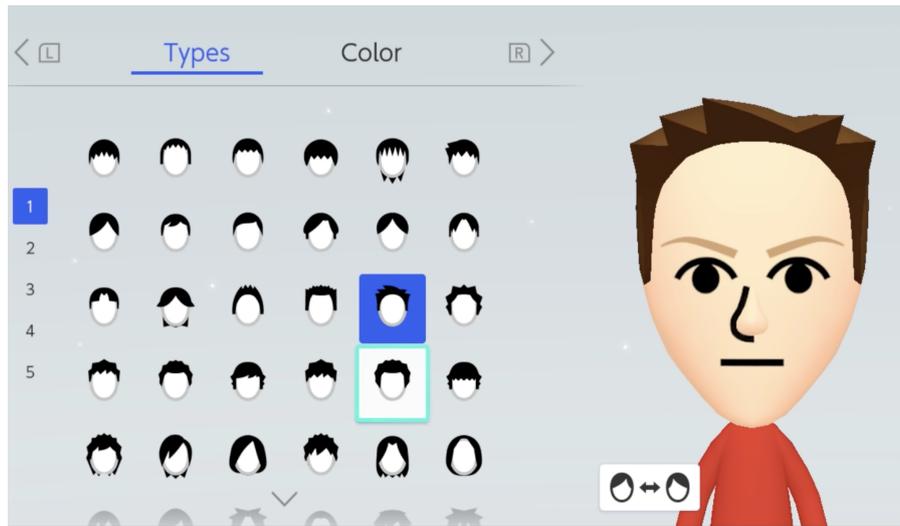
Figure 3.2: Nintendo avatar creation

body parts, in fact it is possible to modify the walking style, the voice, the behaviour and attitude of the avatar during the game but also during the initial character customisation phase;

Figure 3.3: The Sims

- Very different from The Sims is Cyberpunk 2077, a first-person RPG[1] video game with a futuristic setting as the name suggests, here the appearance of the

[1]Role-Playing Game

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character will be very realistic. The avatar configurator is rich in functionality and has some new features compared to other games, in fact it is possible to customise the type of pupil, the nipples, the style of pubic hair, it is possible to change the type and size of the genitals, and among other changes it also allows users to modify the nails by length and pattern.

Figure 3.4: Cyberpunk 2077

- Another game that has been given some importance in the avatar configuration phase is Soulcalibur VI, a fighting game in which the user can decide whether to create an avatar with human features or move away from a real similar look. The difference from the other video games configurators is that it's available the customization of the weapons, armor and especially the avatar's fighting style in different aspects (for example the tendency to attack or defend, the graphic effects of attacks). It allows the customization of the various parts of the body in a very meticulous way compared to the many other video games configurators, for example, it allows the size and length of arms and legs to be altered and enables great customisation of clothing.

3.1.2 Other avatar configuration platforms

The functionality to create a personal virtual character that marks a user's identity is increasingly widespread not only in the game world, just think of social networks or messaging applications that enable to identify the user with the support of personalized emojis[2] and communicate mood through them. For instance, the

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[2]small icon representing an emotion, symbol or object

Figure 3.5: Soulcalibur VI

famous messaging application Whatsapp has recently added the possibility for users to create their own avatar by providing a large number of customizations in order to allow the creation of new and original ways of communicating with friends and family (see figure 3.6). With the growing use of virtual representation, the avatar
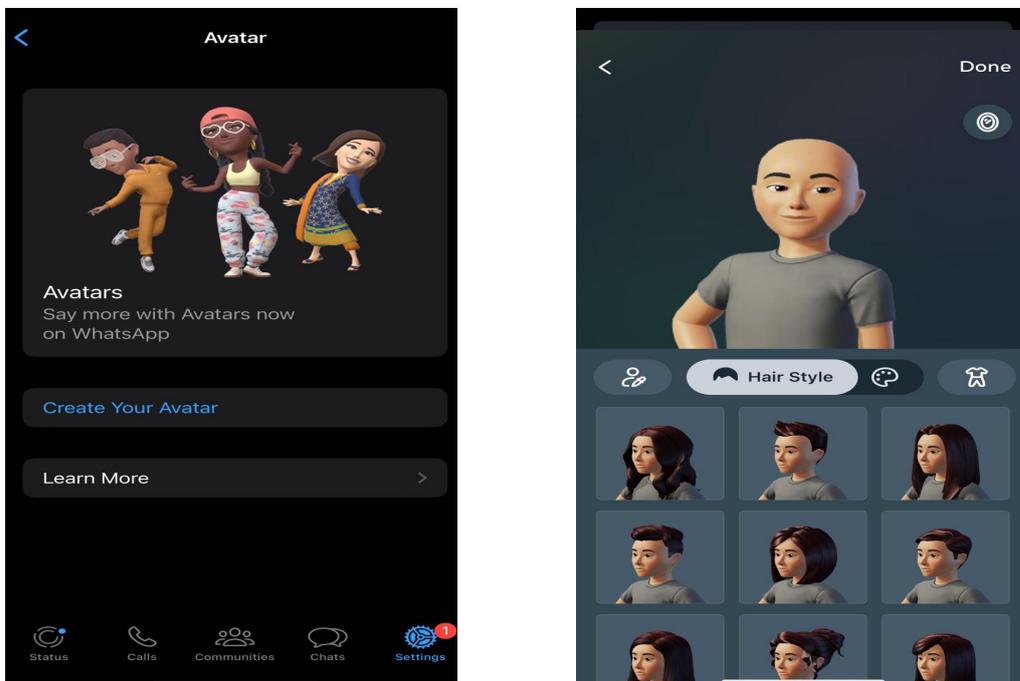
Figure 3.6: Whatsapp Avatar configuration

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setup software has added more functionality, allowing for more detailed character customization: from physical appearance to emotions, from hair style to the type of movements and many other types of customization. These software or websites, which deal with the configuration of avatars, are becoming more numerous due to the strong growth of virtual reality applications and metaverse. There are various types, from those that aim to create super-realistic avatars to those that allow the creation of a more cartoony virtual self, or there are many websites and software, particularly for two-dimensional configuration, that allow to create a character in the style of a particular cartoon, manga, TV series and so on.

- One of the most popular configurator is the one made by Readyplayer 3.7, mainly oriented to the metaverse allows the creation of a cartoon style avatar. One of the strengths of this software is its ease of use, in fact it has a very intuitive interface, compared to the other configurators analyzed in this chapter offers less possibilities of customization but includes an interesting feature to speed up customization, or the possibility to create your own avatar by taking a photo in order to be able to automatically create a personal virtual stand-in.

Figure 3.7: Readyplayer configurator

- Among professional avatar configurators, it is worth mentioning Metahuman 3.8, a software that allows the creation of an avatar with highly realistic graphics, an interesting feature is the 'DNA calibration' that allows users to select three or more avatars ready-made to attribute their characteristics to a new avatar, also it is possible to decide how much of a certain feature to make him inherit. In addition, this feature allows various types of customisation

of both face and body that enable the creation of highly realistic and unique characters, but compared to other such advanced avatar configurators, it has a limited choice of clothing.

Figure 3.8: MetaHuman

- One of the most complete configurators existing today is Character Creator 4. Users can start by modifying a basic model from those available or imported from other sources. It allows practically all possible modifications in order to guarantee the creation of an avatar suited to the user's needs without leaving anything to chance. It is possible to modify various attributes of each part of the body that is selected and allows the customisation of the avatar to be enriched by providing a large number of editing tools, giving the user the freedom to create his or her own skin type, hair style, beard, physique and many other details of the face and body. In addition, it is possible to choose from numerous elements of clothing for one's look and provides several categories of animation, from facial expressions to gestures and poses. Among its many functions, it also allows users to create a face similar to them own using photos. Overall, this is one of the most comprehensive and versatile configurators on the market, which certainly makes it more complex to use than avatar configurators that offer fewer functionalities, such as the one created by Readyplayer.

3.1.3 Comparison between avatar configurator mentioned

The number of functionalities made available by avatar configurators also depends on the objective of the platform itself. Metahuman and Character Creator 4 are

Figure 3.9: Character Creator 4

more focused on the creation of avatars for the world of high-resolution gaming or super-realistic films, in fact they are tools that tend to be used by media professionals. On the other hand, Readyplayer has a very different lens, in fact it is more focused on models that can be used in the metaverse where the demand for particular graphics and quality of the models is clearly different from those used for the latest generation films or video games. This analysis can also be extended to other analyzed avatar configurators, such as those present in video games. Although not a prominent element within a video game, there are more and more complete configurators and full of customization features that aim to make the relationship between avatar and user more intense within the adventure and then feel more involved in the narrative of the game.

3.2 Sense of embodiment

The ability to create an avatar in a virtual reality environment is a very powerful tool. The development of such advanced avatar configurators is made possible by previous studies on the user's sense of achievement in creating their avatar. This concept is called 'Sense of Embodiment' (SoE), more precisely,in the field of virtual reality, it can be defined as a tool used to determine to what extent a certain sensation in a virtual body can be perceived in the same way in the real body of the user. VR is seen as a potentially very effective tool to increase the "sense of embodiment", in fact many experiments without the aid of these technologies have shown that it is possible to recognize a fake limb as part of body, for example one of the most famous experiments is the rubber hand illusion[4]. This concept is very

important and has led to an increase in the use of avatars for research purposes, particularly in the field of psychology [11]. Indeed, avatars could be a tool capable of changing behavioural aspects of the user; specifically, when someone immerses themselves in a virtual experience they have the perception of two distinct bodies at the same time. To increase the sensation of immersion, it is important not to neglect the involvement of any receptor, so it is also important to involve touch, in which case we speak of active and passive haptics: the first concerns the physical characteristics of the object such as softness or hardness, the degree of roughness of an object, weight and so on; while active haptics are more commons and concern vibrotactile feedback. These two types of touch can be combined to simulate the tactile characteristics of more complex elements[3]. Today it is not really possible to influence all senses exhaustively, in fact it is still complicated to allow the user to perceive smells or try to involve the taste receptors, however the possibility of employ these senses is already concrete but very limited: for instance through MetaCookie+ (see figure 3.10) is possible to choose a type of biscuit and smell it using an headset equipped with pipes that pump the smell or to involve the taste has been created an interface that applies two electrodes,one under the tongue and one above to stimulate the taste receptor through heat[25].

Figure 3.10: MetaCockie+

The Sense of Embodiment can be divided in three dimensions, according the definition of Kilteni et al. [21], it is possible to distinguish:

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[3]For example, it is possible to simulate the interaction with an animal by implementing passive touch to feel its weight and its fur, and instead active touch to feel its heartbeat or movements as users interact with it[15].

- **The sense of self-location,** it refers not to the fact of being inside a virtual environment, but to the fact of being inside another body. So it deals with how the user perceives himself or herself within this world and what allows this feeling to increase. In particular, studies have revealed how this sensation increases with immersive virtual reality headset [30] that allow users to visualise the virtual world in a way that is synchronised with head and hand movements.

- **The sense of agency,** it can be defined as the awareness of having control of the body, so it measures how much the user is in control of the various parts of the body and what actions he is able to do.

- **The sense of body ownership ,**it measures how much users feel as owners of the body, this concept is very interesting, in fact, as previously said, a study has shown how it's possible to create the illusion of having a fake hand[4]. This property is still quite limited and for this reason it is not yet used to create other types of illusions about the avatar.

Several factors of influence[12] arise from these three categorisation, virtual reality allows you to control many factors, not only in terms of stimuli but also the aesthetics and morphology of the avatar. It's possible to distinguish them in external and internal factors[9]. External factors focus on conditions such as stimulation, appearance, perspective; internal factors focus more on individual aspects such as body awareness and personality traits.

- **External factor**
  About external factors it has already mentioned the hand rubber illusion experiment: basically the experiment consists in hiding the real hand of the user and make him or her show the rubber hand; both hands will be stroked and she or he will focus on fixing the fake hand. This causes users' brain to replenish the sensation felt in the hand they is staring at, and having lost the real position of their hand they will have more difficulty moving it[19]. Using hardware tools for virtual reality it has been noticed that the use of virtual hands generates a certain sense of embodiment which is greater if the possibility of viewing the avatar in some way is added. This feature gives more and more a sense of ownership, especially if the appearance is similar to that of the user[13]. The use of virtual reality, however, has allowed us to analyze how the 'sense of embodiment' is present even when the user has the possibility of changing the characteristics of its virtual representation. Not only is the sense of ownership involved in this type of factors, in fact as far as the sense of agency is concerned, it is high when the action performed by the user and the visual feedback are synchronized[17]. As for the sense of self-location, it is greater when the view is in the first person while in the third it has been shown that this sensation decreases[23].

- **Internal factor**
  As for the internal factors, there are not many experiments and researches, especially with the use of virtual reality, in fact most of the works are focused on rubber hand illusion, so as far as body awareness is concerned. A number of recent studies have focused on personality analysis in relation to sense of embodiment and have outlined broad scope for future improvements in this direction.

Factors can be modified to change the overall sense of embodiment. Three very important factors are:

1. **Appearance**, this is an important factor to control the sense of ownership. The shape of body and the render style permit to obtain different degrees of realism and fidelity towards the user's real body[12], the more customizations are available, the more the sense of ownership will increase.

2. **Control**, it is about how much people can control the actions that avatars can perform and it greatly affects the sense of agency.

3. **Point of view**, is based on the spatial relationship between the avatar and the virtual body, in fact, a correct stimulation of sight and touch could cause the user to lose contact with reality and feel projected inside the virtual body. This can be a very important factor regarding the sense of self-location.

There is a relationship between the various factors of influence, in fact, several studies show how each factor can influence more components of sense of embodiment, for example, a work demonstrated how a virtual hand with a low level of realism influenced not only the sense of ownership but also the sense of agency[1].

3.3   Innovation aspects of the project

The use of a virtual representation plays an important role in virtual reality. The creation and customization of the avatar spread mainly in the world of video games at the end of the last century. Later it founds a large spread on the internet and on social networks especially in 2D format. The development of technology and the spread of platforms that support virtual reality even avatars have become more realistic and feature-rich. In particular, the spread of the metaverse[4] led to the need

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[4]It is a set of inter-operable, persistent and synchronous three-dimensional virtual worlds that one can explore with one's avatar. It is possible to interact with people and objects. It is characterised by the continuity of data, the identity of users and their history. The metaverse is accessible via immersive devices such as Mixed Reality tools and headsets, but can also be explored with immersive displays.

to develop avatar configurators that would satisfy the user's wishes. However, the role of the avatar configuration assumes mainly an ancillary role in today's market. One of the points in which this project differs from the current avatar configurators is precisely the role that customisation takes on within the application and the scope in which it will be applied: in fact, avatar customisation is the core of the experience and not an initial part of the experience, as could be seen by analysing any avatar configurator on the market today. It is enabled not only by interacting with a customisation menu but also, and more importantly, by venturing inside the island and interacting with it. The aim of the project is precisely to deepen the study of the internal factors that determine the sense of embodiment, in fact in the course of this chapter, it was noted that the analyses in these terms are quite few and limited, particularly for the target age at which this project is dedicated. More precisely it aims at analysing these factors in order to understand how and to what extent the user's character and personality can be influenced and modified by perceiving their body within a virtual environment.

Chapter 4

Technologies used

This section focuses on the two tools used to deliver the project: Unity and Blender. The former is a cross-platform graphics engine, enabling the creation of all kinds of video games and interactive applications in three or two dimensions. With the advent of virtual reality, it has been widely used for the creation of three-dimensional immersive environments through the use of hardware devices such as head mounted displays.
Blender is a 3D creation software, it is also a cross-platform and offers many tools that allow modeling, animation, rigging, texturing, compositing, rendering, in addition it allows users to edit videos and create visual effects. The use of these software gives the possibility to create an interactive application and to obtain a certain graphic quality enriching the virtual environment of all the features that developers want to add.

4.1 Blender

Blender is a three-dimensional graphic engine, it is used to obtain renderings that can achieve very realistic or cartoonish results, simulating the environmental characteristics and objects in real life. In this project only a subset of the available functionalities has been used, more precisely all that concerns the modelling and texturing of objects. Work in Blender is developed within a three-dimensional space in which objects to be modelled can be added; this environment is called the 'Scene'. All objects inside the Scene are included in a list called 'Scene collection', this, in turn, can be composed of other collections. The software provides various objects that can be used to create the desired models, each of which has certain properties. Being mainly used for the creation of models that can be used within the Unity environment, the number of objects used for the thesis project is rather small compared to those made available by the software, specifically they are:

- **Mesh,** is a 3D object consisting of a set of vertices[1], sides[2] and faces[3].

- **Curve,** are defined by mathematical functions, Blender provides two types of curves, Bezier and NURBS. Unlike mesh objects it has the advantage of being defined by a smaller amount of data.

- **Armature,** has the same function as the royal skeleton. The parts that make up the armature are called bones, which can be moved and everything associated with them, such as a mesh, will move and deform accordingly.
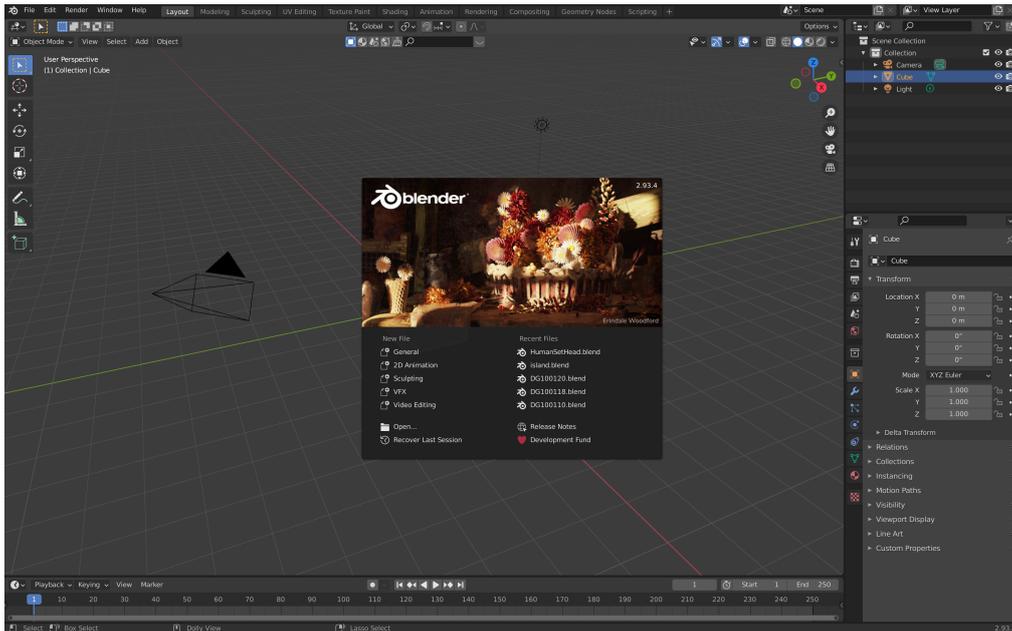
Figure 4.1: Default Blender setup
1

4.1.1 Workspaces

The workspace window is defined by several rectangles that have specific features, these are defined as areas. It is possible to add resize or remove the areas within the working window according to what it is to be done, each of them also includes an editor that allows viewing and editing different aspects. Blender provides eleven ready-made workspaces and each of them has a specific purpose:

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[1]indicates a single point

[2]segments that join two vertices

[3]a flat surface consisting of sides

40

- **Layout,** default workspace.

- **Modeling,** users can modify objects geometry.

- **Sculpting,** users can modify the object mesh.

- **UV Editing,** users can mapping image coordinates to three-dimensional surfaces.

- **Texture Paint,** users can color the surface of a mesh.

- **Shading,** users can specify and modify material data.

- **Animation,** users can animating objects in the scene.

- **Rendering,** users can verify the rendering results.

- **Compositing,** users can compose and improve the result of an image or movie.

- **Geometry Nodes,** users can modify geometry of the objects with nodes.

- **Scripting,** users can write Python scripts and interact with Blender.
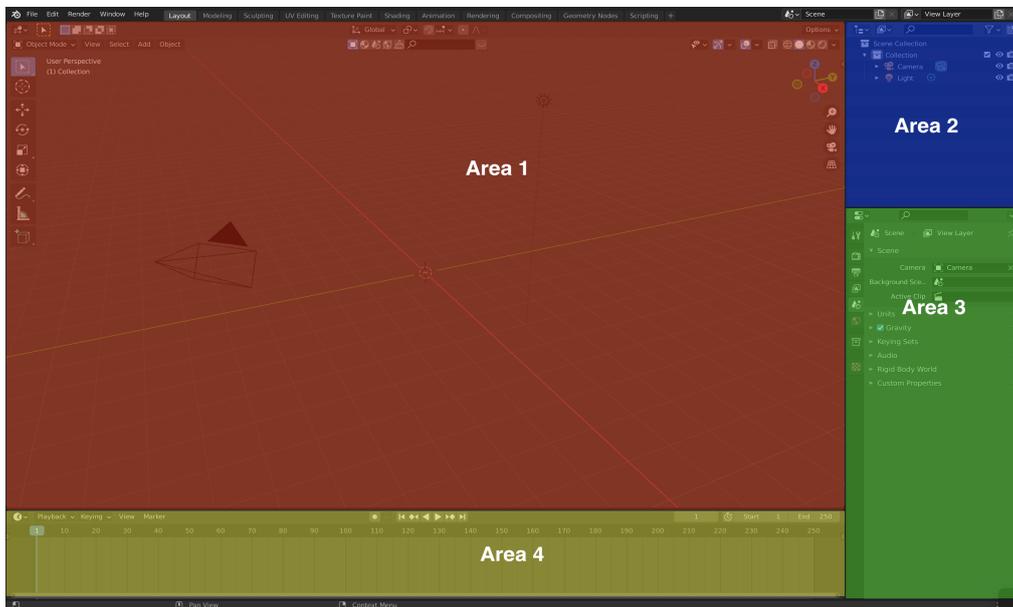
Figure 4.2: Areas in Blender

4.1.2 Editor types

Within the Blender environment there are many editors and provide various tools to fulfill the operations required by the user. They are differentiated into four categories according to the type of task they perform: General, Animation, Data, Scripting. Next, the focus will be mainly on the editors used for the development of the project.

Figure 4.3: Editor types

Animation

There are several editors dedicated to creating and editing 3D animations. Dope Sheet editor gives a complete vision of keyframes[4] inside the scene, in fact it displays when an animation will occur, what kind of movement, for how long and what object. This editor includes different modes: Dope sheet mode offers a comprehensive overview about the animation data and permits to edit multiple action at once, the other modes are more specific such as Action editor; this mode is useful to define and control actions, they contain and record animation data, so actions can be described as data-blocks.

Data

There are two important editors, they are Outliner and Properties. The first is a list and organizes data in the blender file[8] and each row represent a data block.

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[4]it is a marker of time and memorizes the changing of the data[8]

It can enable various functionality in the scene, such as to use to view data, delete objects, select or deselect objects, hide or show objects. The Properties editor allows to edit active objects, it has a lot panels that represent the categories of property editables. These panels provide settings for the active elements in the scene, active collection, objects.
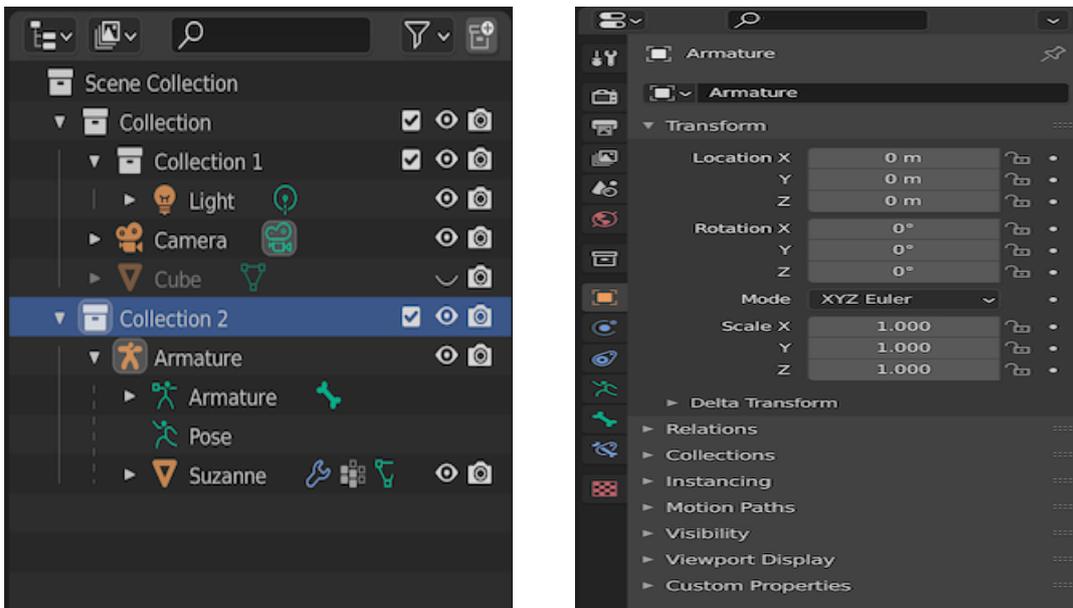
(a) Outliner

(b) Properties

Figure 4.4: Data editors

Scripting

This editor was not used for the realisation of the project, but can be a very important element in Blender. Scripting editors can be very useful if user wants to write code in Python and use it in Blender. However, the info editor is useful because it shows warning messages and errors that can occur during the work.

General

General editors provide the remaining features that Blender can offer. One of these is the 3D Viewport, permits users to interact with Scene and perform various operations. It features several menus that allow the user to change the visualisation of the 3D environment, but also the selection and modification of objects within the scene. Some menus change according to the selected mode, among the fixed menu it is important to mention are Viewport shading and Toggle X-Ray. The first permits to choose four different shading mode, depending on the type of change to

be made: Wireframe, displays only the edge; Solid, shows solid geometry; Material preview, is useful to have a preview of the materials and textures applied on objects; Rendered, shows the final result. Toggle X-Ray makes the scene transparent also allows to see and select objects that are occluded.
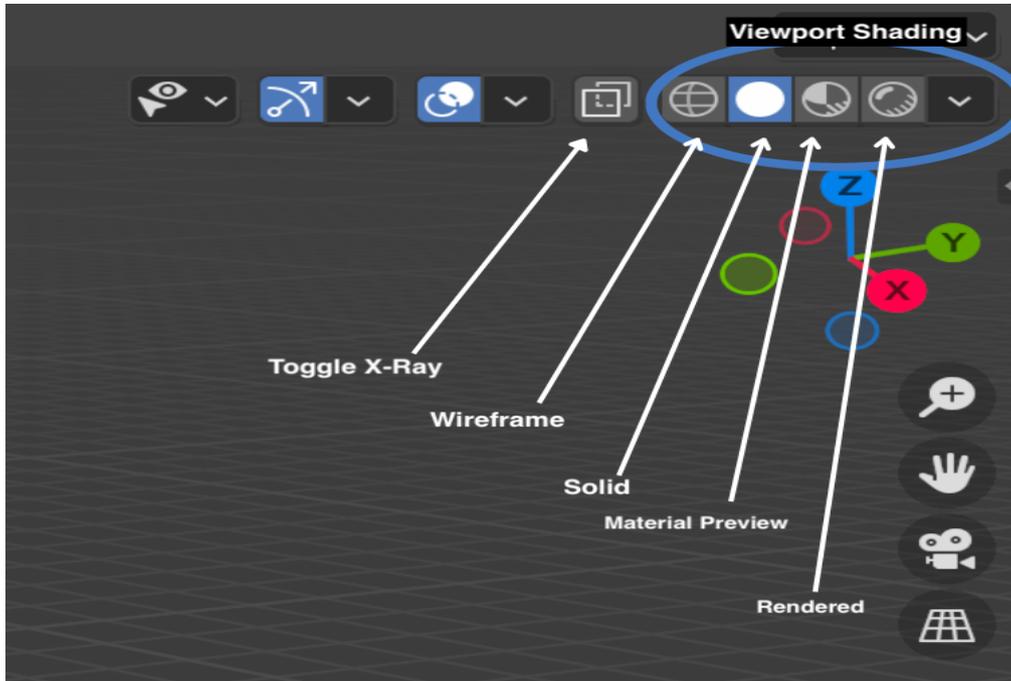

Figure 4.5: Toggle X-Ray and Viewport shading
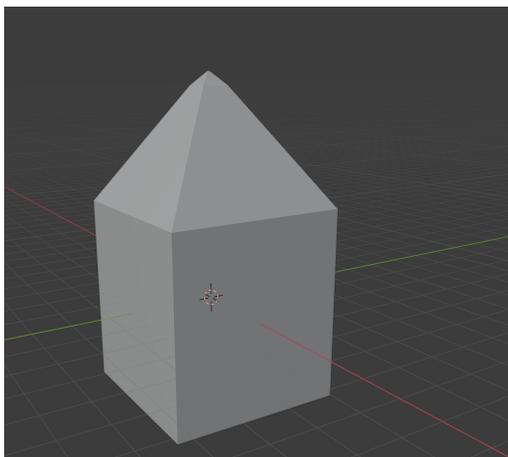
(a) Wireframe mode disable   (b) Wireframe mode active
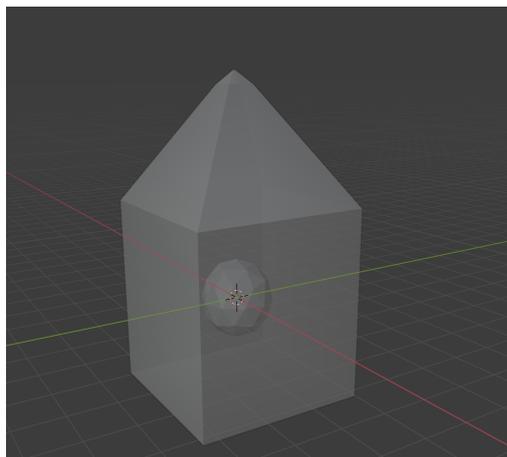
Figure 4.6: Differences between Wireframe mode on or off

The modes of the 3D Viewport show the objects in the scene in different ways and

allow different aspects of them to be modified. For this project five were quite useful:

- **Object Mode** is the default mode and is used to modify the objects of the scene, it is possible to perform operations on objects such as editing, duplication, merging.

- **Edit Mode** is used to modify an object's shape. In this mode modeling something realistic or fantastic takes place, it is possible to start using a simple cube to create a complex object.

- **Sculpt Mode** is similar to edit mode, in fact it is possible to edit shape of a model, but in this case the individual element[5] is not modified but an area of the mesh is modified.

- **Weight Painting** is used also for defining hair density, but the principle use is for rigging meshes, in fact it is possible to define the influence of a bone on the mesh.

- **Pose Mode** is dedicated to posing and modify the relationship among bones. It's an armature-only mode. Here the user can create animations of rigged objects.

4.1.3   External assets

4.2   Unity

This cross-platform engine was released in 2005 at Apple Worldwide Developers Conference. Unity is famous for the development of indie game, but gradually it was used to create interactive content of various kinds enabling development of two dimensional and three-dimensional application. In addition the engine introduced the Mixed and Augmented Reality Studio (MARS) with the purpose to facilitate development of augmented reality application. Nowadays it's widely used for creating simulation and other experiences in virtual reality and in this terms Unity is used by industries so distant by gaming world such as medicine, movie, design and so on. Its success is due to various factors including ease of use, moreover being a free and widely used platform has a very active community and this is useful especially for solving problems that may emerge during the development phase, especially for those who do not know Unity well. A very useful component is the availability of a large number of assets ready to be used, this avoids implementation from scratch and allows the user to save time for project development. Ready assets

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[5]in edit mode users deal with faces, edges and vertices

are available in Asset Store, the users can import them inside of Unity and then by opening the package manager they can get assets within the project. As reported on Unity Documentation the package manager "is a container that stores various types of features or assets", it can contain libraries, projects templates, editor tools and assets collection.
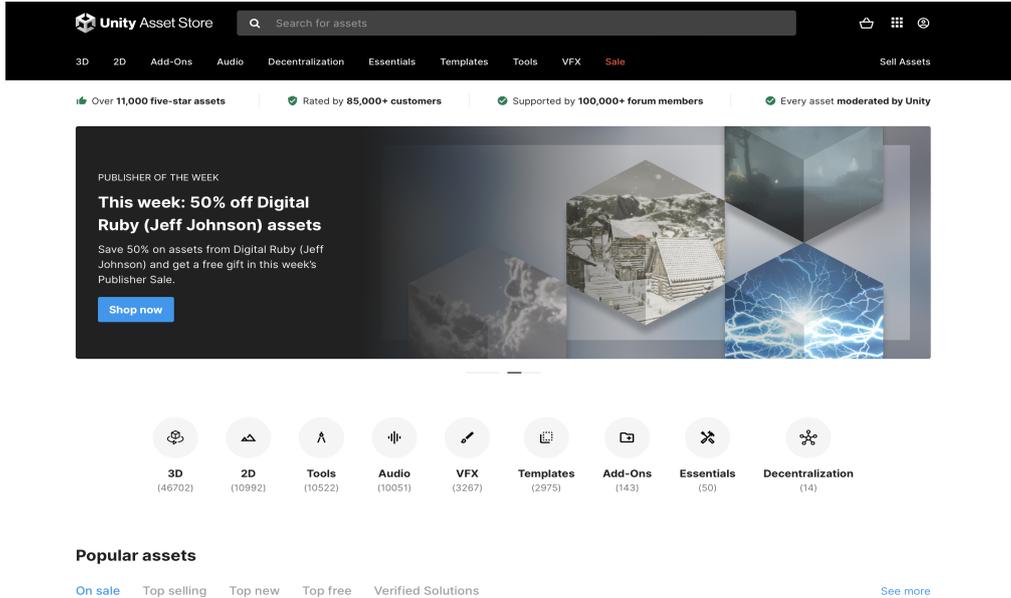
Figure 4.7: Asset store

4.2.1 Development environment

Unity Hub is a very useful application for project management in Unity, it offers an interface that allows access to the Unity ecosystem. This application is not only used to manage projects but it permits to install editors and add-on components; in addition it provides a section to learn new skills in Unity and another section to access the community. Unity Hub is not a compulsory requirement, users can install Unity Editor manually however not having an interface it can be inconvenient for project management.

Windows

Once opened the Unity editor of the project, the default development environment will be shown in Unity. This includes few windows:

- **(1) The Hierarchy window:** it shows every objects in a current scene, it is useful to selects or to organize objects, for instance they can group and

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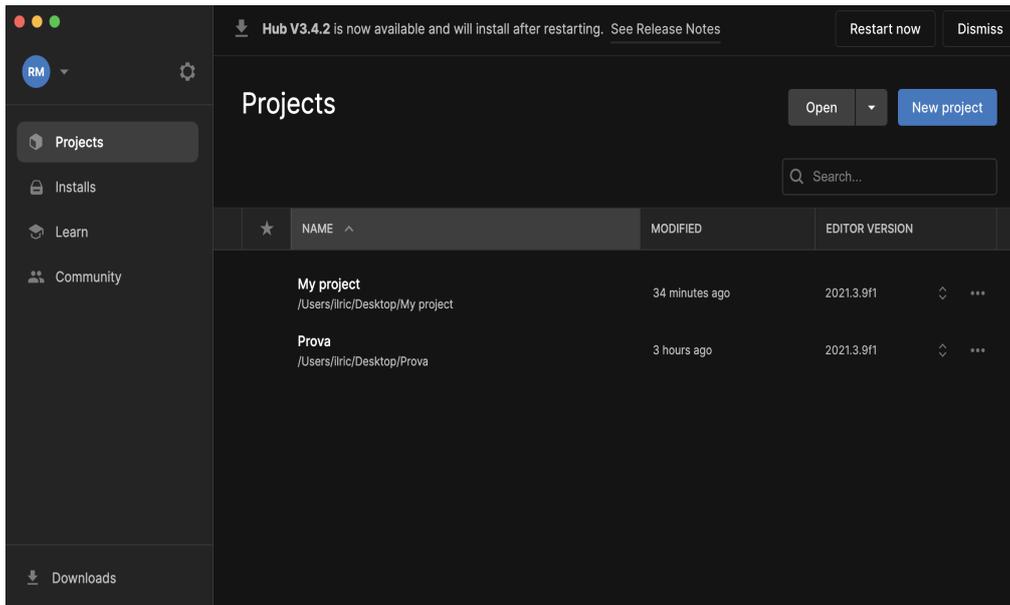
Figure 4.8: Unity Hub

sort, moreover when objects are added or deleted in the scene, they also will be added or removed in Hierarchy window. To group objects Unity uses parenting, an object can contain other objects and inherit its properties.

- **(2) The Game view:** simulates final application, in fact users can visualize final render through the scene cameras. It is possible to activate simulation in Game view clicking on play button in the Toolbar, at the top of unity editor.

- **(3) The Scene view:** users can edit and visualize the element in the scene. They can use the scene view to select, manipulate and modify the objects.

- **(4) Inspector window :** permits to view and edit properties of objects. The content of inspector window changes according to selected object.

- **(5) Project window :** displays the elements in the project, it is useful to navigate and search elements of project.

- **(6) Console window :** is useful to find problems in the project, in fact Unity editor generates warning and errors or other messages and console window displays them. This window also displays the alerts that editor generates automatically.

- **Additional window :** other windows can be added, these include Animation and Animator windows. They are widely used in application development: the first allows users to create an animation for selected object in the scene;

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second allows users to create and edit Animator controller assets. They will be described below in this chapter.
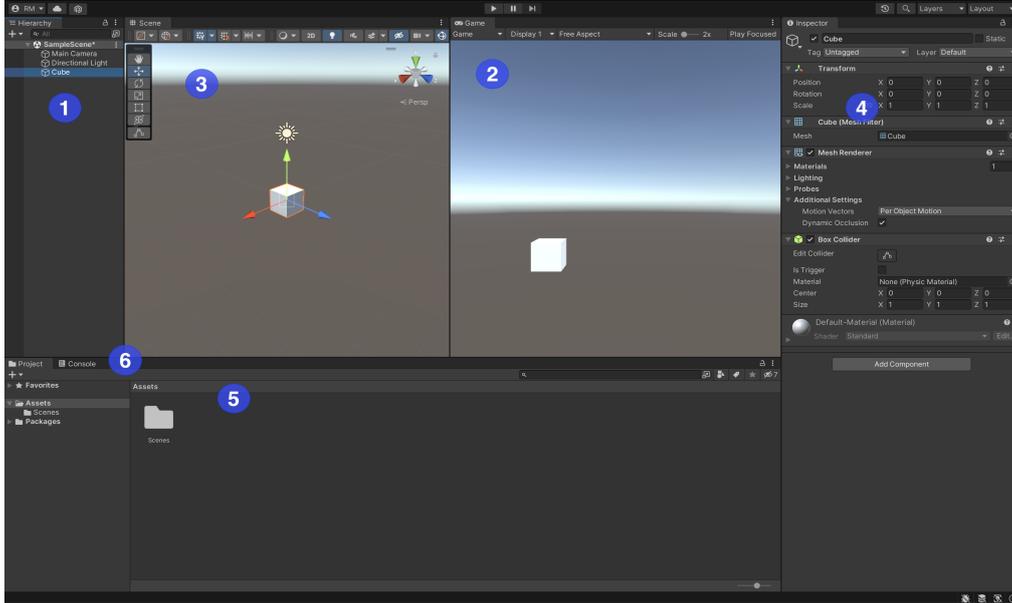

Figure 4.9: Default windows in Unity
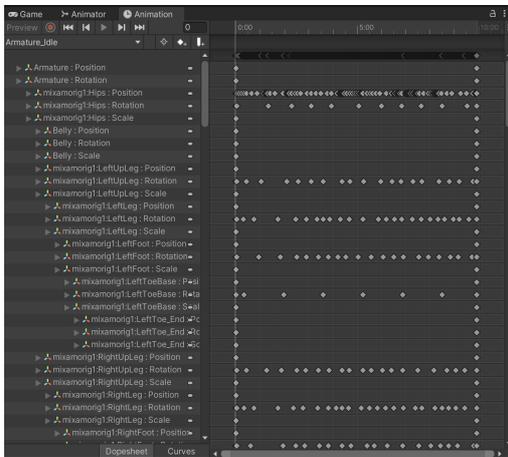
(a) Animation window
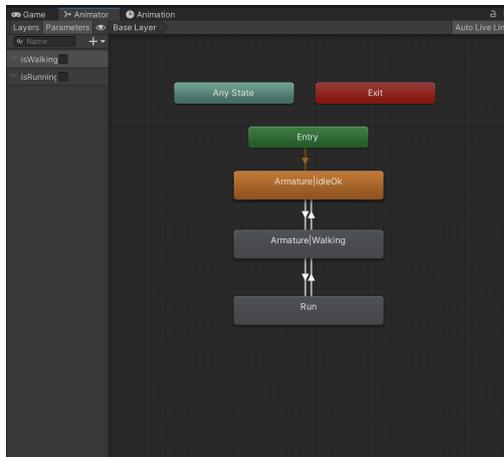
(b) Animator window

Figure 4.10: Two additional Unity windows

4.2.2 Animation in Unity

Unity have several features to facilitate the creation and management of animations. The engine provides an easy way to setup animations for all elements in the project.

It not only supports animations created in Unity, in fact it is possible to import animation generated in other software, such as Blender, with the FBX format. Another useful Unity animation feature is the retargeting, in this way it is possible to apply animation from an object to another, even on human animations. In addition, users can visualize previews for the single animation clip, for the transition and finally the interactions among animations.

An important element for animation in Unity is the Animation controller that permits to maintain and manage a collection of animation clips related to an object. The creation of transitions in animation controller is possible through the State Machine, thanks to this element the developer can trigger an animation after a specific event. In particular there are states, transitions and action: when a certain condition occurs, one will enter a given state (shown in point 1 in Figure 4.11), for each state an action coincides and the shift from one state to another corresponds to a transaction(shown in point 2 in Figure 4.11). States can have more one incoming and outgoing transitions.
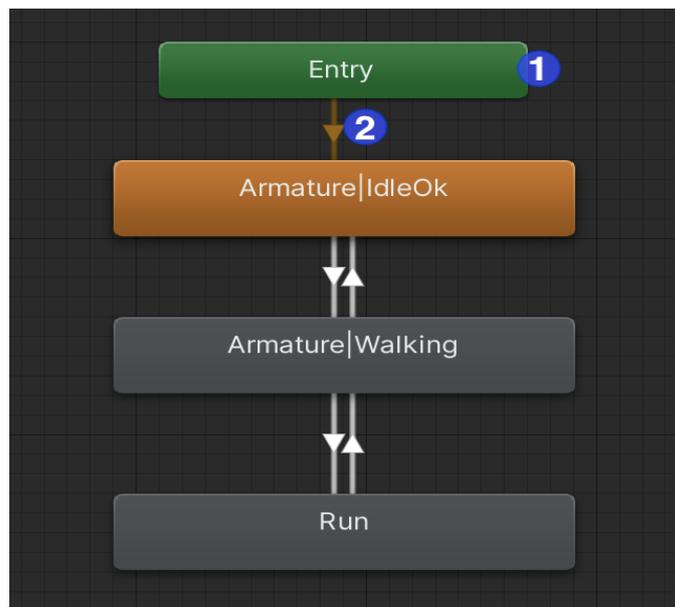
Figure 4.11: State machine

4.2.3   Input Action

In play mode, to trigger an action users usually have to give an input signal, so they have to bind an certain input to an action. The Input Action is a new system in charge of this task, it is downloadable from package manager, in fact Unity uses another tool by default, the Input Manager. An important benefit of the input action is the separation between the input device and the action code, therefore

the developer should not care about the device used, but only about implementing the actions, as distinct from the Input Manager. The new system provides an Action Editor that facilitates control binding and management of actions through a window, the latter is made up of 3 sections:

- **(1)Action Maps:** each action maps have a proper set of actions with their properties.

- **(2)Actions:** is a list of actions associated whit an action map and each action have a list of bindings[6]

- **(3)Action properties:** permits to edit action and binding properties.
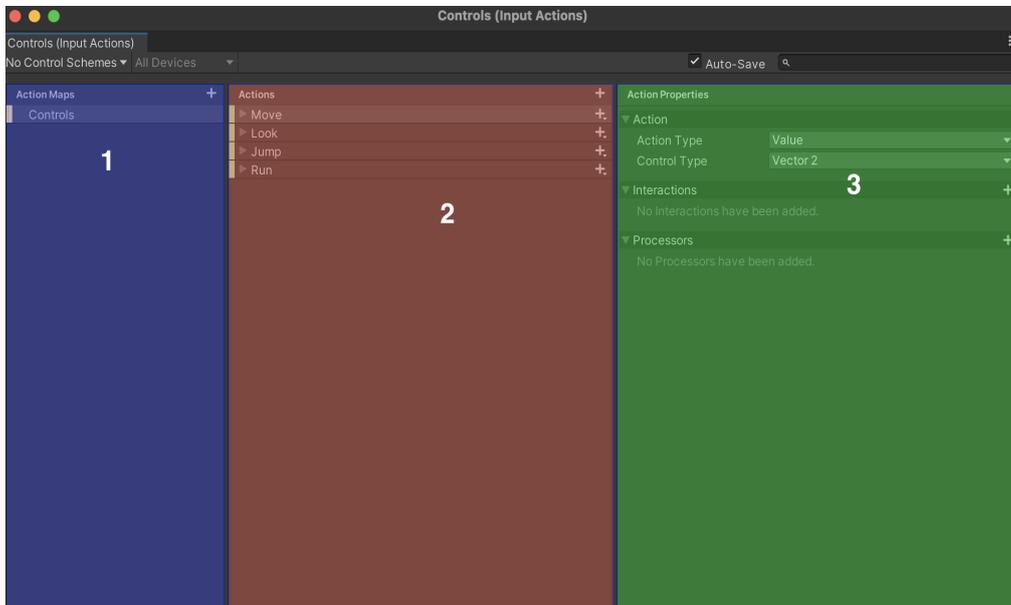
Figure 4.12: Input action

4.2.4 Scripting

In order to develop a project in Unity it is vital to use and create scripts that allow to enrich the application of functionality. Scripting is fundamental to control every aspect. Unity is native C# language programming and the base and most used class is MonoBehaviour, its use is fundamental when scripts are involved in Unity life cycle events. Scripts can be attached to GameObjects, these describes fundamental

---

[6]is the mapping between an input device and an action

objects in Unity and they can be composed of several components that allow you to control their behavior. Unity provides two important functions that are always present when a new script is created: Update and Start. The Update function is called at each frame to manage updates, so it can be useful when developers want to keep a certain state under control. The Start function is called at the beginning of the execution before any other function, even before the Update. When a script in Unity is created, it will appear as shown below.

```csharp
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class NewBehaviourScript : MonoBehaviour
{
    // Start is called before the first frame update
    void Start()
    {

    }

    // Update is called once per frame
    void Update()
    {

    }
}
```

4.3   Overview from Blender to Unity

In order to ensure a better understanding, it is possible to dwell on describing the relationship between the technologies used in the realisation of the project. As shown in the figure 4.13, the first step is the creation of models and materials using Blender. As has already been analysed in this chapter, the software allows to create any type of 3D objects, allowing users to animate and texturise it to their liking; once completed the work within Blender, it is possible to export the elements of the project in different formats, the one supported by Unity is the FBX format. Now it is possible to import these files within the project into Unity, to have the models with their materials loaded correctly within the project, it is important to also import the JPG files created within Blender when using the Shading editor. Finally, Unity automatically imports C# scripts that are created using the VisualStudio development environment.
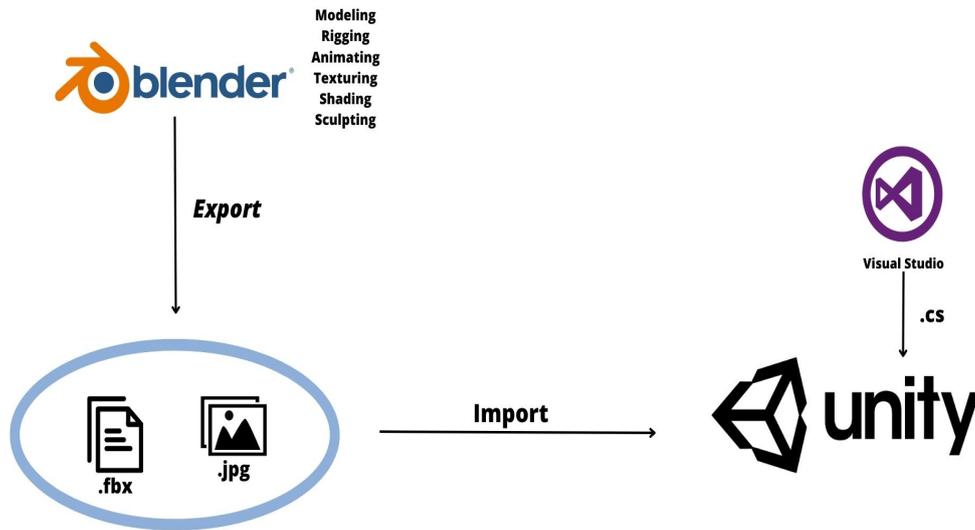
Figure 4.13: Relationship between the technologies used

4.4 HTC Vive

The project aims to analyze the effectiveness of immersive and non-immersive virtual reality in the therapeutic field, these two types guarantee patient involvement in a completely different way. For the development of an application in immersive reality is used a particular viewer called head-mounted display, that is a helmet with a screen that can immerse the user in a virtual environment. The hardware technology used in this project is the HTC VIVE, this device is not only equipped with optical viewer but converts the surrounding environment into a 3D space where the user can move almost freely using "room scale" technology, so if the user moves in the real world then the shift will also be replicated in the virtual environment. This device can track and map user movements through the use of two or more sensors that are placed inside the room. In the figure 4.14 the input and output components are used for the correct use of the HTC VIVE: circled in green there is the viewer; the controllers inside the red circles; finally the sensors, called basestation, are circled in blue.

4.5 Conclusion

Unity is a powerful software for development application. It provides numerous services to implement all the features desired and enable importation file from

Figure 4.14: HTC VIVE

another source, such as animations, audio tracks, scripts and so on. This allows developers to split individual tasks who can create and edit each element in a dedicated software and then import results into Unity. For example, being an application development software, it is not efficient in creating complex animations despite providing the tools to do so. In this regard, Blender is used, which provides more effective tools for the realization of animations, also this software allows users to create models of all kinds paying great attention to detail.

Chapter 5

Design and development of the project

The project aims to immerse the user in a virtual experience with the objective of defining his or her identity. It is possible to define the structure of the project as a client-server application. In fact, when users choose to perform facial analysis to create their avatar, the Unity application sends a message to the python script, which acts as a server, and starts communication. The server will activate the webcam and once the photo has been taken, it will perform a facial analysis.

In order to better understand the execution of the application, figure 5.1 illustrates the application pipeline.
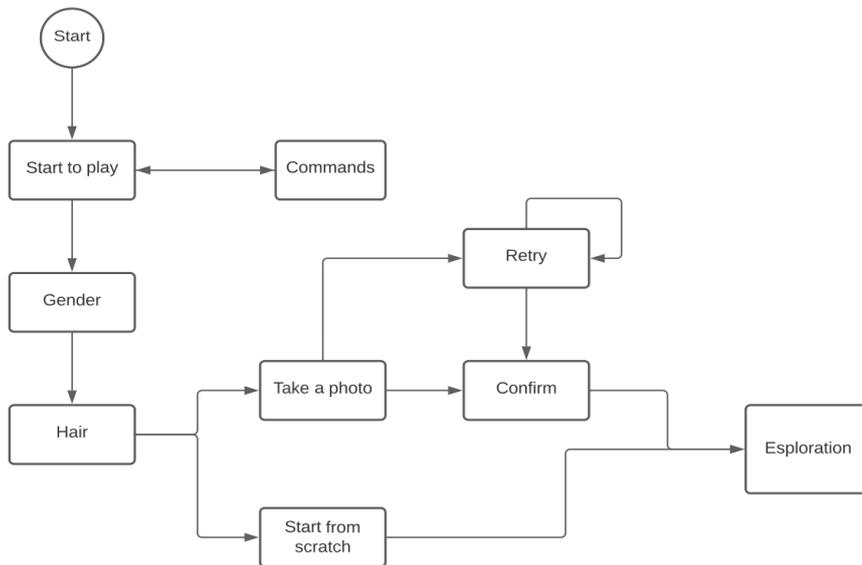

Figure 5.1: Application pipeline

5.1   Requirements

In order to make the experience as pleasant as possible, the commands and functionalities within the application must be easy for the user to understand. To this end, it is important to determine a section where the game commands can be consulted and, above all, to ensure smooth access to the customisation menus. Another important element is visual feedback; when a user selects a change, the avatar should immediately update with the selected change; furthermore, since it is possible to make customisations by interacting with objects within the virtual environment, visual feedback confirming the interaction is also important. Finally, in order to simplify the search for objects, the implementation of a searchable map and auditory feedback suggesting proximity to an interactive element is important. Before delving into implementation, it is important to first outline what is needed in order to customise and create unique virtual avatars. In order to develop a comprehensive and engaging avatar configurator, it is necessary to define a set of functional requirements that can serve the purpose of the project, thus support therapy, and offer a personalised and intuitive experience. Some basic requirements are listed below:

1. **Define the customisation of basic characteristics:** The project should allow users to select the basic characteristics of their avatar, such as gender, age, skin colour. This allows users to create an avatar that reflects their preferences and identity.

2. **Define the customisation of facial features** Users should be able to modify the facial features of the avatar, such as face shape, eyebrows, nose, mouth, ears. Providing variety of customisation options should ensure a wide range of creative possibilities.

3. **Define body modifications** The project should allow users to modify the body of the avatar, such as height, weight, physical structure. This customisation helps to create avatars that are unique and representative of the user.

4. **Allowing the user to choose the appearance** Users should be able to choose haircuts, colours and accessories.

5. **Allowing the user to explore the environment** In order to make the experience more immersive, the user must be able to visit the virtual environment.

6. **Allowing the user to interact with objects in the virtual world** The user must be able to interact with objects within the virtual environment and be able to perform actions accordingly.

5.2   Application phases

To better understand the structure of the application, it's possible to define three phases. The first phase concerns the start of the application, which will see the initial menu where, as shown in the figure 5.2, users will have the option to select the command menu or to start playing immediately. The command menu shows the various actions that the user can perform during the game. The second stage
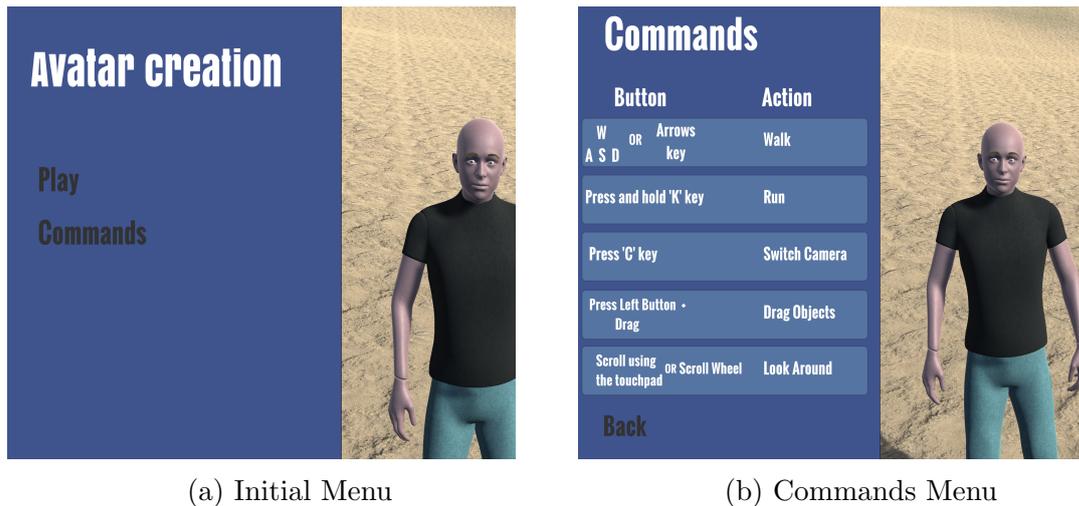
(a) Initial Menu

(b) Commands Menu

Figure 5.2: First phase

involves selecting the initial characteristics of one's avatar; gender and hairstyle are user-selectable. Other characteristics can be added at this preliminary stage by choosing to take a photo, otherwise they can be changed later during the virtual experience. Taking the photo contacts the server to perform an analysis of certain facial characteristics. The server can recognise age, eye colour, ethnicity, the possible presence of a beard and even glasses; furthermore, it may happen that the facial analysis is not entirely correct or even fails, so the user can decide to take the photo again or continue with the modifications made by the server. After choosing whether to take the photo or create one's own avatar from scratch, the virtual experience begins.

The third and final stage allows users to control the avatar to explore the virtual island and customise their character. The avatar can be customised through the three menus available during the game: the first concerns the customisation of the face; the second the hair, eyebrows and eyes; the third the body. Another way to carry out customisation is to drag the equipable items found within the island onto the avatar. To simplify the search for the draggable items, there is a map indicating the location of each item that can be equipped and, in addition, when the avatar is close to a draggable item, users can hear a proximity sound to simplify the search.

(a) Gender Menu

(b) Hair Menu

(c) Initial customization menu
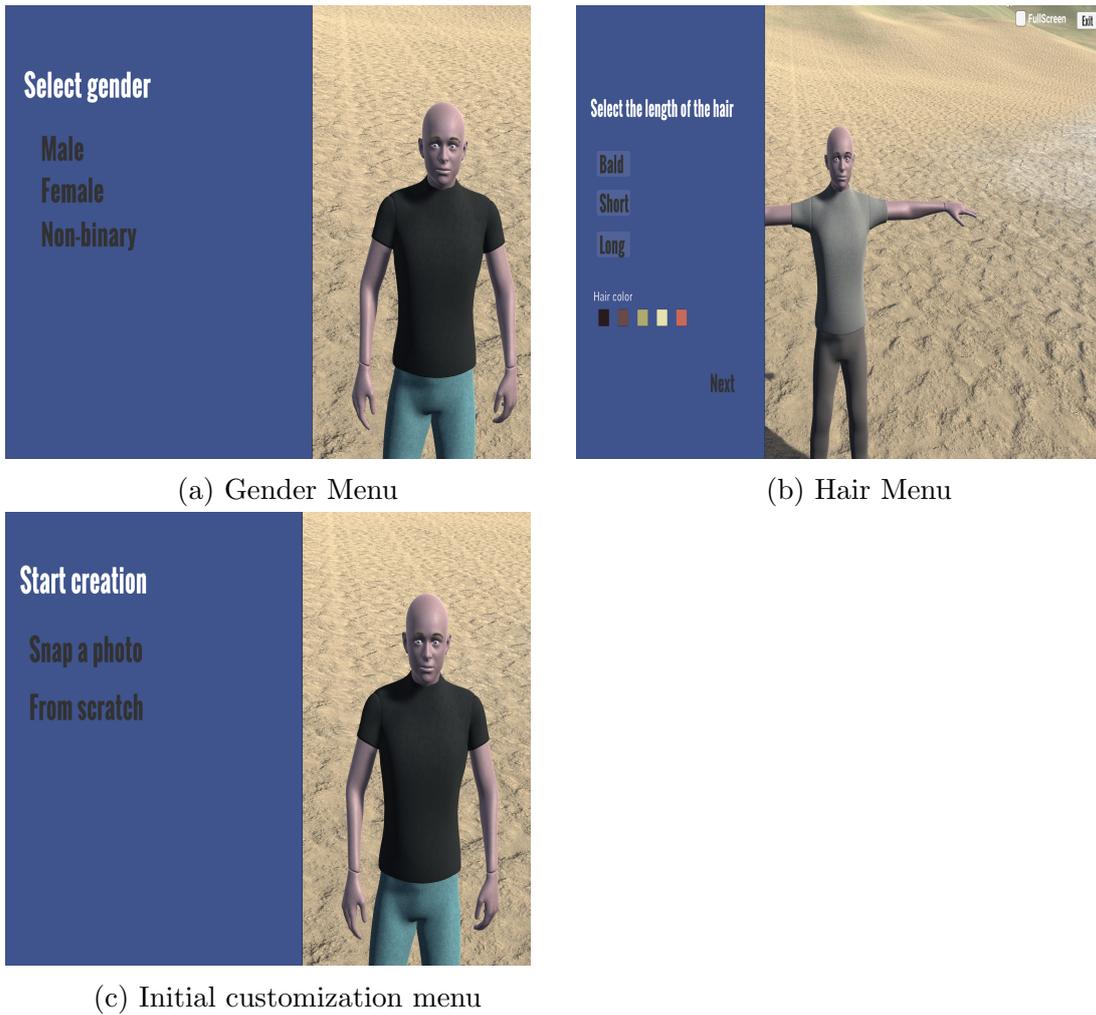
Figure 5.3: Second phase: Initial customization

5.3 Development of the application

Now let's analyze in detail the various steps that allowed the realization of the application.

5.3.1 Implementation of functionality

Avatar customization

The purpose of the application is to allow users to create their own avatar within their adventure on the virtual island. The first step in the development of the project was the implementation of all the functionalities that allow the customisation of the virtual self. There are two ways to do this, one of which is the dragging

(a) Failed facial analysis

(b) Retry analysis
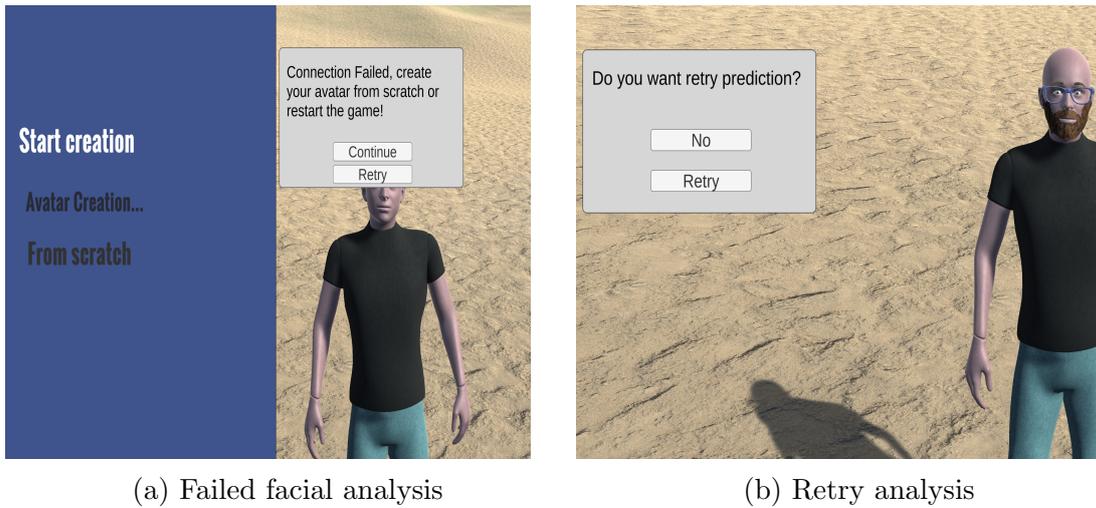
Figure 5.4: Facial analysis behaviour

Figure 5.5: Exploration of the island

of objects to the avatar. Users can activate dragging by holding down the left mouse button and releasing it once the left button has been pressed. Each GameObject can be assigned a Tag and a Layer in Unity through the Inspector window; this can be useful for assigning the same feature to a group of objects. As can be seen from the code below, all GameObjects that can be dragged within the virtual environment are part of the 'Draggable' Layer; without this feature, it is not possible to move objects within the application.

```
1 private void MousePressed(InputAction.CallbackContext context)
2 {
3         Ray ray = mainCamera.ScreenPointToRay(Mouse.current.
            position.ReadValue());
4
5         RaycastHit hit;
6
7         if (Physics.Raycast(ray, out hit))
8         {
9             if (hit.collider != null && ( hit.collider.
                gameObject.layer == LayerMask.NameToLayer("
                Draggable")))
10            {
11                StartCoroutine(DragUpdate(hit.collider.
                    gameObject));
12            }
13        }
14 }
```

The Tag was instead used to identify the type of object, for example, as it is possible to see in the figure 5.6, we have a GameObject of Layer 'Draggable' and with Tag type 'Beard', if the user were to drag this element toward avatar then that particular object would be equipped. Unfortunately it is not enough just the use of Tags and Layers to enable this type of functionality, in fact it is important that Unity recognizes when an object is dragged to the avatar. To do this, all draggable objects must have the RigidBody component, whereas the avatar must have the BoxCollider with the isTrigger property set to true, which is called with the OnTriggerEnter method when a rigid body enters and OnTriggerExit when a rigid body exits.
The second way of customization is through the edit menus 5.7.

During the game session, users can decide to change the characteristics of their avatar by selecting the panels on the left one at a time. The first mainly concerns facial characteristics (figure 5.7a); the second allows the user to modify hair, eyebrows and eye colour (figure 5.7b); the third concerns body characteristics (figure 5.7c). Two Unity objects were mainly used to customise the avatar's body parts:

- The first concerns the selection of a Unity button, usually with an image component showing the type of modification that can be made. For example, this method is used to choose the shape of the face: there are several panels and each one shows an image representing a certain type of face that can be chosen, so that users can select the element they prefer for their avatar.

- Also in the first menu it is possible to see that the age of the avatar can be changed making the latter more or less old. In this case the change is made using a Slider, it is an interactive object and has a maximum and a minimum value. In the case of age, if users change the value of the slider
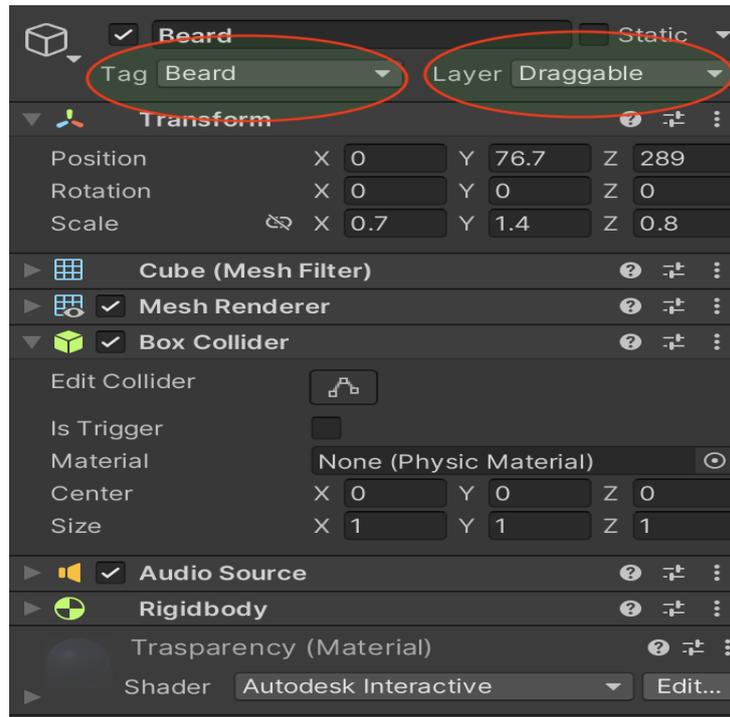
Figure 5.6: Example of an item that can be fitted.
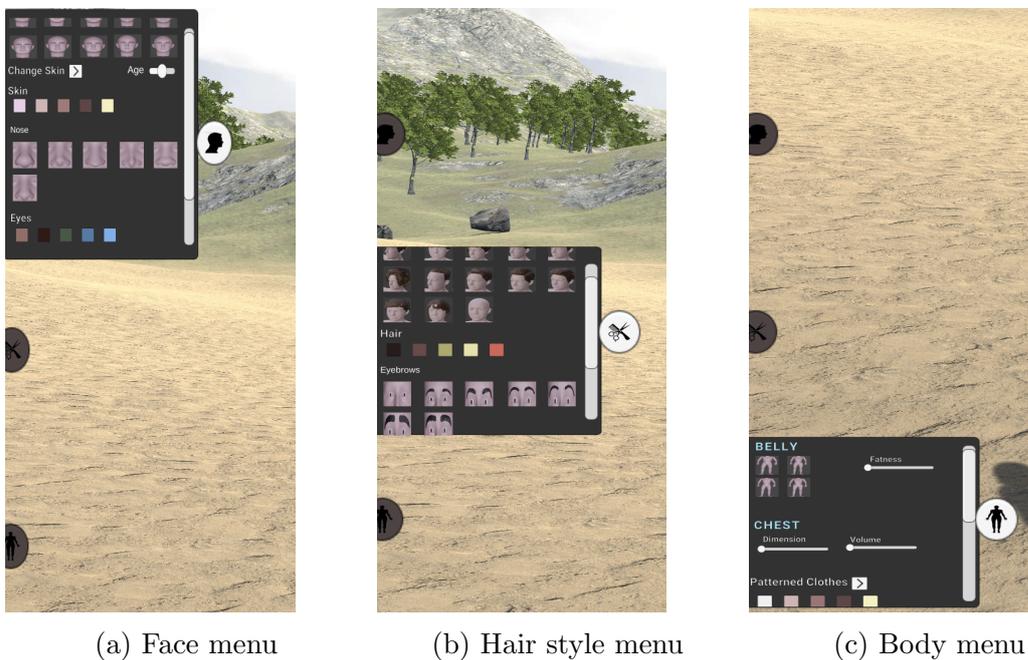
(a) Face menu   (b) Hair style menu   (c) Body menu

Figure 5.7: Customization menu

to the minimum, the avatar will assume the appearance of a child; on the contrary, it will assume the appearance of an elderly person; finally, half an adult. Mainly the Slider is used for the modification of some parts of the body, such as the weight. The higher the slider, the heavier avatar will be; if the value decreases then the avatar will be slender. In this case each change in value will have a weight change.

Cameras

Another important aspect is related to the cameras, in the application there are 4 types: one take the avatar from behind; the second take the face and is activated when the user customizes the avatar through menu; the third takes the entire avatar showing both the face and the body and can be selected by the user through input; the fourth is used for the creation of the minimap. The most important requirement of the cameras is that they must follow the character, so they are never static. To do this Unity makes available in the Unity Package Manager the Cinemachine, is a built-in suite of camera tools, is an integrated suite of camera tools and allows, without adding code, to implement which object the camera should follow. In addition users can change the priority of the camera, this allows them to activate only the camera with higher priority: for example, in figure 5.5 there is the camera 'CMBehind' active that takes the avatar from behind, so in this case it has in the Cinemachine component the value of priority equal to 10, all the other cameras instead have this value equal to 0. The figure 5.8 shows the priority values of the three cameras in the previous example, also in the same figure, besides the Priority and Follow variables, there is also LookAt, this is used to orient the camera frame towards the selected object. Finally an additional camera is used for the minimap, this allows the users to see the location of the avatar within the virtual environment and also the objects that they can drag. This camera frames the whole island from above and show only object icons.

Avatar actions

During the game, the user has the possibility of moving the avatar to go in search of objects to equip; to do this, the Input action, already described in the previous chapter, was used, which allows to map the code that implements an action with a given input while keeping these two aspects distinct. The actions that the character can perform are walking, running and the ability to turn around. Once the input types for each action have been defined in the Input Action, the latter can be added as a component to a GameObject and finally associate each created action with the corresponding code, e.g. walking. Below it's possible to see the script CharacterController in which there are the actions implemented:

```
1 public class ControlsCharacter : MonoBehaviour
```
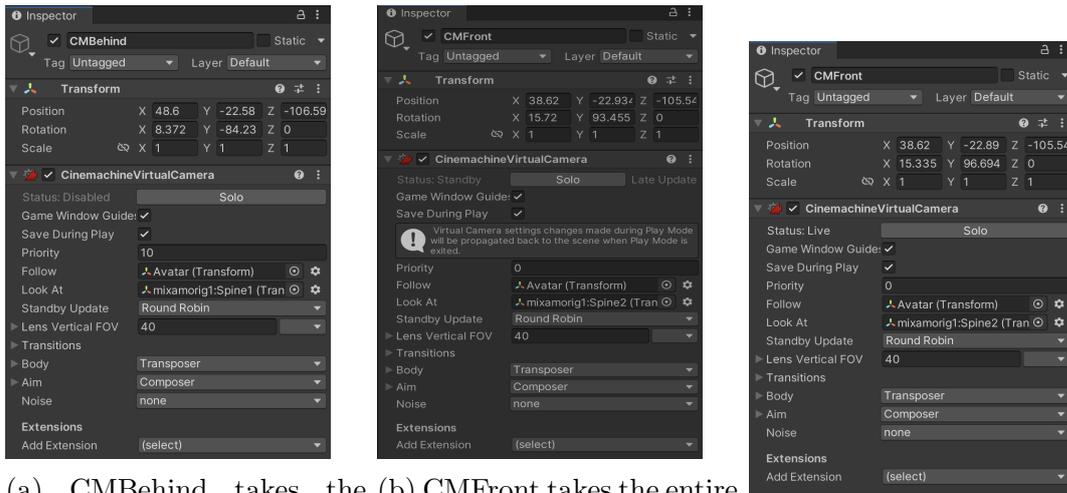
(a) CMBehind takes the avatar from behind

(b) CMFront takes the entire avatar

(c) CMHead takes the face

Figure 5.8: Cinamchine
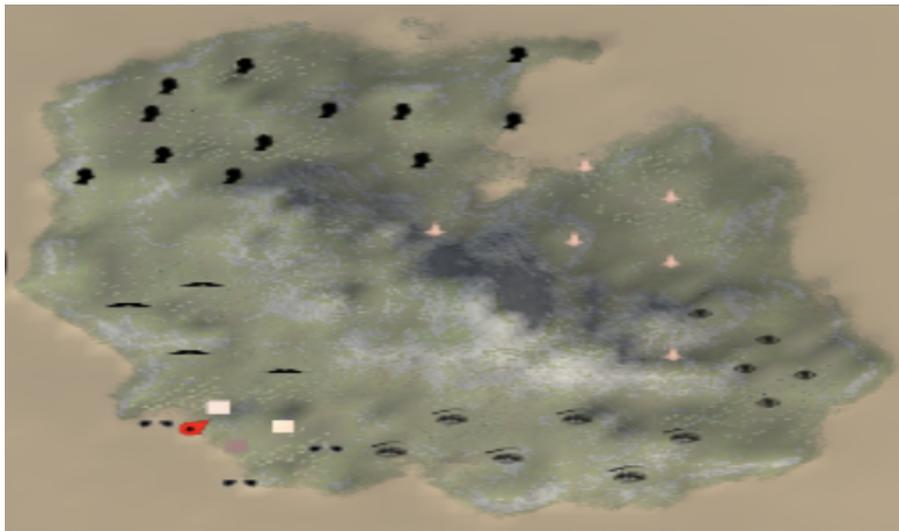
Figure 5.9: Minimap

```
2   {
3       [SerializeField] private float moveSpeed = 5;
4       [SerializeField] private float jumpHeight = 10;
5       [SerializeField] private float gravity = 9.81f;
6       [SerializeField] private float lookSensitivity = 5;
7
8       private Vector2 moveVector;
9       private float verticalVelocity;
10      private Animator animator;
11      private Vector2 lookVector;
```

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```
12      private Vector3 rotation;

13

14      private CharacterController characterController;

15

16      // Start is called before the first frame update
17      void Start()
18      {
19          characterController = GetComponent<CharacterController
                >();
20          animator = GetComponent<Animator>();
21      }

22

23      // Update is called once per frame
24      void Update()
25      {

26

27          Move();
28          Rotate();

29

30      }

31

32      public void OnMove(InputAction.CallbackContext context)
33      {
34          moveVector = context.ReadValue<Vector2>();
35          if (moveVector.magnitude > 0)
36          {
37              animator.SetBool("isWalking", true);
38          }
39          else
40          {
41              animator.SetBool("isWalking", false);
42          }
43      }

44

45      private void Move()
46      {
47          verticalVelocity += -gravity * Time.deltaTime;

48

49          if (characterController.isGrounded && verticalVelocity
                <0)
50          {
51              verticalVelocity = -0.1f*gravity*Time.deltaTime;
52          }

53

54          Vector3 move = transform.right * moveVector.x +
                transform.forward * moveVector.y + transform.up*
                verticalVelocity;
55          characterController.Move(move * moveSpeed * Time.
                deltaTime);
56      }
```

64

```
57
58      public void OnRun(InputAction.CallbackContext context)
59      {
60          if (moveVector.magnitude > 0 && Input.GetKey(KeyCode.K))
61          {
62              animator.SetBool("isRunning", true);
63              moveSpeed = 8;
64          }
65          else
66          {
67              moveSpeed = 5;
68              animator.SetBool("isRunning", false);
69          }
70      }
71
72      public void OnLook(InputAction.CallbackContext context)
73          {
74              lookVector = context.ReadValue<Vector2>();
75          }
76
77      private void Rotate()
78          {
79              rotation.y += lookVector.x * lookSensitivity * Time.
                    deltaTime;
80              transform.localEulerAngles = rotation;
81          }
82 }
```

Python server

As it was shown at the beginning of the chapter, the user can decide whether to create the avatar from scratch and start the exploration immediately or can leave the application the possibility to configure some features of the face by selecting the 'Taking a Photo' option. In this case the application in Unity will put in communication with a python application that acts as a server. The latter, received the message from the client to initiate communication, activate the webcam and wait for the user to take the photo. Once the image is captured the server will capture the area where the face is present and perform an analysis of the facial characteristics, in particular will be analyzed: the color of the eyes, the presence of beard, ethnicity, gender, whether wearing glasses and an age estimate. For the analysis results to be as correct as possible it is important that the photo is taken in a well-lit environment and with a white background. Within the server application there is a class that implements all the features needed to create a UDP communication. Messages are received and sent in byte type, once the recipient receives data they are converted to string type. Below are shown two methods that allow first the reception and then the data conversion. The 'ReadUdpThreadFunc'

method is automatically invoked by the thread and waits to receive data, once it is received call the 'ReceiveData' method which, if possible, converts data from bytes to strings.

```python
def ReceiveData(self):

    if not self.enableRX:
        raise ValueError("Attempting to receive data without
            enabling this setting. Ensure this is enabled
            from the constructor")

    data = None
    try:
        data, _ = self.udpSock.recvfrom(1024)
        data = data.decode('utf-8')
    except WindowsError as e:
        if e.winerror == 10054:
            if not self.suppressWarnings:
                print("Are You connected to the other
                    application? Connect to it!")
            else:
                pass
        else:
            raise ValueError("Unexpected Error. Are you sure
                that the received data can be converted to a
                string")

    return data

def ReadUdpThreadFunc(self):

    self.isDataReceived = False # Initially nothing received

    while True:
        data = self.ReceiveData()
        self.dataRX = data
        self.isDataReceived = True
```

The main class, in addition to calling the script that implements the communication between server and client, makes use of other very important classes that concern the analysis of facial attributes. One tool that has been very useful for this purpose is deepface, a framework designed for facial recognition and for the analysis of some attributes, such as age, gender and ethnicity, using a few lines of code.

```python
from deepface import DeepFace
import cv2
import matplotlib.pyplot as plt

def prediction(img_path):
```

66

```
6
7       img = cv2.imread(img_path)
8       plt.imshow(img[:, :, ::-1])
9
10      demography = DeepFace.analyze(img_path, actions=('age', '
            gender', 'race'))
11
12      age = demography[0]['age']
13      race = demography[0]['dominant_race']
14      gender = demography[0]['dominant_gender']
15
16      return age, gender, race
```

5.3.2   Model development

For the configuration of avatars, it is essential to use different templates that can be selected by the user to create their own virtual representation. The starting models for the realization of the avatar and the animations were downloaded from the site of Mixamo[1], a company of 3D computer graphics technology that provides a large number of rigged characters and animations created by them. Starting from
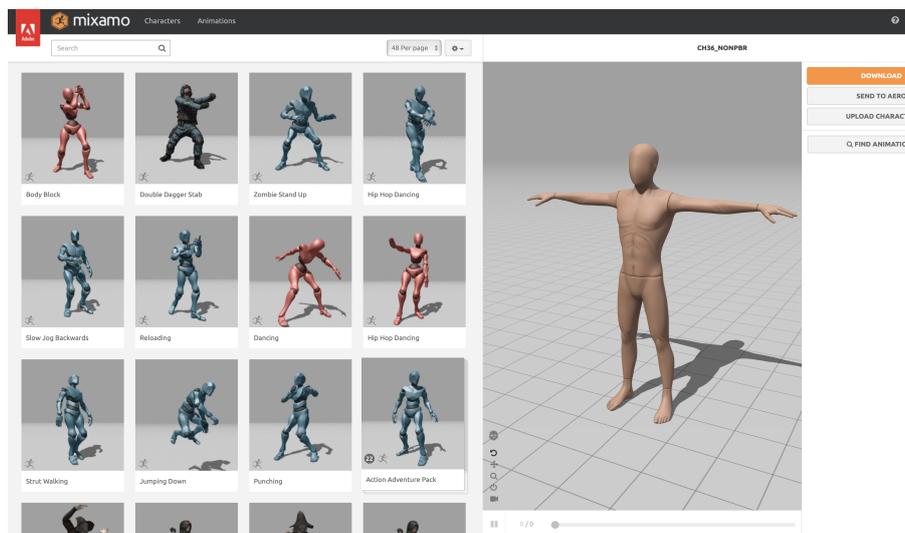

Figure 5.10: Mixamo

these models, they have been modified, modelled and sculpted in order to obtain different elements that can be selected within the application, an example of this kind concerns the user's ability to select the shape of the head, wrinkles and so

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

on. Avatar animations and armature were also imported from Mixamo and then modified. Once added to the scene in Blender, bones were added to the armor in order to be used in the final application to implement some customization features, such as the 'Belly' bone connected to the mesh in the abdomen area, figure 5.11. This allows to deform the size of the belly by changing only the properties of the bone in question. Once imported the avatar rigged in Unity, can be added to 'Belly'
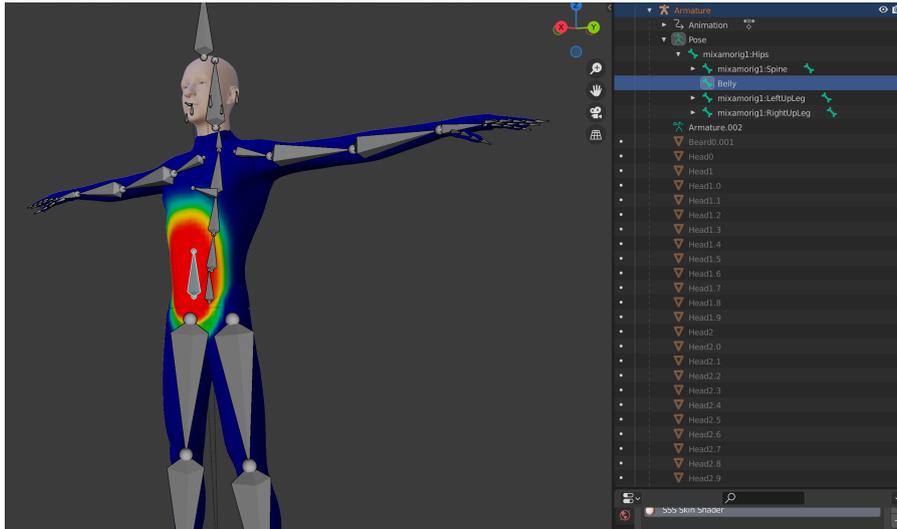

Figure 5.11: Belly bone

a script that allows users to change the properties of the bone to vary the value of the associated slider: this way when the user changes the value of the slider to the minimum, this will deform the bone giving the avatar a slimmer look, on the contrary changing the value of the slider to the maximum the avatar will tend to be increasingly fat.

In addition to modelling, Blender has been fundamental for the creation of materials, they have the purpose of defining the appearance of the elements in the scene. A very useful add-on that has been used for project development within this engine is BlenderKit. Once installed, a search bar will appear within the scene that allows to have models, materials and more ready to be used (figure 5.13).

5.3.3 Final stage

After the necessary features have been implemented, the animations and created the various parts of the body that will allow the users to create their own avatar, it is possible to import everything on the project in Unity. To import files from Blender

(a) Skinny avatar   (b) Fat avatar

Figure 5.12: Slider modification

Figure 5.13: Selection of materials from the BlenderKit add-on

to Unity you can use the FBX[2] format or .blend, the native Blender format. In case there are multiple templates within the Blender file, it is preferable to export them one by one using the format FBX, in fact, if the .blend files are imported directly, every time they are modified the project in Blender it will be modified within Unity

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[2]Filmobx is a type of 3D model file, it can be designed and modified in various modeling applications such as Blender and Unity

automatically. The final step is creating the environment, for the creation of the island were used several assets that provided ready-made models of vegetation, sea and islands.

5.4 Conversion to immersive Virtual Reality

Once the desktop application was implemented, the conversion was made to immersive virtual reality. To do this, packages have been installed in Unity that allow development through the use of immersive equipment.

5.4.1 VIVE setup

For this project was used the HTC VIVE, which as mentioned in the previous chapter guarantees us not only the visualization of the virtual environment but also the use of "room scale" technology. This device is not "stand alone", so for proper operation must communicate with other accessories that allow access to the use of VIVE, these elements must be placed inside the room and they are:

- The headset and the controllers;

- The link box, to interconnect computer and headset;

- Two base stations, they perform the tracking of move sensors on headset. The placement of the base stations affects the playing area, especially if the user chooses to move in the scenario and not remain motionless in a point.

5.4.2 Unity setup

Once all the components of the VIVE work properly and are connected to the computer, it possible to move inside Unity and continue the configuration to make it possible to implement the project in immersive virtual reality. The first step is to install XR plugin management by accessing the Unity window called Project Settings, this latter, as shown in figure 5.14, defines the settings of the project. After installation completes, it is possible to select a Plug-in Provider to enable it for the corresponding build target. Finally, to simplify the implementation, the package "XR interaction toolkit" can be installed from the Packet Manager window, it offers an high-level interaction system for creating VR application.
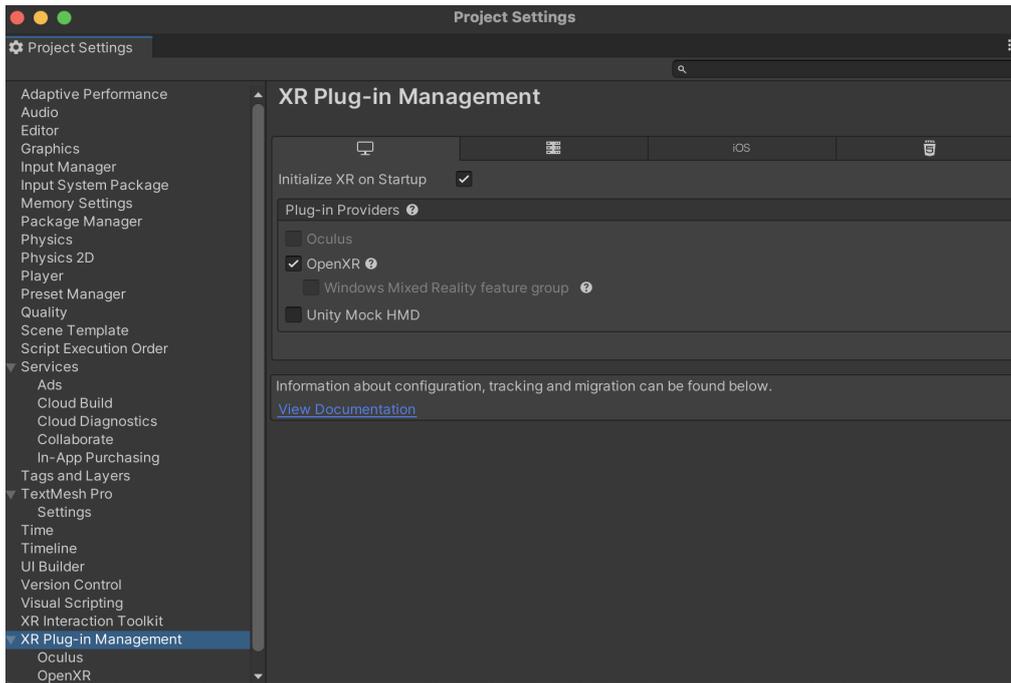
Figure 5.14: Project Settings window

5.4.3 Implementation and differences with the desktop application

The use of the package "XR interaction toolkit" allows users to have scripts and other components very useful for quick development of immersive application functionality, such as the ability to teleport from one point to another of the map, or the possibility of grabbing objects and much more. The interaction takes place through the use of VIVE controllers that are displayed inside the virtual environment as human hands that can be moved freely and that allow to interact with the surrounding objects as if they were real hands and also allow users to interact with the avatar customization menu. One of the main scripts is the "XR Origin", which permit to choose which GameObject to take the point of view within the experience and which camera to use. You can create a pre-configured GameObject by opening the Scene Inspector menu and selecting "XR Origin".

The conversion of the project from desktop to immersive virtual reality has produced different changes not only concerning the implementation of functionality, but also the interface underwent changes within the game such as the menu. The menu was implemented with the aim of being always present during the virtual experience, in fact users are able to make the menu appear at any time by pointing the palm of their left hand towards themselves, once it appears, they can interact with it using the index finger of their right hand. This functionality gives the

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(a) XR Origin scripts

(b) GameObject "XR Origin" selection from the Scene Inspector menu

Figure 5.15: XR Origin

impression of using a touch screen within the experience. Another different element
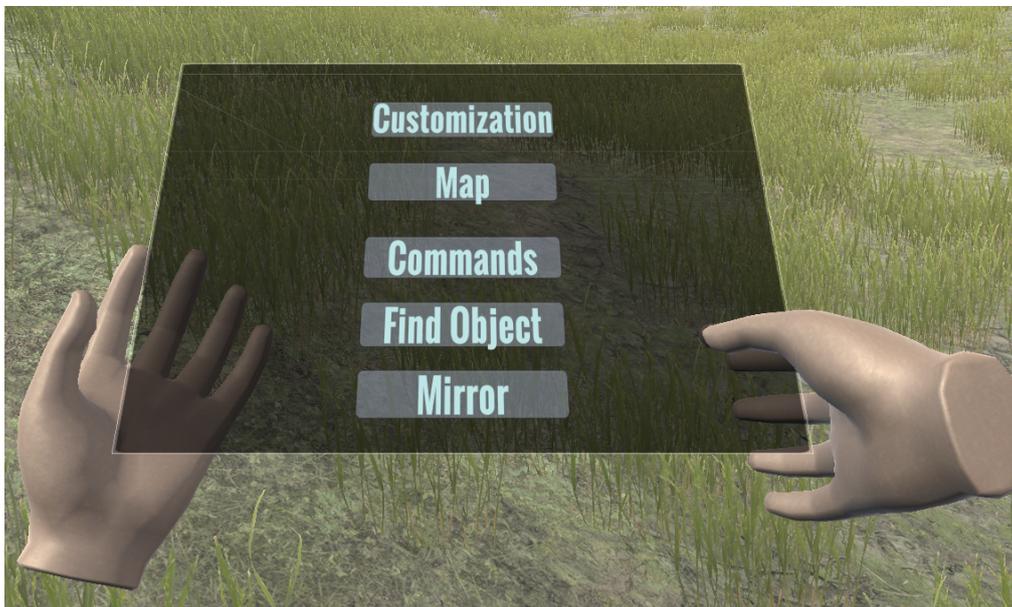
Figure 5.16: Customization menu in VR application

from the desktop application is the display of the avatar, Indeed, in this case it is not possible to use several cameras to obtain different views of the avatar. This

is because in immersive reality a first-person experience is simulated. Therefore, as in reality, it is possible to create a mirror in the scene to observe character. Furthermore, in the immersive virtual reality application, the possibility of pre-configuring the avatar using the sever written in Python was removed, because it proved impossible to implement a functionality that would allow the user's photo to be taken once the VIVE headset was worn.

With the development of an immersive virtual reality application that includes the ability to explore the surroundings, certain needs emerge, such as the need to move quickly from one point to another on the map. This is enabled by Teleporting, which allows the user to move quickly from one point to another without being forced to explore the entire environment by walking. In this project, teleportation has also been implemented via the game menu; in fact, you can select where you want to be teleported by interacting with the map (Figure 5.17).
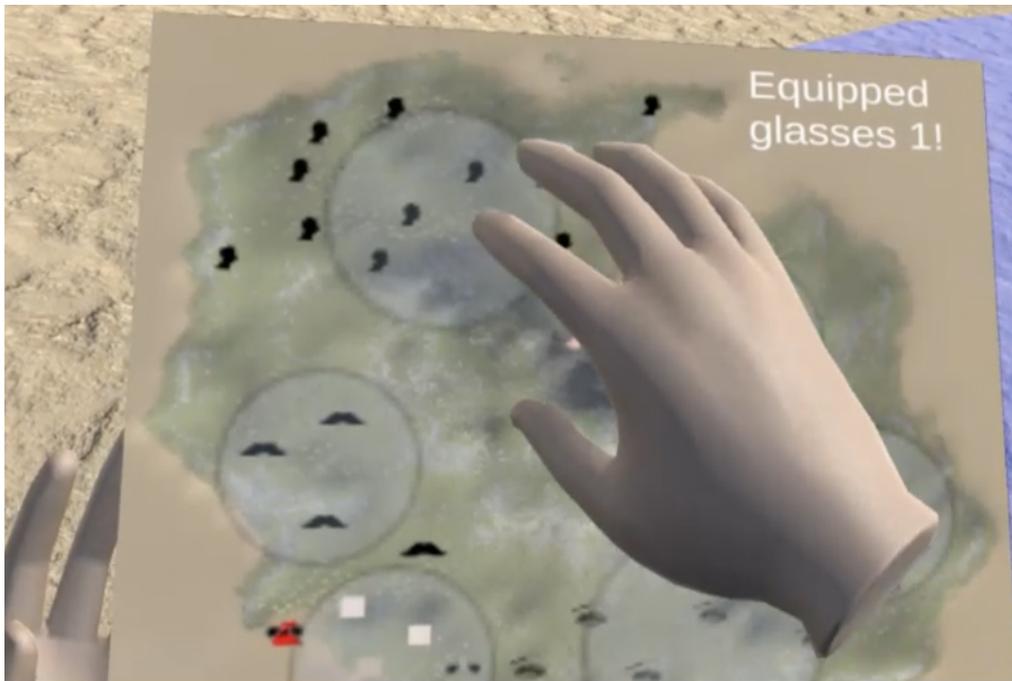

Figure 5.17: Teleport from the map

5.5 Tutorial

In order to make it clearer for the user to use the application, a small tutorial phase was implemented at the beginning of the experience. In both the desktop version and the immersive virtual reality version, the need was felt to add a short guide in order to make the use easier to understand. For example, in the case of the

application developed for the HTC VIVE, it might not be immediately intuitive to interact with the menu as one has to turn the palm of one's hand towards the camera. In the following figures 5.18 and 5.19 it is possible to observe some steps of the tutorial in desktop and immersive VR version of the application.

Figure 5.18: Tutorial on desktop application

Figure 5.19: Tutorial on immersive VR application

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Chapter 6

User test

Once the entire project and all the functionalities have been developed, moving on to the testing phase, the aim of which is to extract as much information as possible from the users who have been made to test the application in order to be able to find comprehensive answers to the research questions that emerged during section 1.5. To this end, the first thing to define is the nature of the test. After defining the questions to be answered, we move on to user research and finally to the analysis of the results obtained. This chapter will present the various steps just described in more detail.

6.1   Defining objectives

The aim of the project is to provide an effective tool in the hands of clinicians to understand any identity conflicts that may exist in an individual. To this end, a number of research questions can be defined in Chapter 1 to which one must be able to give comprehensive answers through testing. Therefore, the objectives that emerged are:

- **Understanding the usability of the application,** understanding how intuitive it is to use the different functions implemented in order to create one's own virtual representation.

- **Time spent customizing the avatar,** the user is able to modify their own virtual self by exploring the island or using the menu. For this reason it is interesting to understand if users prefer to fully enjoy the experience by visiting the island or prefer to go straight to the point using the menu.

- **Degree of immersivity,** how much the user has felt part of the virtual experience. In this case the difference of hardware between the desktop and virtual reality versions could be a relevant factor.

- **Degree of satisfaction,** that is how satisfying the customizations are available and how pleasant the experience.

6.2   Use cases

Two types of tests have been carried out:

Use case 1

The first test is primarily aimed at verifying the usability and the degree of involvement the application as a whole in its non-immersive version. Users will have to customise their virtual avatar through the use of the available features, so once the experience begins they can explore the island in search of items to collect and equip, but also use the menu to change the avatar's appearance. Users are free to perform any desired action within the application in its desktop version, i.e. using mouse and keyboard. Furthermore, this type of test is important to understand which approach to avatar customisation is adopted by users.

Use case 2

The second test allows the users to use the application in the immersive version. The tasks to be performed are the same as for the test#1, so users are required to create an avatar according to their preferences, but in this case through the use of the HTC VIVE. Once the application is launched, the user is able to immerse himself or herself in the virtual reality experience in a completely free manner. The aim is to see if there are any differences in the use of the application between the desktop and immersive versions.

6.3   Procedure

Tests are performed using a certain methodology:

1. The users are described the two types of tests and the reasons why they are proposed, then they are guided to the choice of one of the tests.

2. The user will be placed at the location where the hardware to be used for the test is present.

3. The user can run the tutorial which will make the use of the application clearer.

4. If the users asks for clarification or declares that they are in difficulty, explanations are given in order to guide the users to the correct execution of the test.

5. At the end of the test the users are subjected to a questionnaire, using Google Form, and some free questions.

6.4   Questionnaire

The questionnaire is divided into three parts: the first module deals with the user's personal information; the second module aims to understand the usability of the application and follows the SUS model, System Usability Scale[6]; finally, the last module focuses on the aspects of the application in order to understand the differences between the desktop and immersive version and also includes open questions. Modules includes multiple choice questions and statements for which the users have to express how much they agrees from 1 to 5. It is possible to see the modules in the appendix 7.1.

6.5   Participants

Of a total of 16 test persons, 11 underwent the first test and 5 the second. Of these, 62.5% were male, the remaining 37.5% female; the age range is between 20 and 60 years (M=30.27, SD=14.06). The graph in the figure 6.2 shows that the
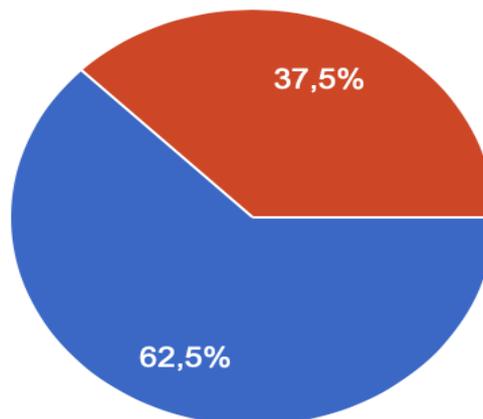

Figure 6.1: Age of users

educational level of the users is mainly divided between those who have obtained

a bachelor's degree and those who have obtained a diploma, and in a slight minority are those who have obtained a master's degree. As far as virtual reality
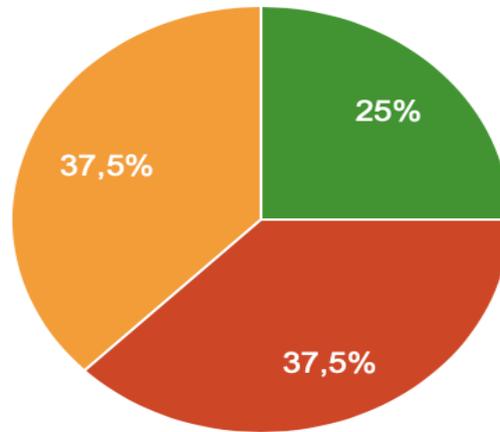

Figure 6.2: Level of instruction of users

is concerned, most are familiar with the subject (81.3%) and only 18.7% of users answered differently (6.3% know it by hearsay, 6.3% do not know the term and another 6.3% are not sure what virtual reality means). Of the 81.3% who knew the term, only 31.3% had experienced immersive virtual reality at least once, i.e. 5 out of 13 people. More generally, among all participants, only 31.4% had used an immersive reality tool, while the remaining 68.6% had never used this type of technology. Another relevant piece of information concerns the presence of visual impairments and pathologies that may impair the immersive and non-immersive virtual experience in some way. With regard to visual impairments, 12 out of 16 people suffer from myopia, i.e. 75% of the participants; approximately 25% suffer from stigmatism and another 25% have no visual impairment at all. Users had the possibility to select one or more options, so the sum of the number of subjects in the figure for each individual visual disturbance does not indicate the total number of users but only those suffering from that condition. Finally, a piece of information that may be important in the project analysis is the presence of one person who suffers from claustrophobia, one suffers from hypertension and another user has bilateral deafness.

6.6 Analysis of results

As discussed above, all users were subjected to the usability questionnaire, SUS. The statements to be evaluated in the SUS are thus distributed: the statements in
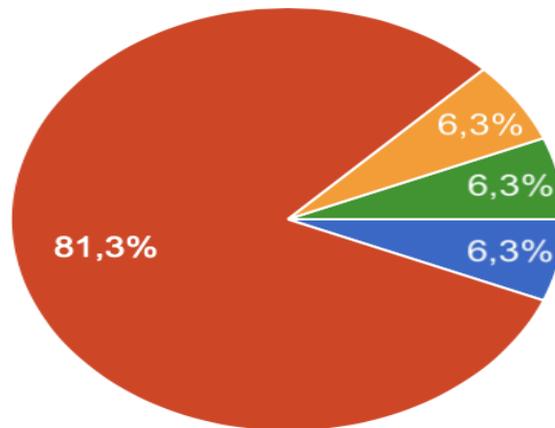
Figure 6.3: Knowledge of virtual reality: in orange are those who know the term only by hearsay; in green those who may know the term; in blue those who do not know the term at all; finally in red those who know the term
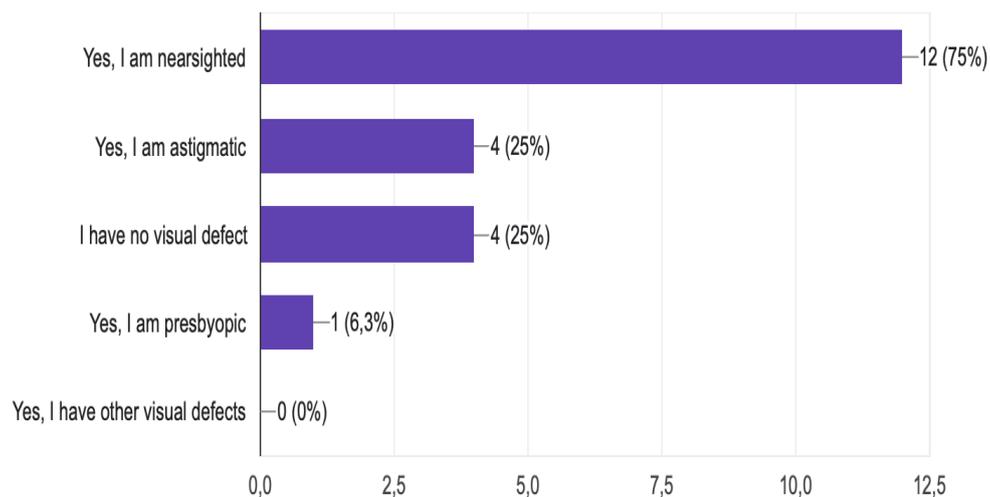

Figure 6.4: Type of visual disturbance

odd positions evaluate the good quality of the project, those in equal positions the bad quality. The data obtained are then processed in order to obtain a score from 0 to 100 that can suggest usability. In general, as can be seen from the graph in the figure 6.5, the project was rated as having good usability, obtaining an average score of 77.97 and also using standard deviation values, it is possible to state that it has a very low index of variation, 0.05 out of 1, pointing out that all values are very close to the average.. In addition, to have a clearer vision in figure it is possible to observe the average score for every statement: it can be seen as the average
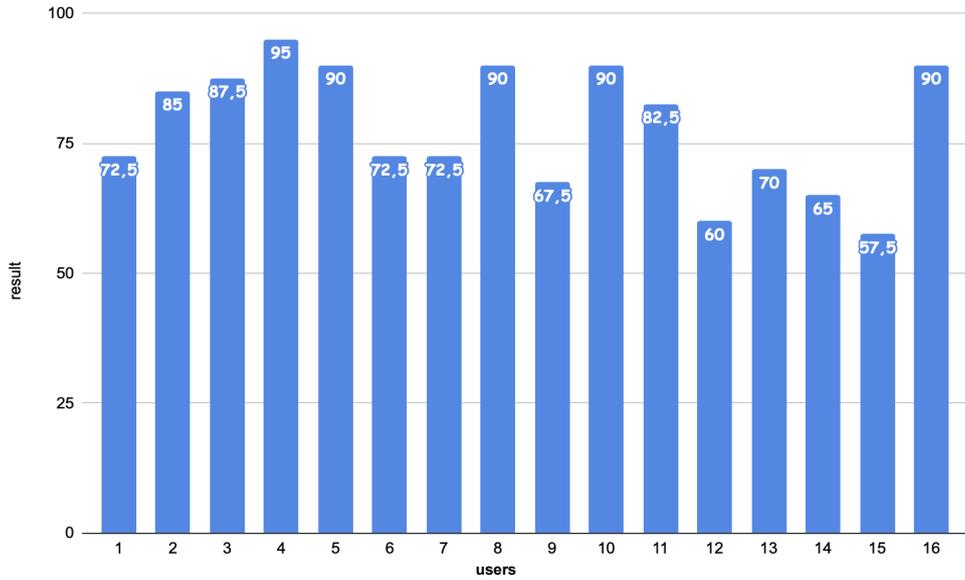
Figure 6.5: Usability

score for the odd answers is of 4.01; instead the odd affirmations maintain a score of 1.78. Specifically, a clear difference can be seen in the usability values between
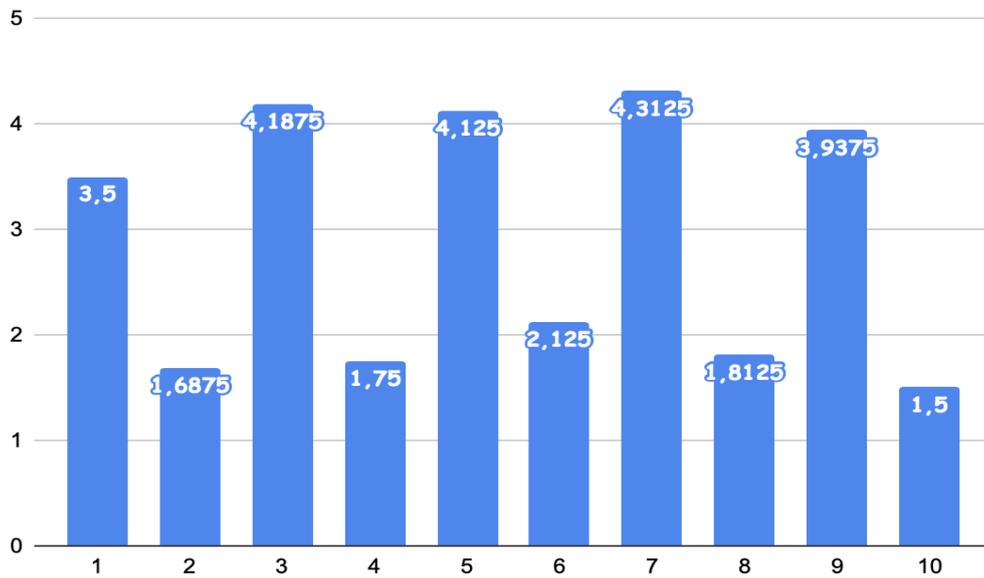

Figure 6.6: Average score for each statement

those who underwent the test#1 and those who underwent the test#2. The first test consisted of using the desktop application, and in the figure 6.7 is possible to

see that the usability results are rather high, arriving at an average usability value of 82.27. On the other hand, as far as the second test is concerned, which involved
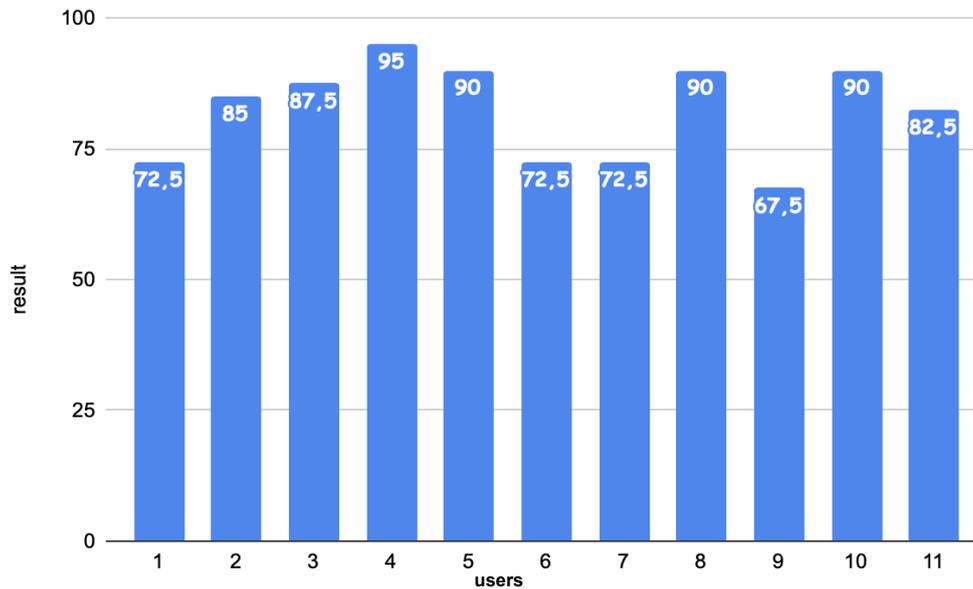

Figure 6.7: Usability desktop application

using the application in immersive virtual reality, the usability results obtained are decidedly inferior to those of test#1, arriving at an average usability value of 68.5 (see figure 6.8). However, by analysing data from a rather small sample of users, the average value may be unreliable. In fact, it is important to consider the variability of the sample that may differ depending on the group of users chosen to carry out the tests, which is why it is important to carry out tests that can make the reliability of the average values clear. In this case, the t-test was chosen because the distribution of the data can be defined normal, as can be seen from the boxplot in figures 6.9 and 6.10. The result of the test revealed a very low probability, of about 1.4%, so the difference in the averages between the desktop application and VR is very significant. This divergence of results can be found in some aspects of no small importance for the purpose of the project. The majority of the users who have carried out the test#1 already had familiarity with the technologies used, i.e. mouse and keyboard; to the contrary almost all of those who had undergone the test#2 had never used immersive virtual reality (4 users out of 5) devices experiencing difficulties in using, despite, as already specified in the section 6.3, all users before carrying out the test were given all the useful information in order to have a complete view of the project and adequate knowledge about the operation of the HTC VIVE. Furthermore, an element that was observed to be not immediately comprehensible was the selection of buttons using the index finger of the virtual hand: in fact, users initially found some difficulties in selecting buttons with this
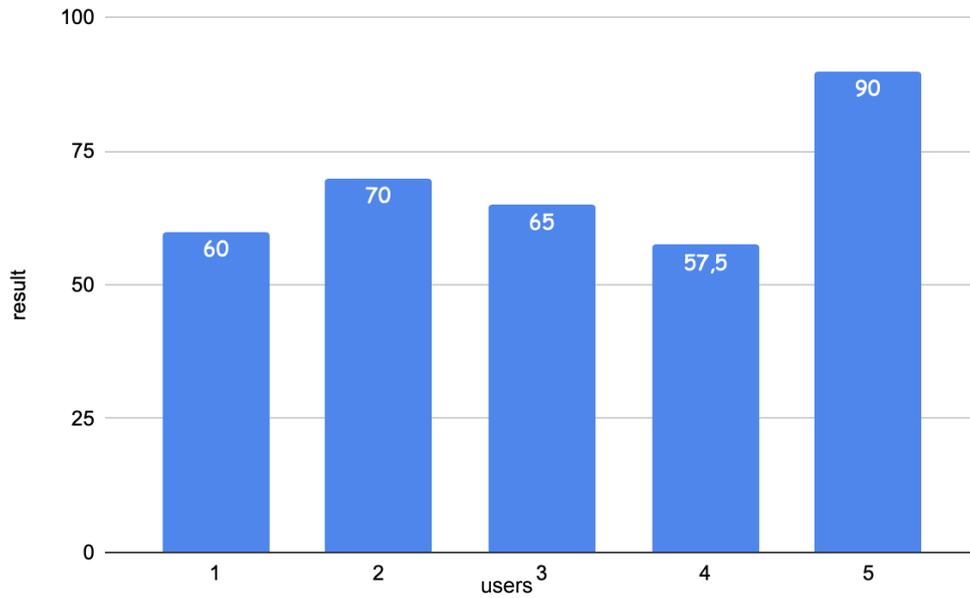
Figure 6.8: Usability immersive VR application
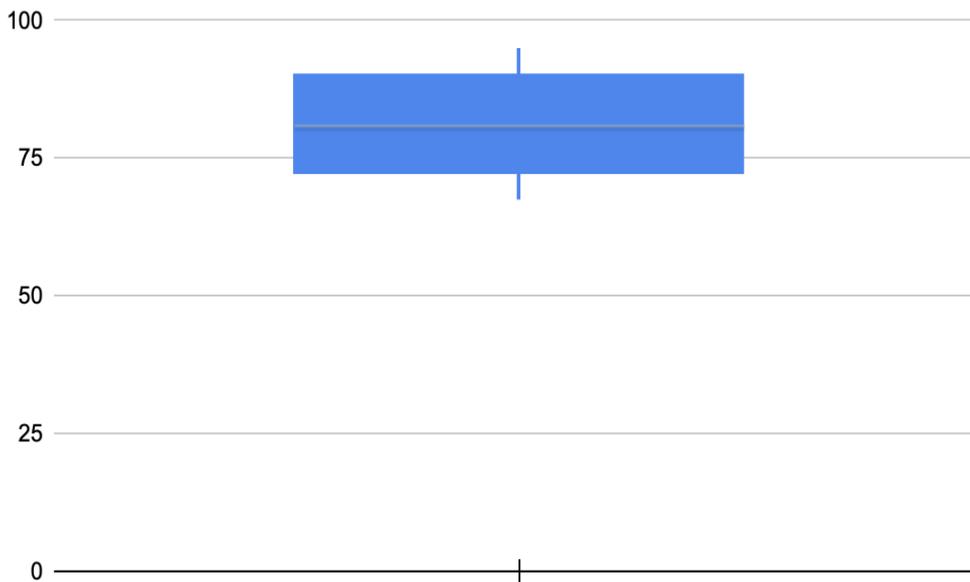
Figure 6.9: Boxplot desktop application

functionality, but after a few attempts, the problem was solved. In particular, this type of difficulty was only encountered in scrolling menus and not in static ones. Finally, another element that has determined this difference in usability concerns the motion sickness found using the HMD: in fact almost all the users subjected to the tests #1 and #2 have given a certain importance to the exploration of
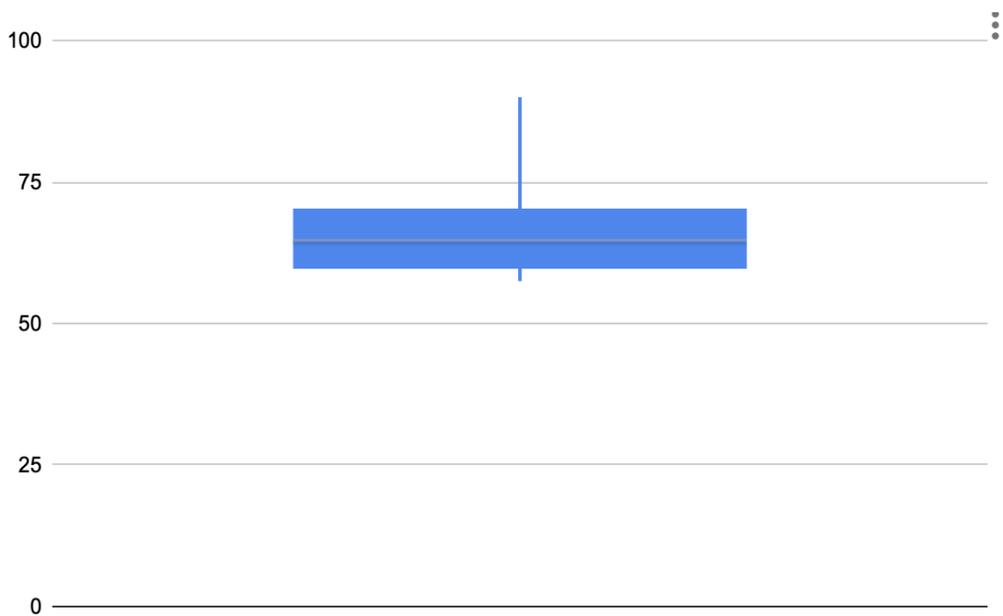
Figure 6.10: Boxplot VR application

the virtual environment with the difference that after some minutes, those who underwent the second test had a feeling of nausea and preferred to conclude the test, this issue was in fact expressed in the gaming experience questionnaire by 4 out of 5 users.

With regard to customisation and the gaming experience, very positive and similar evaluations emerged for both tests, with around 87% of the participants more than satisfied. (see figure 6.11).

The behavior observed by users during the tests reveals a certain tendency to devote the same attention to the possibility of customization of the avatar both through menus and collecting them during the visit of the virtual environment, in fact the possibility of modifying one's body by dragging elements to one's avatar was considered very entertaining and fun. Another behaviour noted during the tests concerning the creation of the avatar showed that female test users tended to create a virtual representation as close as possible to their appearance; on the other hand, male test users tried to customise their avatar with different characteristics to their real appearance. An important role in finding objects was also played by the use of proximity and arrow sounds that help the user in finding the objects closest to him or her. Returning to the test results, a big difference can be seen in the values of immersiveness in the two tests: in fact, in the first test, an average immersiveness value of 1.63 out of 5 was recorded; on the other hand, the value obtained in the second test, 4 out of 5, was much higher. In addition, users through free questioning brought out important food for thought. The most frequent consideration was the possibility of adding more audio effects to enhance the feeling of immersion within
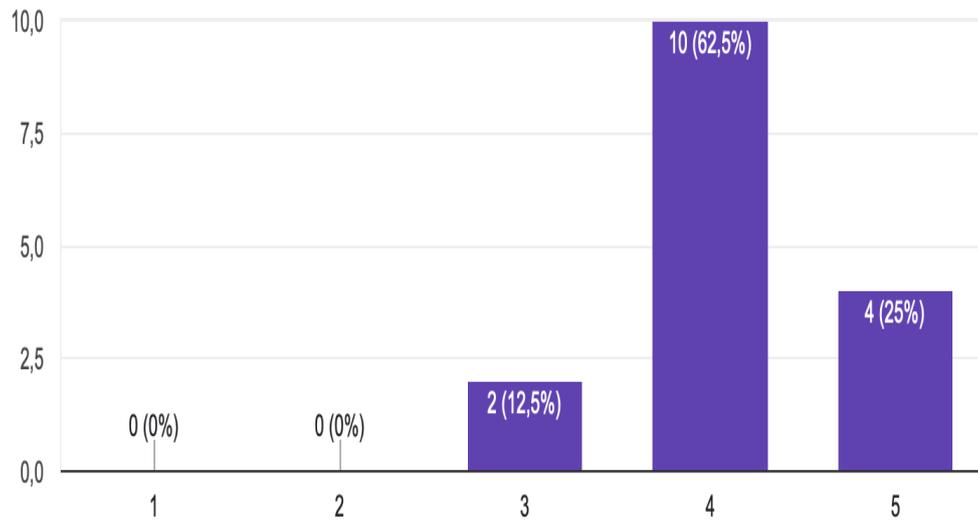
Figure 6.11: Level of user satisfaction

the virtual environment, such as the sound of the sea or leaves, and customization elements, particularly the possibility of wearing hearing aids for those with deafness or other elements for people with disabilities. Another interesting element that emerged is the possibility during exploration to meet and interact with other living things such as animals or even interact with other users in the world within the island through their avatars and then follow a process of avatar customization together. A very interesting idea that emerged among the comments concerns the possibility of increasing the immersiveness of the application with the use of HTC VIVE by integrating motion tracking devices, such as a suit or cameras, which would allow one to see one's digital body and have an augmented sensory experience.

6.7   Reflection on research questions and conclusions

Now, after analysing the test results, it is possible to draw answers to the previously defined research questions:

- **Can the user create his or her own avatar in a simple manner?** The project developed in its two versions, immersive and non-immersive, was evaluated positively on the whole. From the point of view of usability, the desktop version performed better, this result being mainly due to the fact

that the technologies used for this type of application were quite familiar to all users.

- **How does the user prefer to make changes to their avatar?** An interesting information that emerged in both tests concerns the tendency of users to devote the same attention to the possibility of personalizing the avatar through menus or through the exploration of the island.

- **How involved does the user feel in the virtual experience?** The questionnaires revealed that the experience through the use of the HTC VIVE was more immersive than that of the desktop version; however, it pointed out that immersive virtual reality experiences still give rise to motion sickness problems and this also affects the time the application can be used with the use of the headset.

- **Is the user satisfied with the result?** Most users were more than satisfied with the final result in both tests. The ability to customise the avatar not only via the menu but also by searching the island for items to equip certainly contributed to this result.

Finally, several ideas for future improvements emerged through the free comments, which revealed a need for more customisation features to make the avatar unique and include all the subjects in their diversity, but in particular have brought out the idea of being able to ensure greater immersivity using more sophisticated devices that would allow an even more evocative and fun experience for the user.

Below are some shots of the tests:
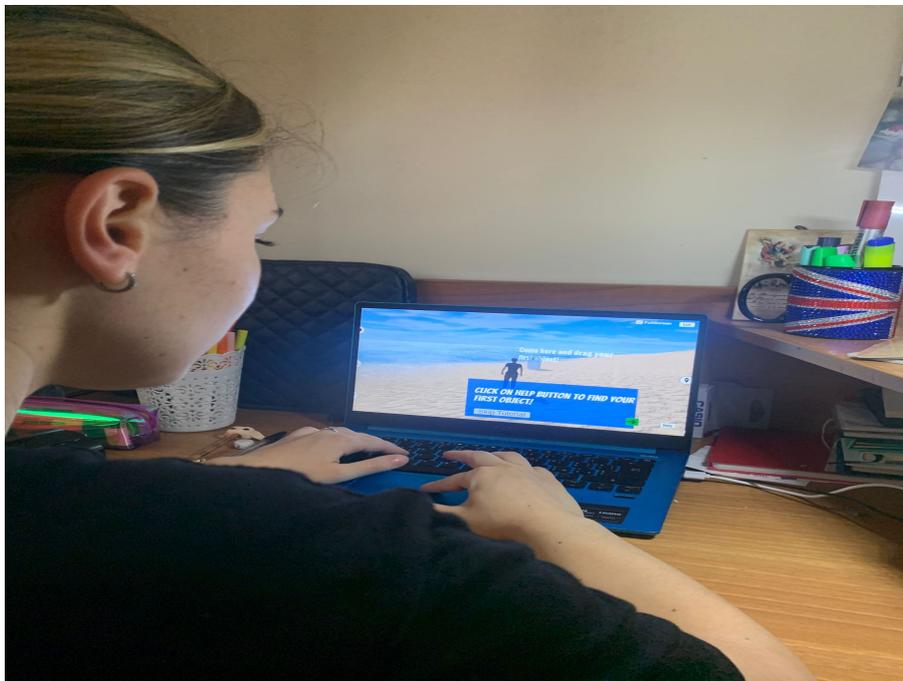
Chapter 7

Conclusions and future developments

The project described in this thesis aims to be an effective tool for virtual reality therapy. It was analysed how this methodology can be effective for therapists, how it is increasingly gaining ground in many sectors, even if the most advanced one is still video-ludic, and how it can also be advantageous from an economic point of view to focus on virtual reality technologies. Furthermore, the focus was on the central aspect of the realised application: avatar creation. In the therapeutic sphere, this aspect has proved to be a great ally in the psycholigical analysis of patients, who, through the virtual representation of their selves, are more inclined to show themselves freely. As noted in the previous chapter, the tests carried out demonstrated how virtual reality can allow one to immerse oneself in a world different from the real one, making the therapy experience more stimulating and enjoyable for the user. As a matter of fact, one of the most important goals of VRT is precisely to allow the user not to experience therapy as a discomfort, especially for very young people. The results of the tests carried out encourage research and the use of virtual reality in the psychotherapeutic field, and in particular have revealed important developments that can be carried out in the future in both the desktop and immersive application.

7.1   Future developments

Customization

In fact, most of the test users indicated, among future developments, the increase of customisation features such as facial expressions, the possibility to make up the avatar or to add accessories. Thus, users indicated the need to modify the avatar more, which from a therapeutic point of view could certainly be an advantage since the more detail they are able to modify their virtual representation, the more it is

possible for the therapist to gather useful information. Another important aspect of customization could be the ability to change the characteristics of the virtual world such as changing the colors of the environment, adding and removing objects.

Increasing immersiveness

One of the possible future developments in the immersive application is also to allow the user to control not only the hands in the virtual world but also the body in order to create an even stronger feeling of immersion. One of the possible future developments in the immersive application is also to allow the user to control not only the hands in the virtual world but also the body in order to create an even stronger feeling of immersion. Another concerns haptic feedback, in fact the possibility of perceiving the weight or softness of the objects you interact with through the vibration of the controller would increase the quality of the experience.

Facial Analysis

Concerning the desktop application, another aspect where important improvements can be made is facial analysis. This type of functionality is implemented in the server in python, but also from what emerged from the tests was not always reliable. In general, it works well when there is a lot of contrast, but is less reliable when the environment is not very bright or the background colours are dark. In addition to the quality of the analysis, other developments could include the addition of new features, such as the recognition of hair or the length of the beard or the shape of the face.

Audio

Another aspect that would make the experience even more complete is that concerning sounds. This aspect has been treated in a superficial way, in fact inside the desktop mode of the project you can notice that the sounds are used to guide the user in the search for objects to equip. It would be very useful in order to increase the degree of immersivity include in the application environmental sounds.

Appendix A

Survey

This section is dedicated to showing which modules test users have undergone.

A.1   Personal Data

1. What is your gender?

    (a) Male
    (b) Female
    (c) Prefer not to say
    (d) Other

2. Which category best represents your age?

    (a) 9-13
    (b) 14-18
    (c) 19-23
    (d) 24-30
    (e) 31-40
    (f) 40-49
    (g) 50 or older

3. What is the highest level of education you have obtained?

    (a) Less then High School Degree
    (b) High School Degree or equivalent
    (c) Bachelor Degree

(d) Master's Degree

4. Do you have visual defects?

    (a) Yes, I am nearsighted

    (b) Yes, I am astigmatic

    (c) I have no visual defect

    (d) Yes, I am presbyopic

    (e) Yes, I have other visual defects

5. Do you know what Virtual Reality means?

    (a) No, I've never heard it

    (b) Yes, I know what is it

    (c) Only hearsay

    (d) Maybe

6. Have you ever used virtual reality?

    (a) Never

    (b) Yes, I tried it a few times

    (c) Yes, I have used it many times

    (d) Yes, only once

7. Do you feel satisfied with your appearance?

    (a) No, not at all

    (b) Yes, I am completely satisfied

    (c) Not completely

8. Do you suffer from any illnesses that you think might complicate the virtual reality experience?

A.2 System Usability Scale

1. I think that I would like to use this system frequently.

    (a) 1

    (b) 2

    (c) 3

(d) 4

(e) 5

2. I found the system unnecessarily complex.

    (a) 1

    (b) 2

    (c) 3

    (d) 4

    (e) 5

3. I thought the system was easy to use.

    (a) 1

    (b) 2

    (c) 3

    (d) 4

    (e) 5

4. I think that I would need the support of a technical person to be able to use this system.

    (a) 1

    (b) 2

    (c) 3

    (d) 4

    (e) 5

5. I found the various functions in this system were well integrated.

    (a) 1

    (b) 2

    (c) 3

    (d) 4

    (e) 5

6. I thought there was too much inconsistency in this system.

    (a) 1

    (b) 2

    (c) 3

    (d) 4

    (e) 5

7. I would imagine that most people would learn to use this system very quickly.

    (a) 1

    (b) 2

    (c) 3

    (d) 4

    (e) 5

8. I found the system very cumbersome to use.

    (a) 1

    (b) 2

    (c) 3

    (d) 4

    (e) 5

9. I felt very confident using the system.

    (a) 1

    (b) 2

    (c) 3

    (d) 4

    (e) 5

10. I needed to learn a lot of things before I could get going with this system.

    (a) 1

    (b) 2

    (c) 3

    (d) 4

    (e) 5

A.3   Avatar Configuration experience

1. How much are you satisfied with your avatar?

    (a) 1
    (b) 2
    (c) 3
    (d) 4
    (e) 5

2. Did you enjoy the experience?

    (a) 1
    (b) 2
    (c) 3
    (d) 4
    (e) 5

3. How immersed did you feel in the experience?

    (a) 1
    (b) 2
    (c) 3
    (d) 4
    (e) 5

4. How satisfying did you find the available customisations?

    (a) 1
    (b) 2
    (c) 3
    (d) 4
    (e) 5

5. How useful do you think it might be useful to use this method in therapy?

    (a) 1
    (b) 2
    (c) 3

(d) 4

(e) 5

6. During the experience, did you experience any discomfort such as nausea, headaches, disorientation, etc.?

   (a) Yes

   (b) No

7. What would you improve? What customization feature would you like to add?

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