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Bachelorarbeit

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The benefits of Virtual Reality in Education

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Kurzzusammenfassung

In dieser Arbeit geht es um eine Fallstudie, die die Vorteile von Virtual Reality in der Lehre erläutern soll. Nachdem ein Überblick über das Thema Virtual Reality geschaffen und eine Beschreibung und ein Vergleich verschiedener „Head-Mounted Displays“ gegeben wurde, konnte ein für die Studie passendes Modell ausgewählt werden. Dies war wichtig, da sonst im großen Feld der Virtual Reality der Leser schnell den Überblick verlieren kann. Die Bedeutung von Virtual Reality in der Lehre ist stetig wachsend. Dies liegt an den Lernmöglichkeiten, die diese sichere und vorteilhafte Technik mit sich bringt. Ein Spiel wurde entwickelt und von verschiedenen Personen unterschiedlichen Alters und Tätigkeitsfelder getestet. Rückschlüsse aus ihren Erfahrungen lassen folgern, dass Virtual Reality ein Feld ist, dass sich noch weiter zu entwickeln hat und es ethische und deontische Probleme hat, die man sorgfältig analysieren muss. Jedoch werden mit dem technischen Fortschritt die Resultate, die aus dieser Studie hervorgehen, es ermöglichen noch tiefer zu forschen und die Ergebnisse in der realen Welt anzuwenden.

Abstract

This thesis describes a case study conducted with the aim of perceiving the benefits of Virtual Reality in education. As Virtual Reality is a large and extensive field a decision was made in order to contextualize the reader. An overview of the field of virtual reality as well as a description and comparison of Head-Mounted Displays was made and thus enabled the choice of the most appropriate one for this study. Virtual reality is increasingly present in education which provides safe, advantageous and conducive environment for students to improve their learning strategies. A game was developed and tested by a group of people from different backgrounds and ages. Conclusions from their experience allowed to realize that Virtual Reality is a field that still has much to develop even though there are many ethical and deontological issues that need a careful analysis. However, with the advancement of the technology, the results that came from this study allow a deeper research in order to apply future results and findings in the real world.

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This thesis is the culmination of an academic cycle. The area of virtual reality has always aroused my interest and this thesis allowed me to brought everything swept under the carpet out into the light of day and discover a world that still has much to flourish.

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1 Introduction

1.1 Problem Definition

Technology is increasingly present in the daily life of every human being. As children grow up they are confronted with tablets, mobile phones, television and computers which makes the contact with these devices natural being sometimes a basic necessity. Also, science fiction films have contributed to the interest of younger generations. The perception of what is real or not captured the attention of movie lovers to an emerging technology in the market. Virtual reality is just another technology that takes advantage of some of these devices to reach the target audience. This technology has existed for a long time, since the 1990s but only a few years ago has been gaining popularity within the internet community with the investment of large companies, such as Facebook according to Steinicke [35]. Due to this investment it has been possible to develop hardware and software that allow to reproduce virtual reality. Although virtual reality is in vogue these days it is not yet present in today's educational systems.

1.2 Motivation

Over the last few years it has been possible to note an increase regarding technology in schools which facilitates the work of teachers and helps students learning. The incorporation of computers in the teaching rooms, ardosia frames being replaced by interactive whiteboards are all changes that have brought benefits to the education system. In addition, in educational terms it is possible to notice an increase of online courses and being the internet so easily accessed it allows doubts to be clarified very quickly according to Bernard [7]. A different, innovative education system where students can be immersed in information can facilitate their learning. The motivation for this research comes from the fact that education is the basis of a cultured society that is thus more likely to thrive.

1.3 Aim of Study

The purpose of this study is to understand the benefits of virtual reality in education. In order to achieve that a game was developed and tested by people of different backgrounds and ages being the educational experience that each individual had or is still having the factor of comparison with this new educational strategy. These study conclusions showed that with the technological advance to grow exponentially, it will not be long before virtual reality is introduced into the educational system. The future in which the student immerses himself in a totally virtual environment and learns in a safe and controlled environment is no longer a mirage and is now something palpable and achievable in a short period of time.

1.4 Structure

This thesis begins by describing the hype of virtual reality. Then the history and the milestones of Virtual Reality are taken into account along with the head mounted display that are reanimating this technology these days. With this analysis it is possible to point out the problems that affected the ephemeral popularity of this technology that reached its highest point soon after being launched in the market but after a short period of time its popularity and interest fade away as it is possible to see in Steinicke [35]. Then virtual reality is discussed in education, its benefits and handicaps. Different areas of application of virtual reality in education are discussed such as education for students with special educational needs, education for primary, basic, secondary and university students and education in military areas. Important issues and challenges such as motion sickness and cybersickness are discussed and analyzed in the light of previous studies and also the need for better hardware and software. Next, the case study described in the previous section is put into practice and its results analyzed. Then the conclusion and a possible future research are described. The first proposes the benefits that can warn of the use of technology, virtual reality, in education. The second proposes a possible strategy to a target group that can be analyzed and put into practice in a future analysis.

2 Virtual Reality

2.1 Fifteen Minutes of Fame

Almost thirty years ago Virtual Reality began to appear in the headlines of the media and now it seems that it is showing again more and more often. Back in the 1990s the science fiction movies and their special effects captured people's interest in this field. Virtual Reality came with the promise of revolutionize the way computers were used.

One small detail was that these two words, Virtual Reality, left the audience enthusiastic and disillusioned at the same time. In order to understand what that means the definition of Virtual Reality should be clarified. As Delaney [13] states Virtual Reality definition has three parts:

1. Virtual Reality is an interactive experience created and mediated by a computer;
2. Virtual Reality is comprised of worlds which are made up of 3D objects;
3. Virtual Reality provides random interactivity.

As an interactive and immersive experience in which the user is in a totally virtual environment, virtual reality stands at one end of the concept of 'virtuality continuum'. A concept that separates into extreme points a real environment and a virtual environment. Among these emerges the concept of mixed reality where there is a term that can be considered similar to virtual reality, augmented reality.

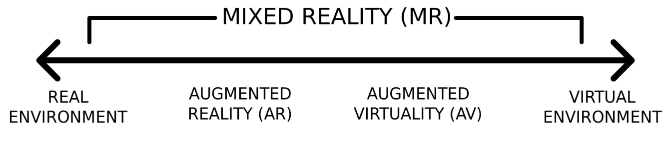

Figure 2.1: 'Virtuality Continuum' from Paul Milgram

Augmented reality differs from virtual reality in a way that the first one uses the user's real environment to overlap information while the environment used in the second one, as mentioned above, is totally virtual, Milgram and Kishino [23], and sometimes in both environments distinguishing the real from the virtual can be misleading. The excitement that comes from this field is the idyllic idea of the user being able to jump into an alternative reality simply by putting equipment developed for that purpose. However not everything was exciting and the disappointment came when the public tried this technology and their expectations were too high for what was actually provided. The colors were almost non-existent, the shape of the objects was defective, irregular and inaccurate, the hardware at that time did not allow the most adequate resolution, and huge latencies also contributed to the disappointment. The fact that it is very expensive, which makes it not accessible to everyone along with problems such as complexity, interactivity and simulation have made virtual reality replaced by two new worlds that are well present in the day-to-day, the World Wide Web and the smartphones. From a market perspective, virtual reality has lost the public's interest which has subsequently made it lose its potential investors. A reality contrary to what is possible to observe these days according to Delaney [13].

2.2 The long journey until the break

The long nose of innovation from Buxton [9] describes the growth of an idea, as the name implies, in the form of a nose. Three steps are described in his article being the first one invention, the second, refinement and augmentation, and the third and last one, traction. His theory holds that the second stage, refinement and augmentation, is the most important because it requires the subtlety and who knows, avarice, to find value in what seems worthless and only then can the product have value for the market. This theory argues that several products, such as the mouse which is the example in the article, have been around for at least ten years and only after being refined have a wave of popularity reaching the target audience and making them consistent and present in the long run.

2.2.1 The Link Flight Trainer

The reader should notice that Virtual Reality gained a notorious popularity in 1990 but already exists since 1929. What seems ancient was used forcefully in World War II, The Link Flight Trainer, a flight simulator, developed by Edwin A. Link which was patented in 1931. Necessity is the mother of innovation and it also was for Edwin A. Link since it was only after obtaining is pilot's license in 1927 that he noted flights could not always be made under the best possible atmospheric conditions and thus decided to build a simulator that could be operated on the ground. According to Angelo [3], the simulation was of a normal plane where the pilot could banking, pitching, and turning but adverse atmospheric conditions such as wind and fog were also features available in this simulator.

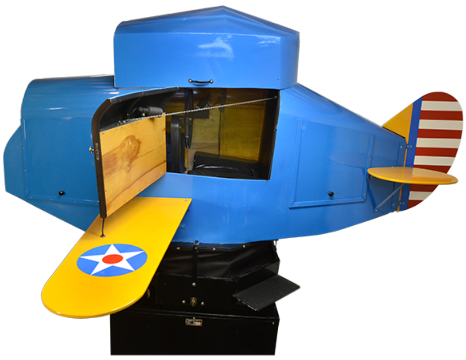

Figure 2.2: The Link Flight Trainer

During the second world war, 10000 of these simulators were used by 500,000 pilots which made it possible to save material and human resources avoiding casualties during the training of inexperienced pilots. Without realizing, Link built a virtual reality so that pilots could experience similar situations to those they could find in the skies.

2.2.2 Sensorama and Telesphere Mask

Another important milestone in the history of Virtual Reality was the Sensorama, developed since 1950 and patented in 1962 by Morton Heilig. Heilig was a cinematographer and a filmmaker who had the dream that the audience would be able to experience the film within the film itself.

Heilig built a machine that stimulated all the senses that a person can experience. A wide field of vision for the sight, sounds for the hearing, smells that stimulated the sense of smell along with fans and a vibratory seat that stimulated the tact.

Figure 2.3: Sensorama

According to Steinicke [35] Heilig has never had the opportunity to reach the market with its innovative, revolutionary and contemporary idea.

Along with the sensorama Heilig also developed the so called Telesphere Mask, the first example of a head mounted display. This was patented in 1960 and was capable of transmitting 3D photographic slides and sounds however the device did not have any type of motion tracking. The image below shows Heilig's Telesphere Mask and it is easy to recognize many similarities with the head mounted displays of nowadays.

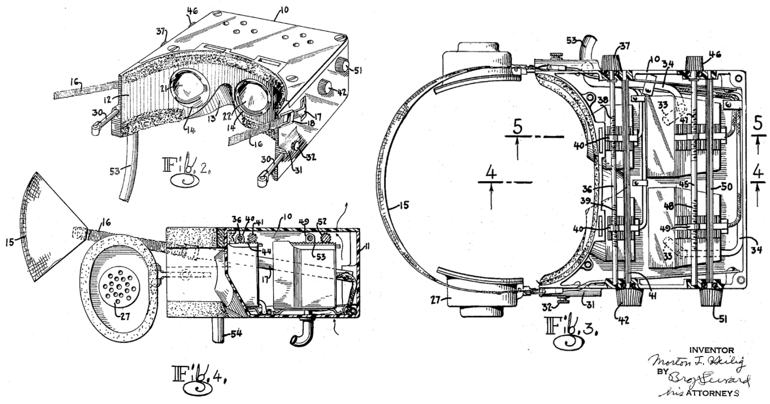

Figure 2.4: Telesphere Mask

2.2.3 Headsight

Although Heilig's Telesphere Mask is very similar to today's head mounted displays, in 1961 Charles Comeau and James Bryan developed the first Head Mounted Display (HMD). This device contained a video screen corresponding to each eye of the user and a magnetic motion tracking system which was linked to a closed circuit camera. The device was constructed from a military point of view that allowed the militaries to experience a dangerous situation in a controlled environment for instance they could look around the environment around them and identify possible hazards according to Steinicke [35].

2.2.4 The Ultimate Display

Ivan Sutherland, whom many consider the father of computer graphics described the concept of 'Ultimate Display' in Sutherland [36]. In his concept, Sutherland describes a simulation of reality where it is not possible to distinguish what is real from what is not. Sutherland proposes a virtual world where the portal is a head mounted display and along with the audible and haptic senses stimulated gives the feel of a real world. This virtual world is computer generated and managed in real time. For the perception of reality to blur in a thin line the contact with the objects of this world has to be done in a realistic way. Sutherland gives the example, in a passionate phrase, quoted here: 'With appropriate programming such a display could literally be the Wonderland into which Alice walked.'

2.2.5 The Sword of Damocles

Prior to the description, this name, 'The Sword of Damocles' should be considered and explained. According to Weiner [40] in the ancient land of Syracuse the tyrant Dionysius had a courtier named Damocles. Damocles always said the best possible things to the tyrant and one day he commented on how magnificent it would be to be king. Dionysious, then, suggested that they would change positions. When Damocles sat on the throne he noticed that hanging above his head was a splendid sword held only by a small horse's hair. Damocles promptly asked the tyrant to change positions once again, as the sword was there for the tyrant never forget that with great fortune and power also comes great danger.

Figure 2.5: Ivan Sutherland's 'Sword of Damocles' (copyright by Harvard University)

Suspended from the ceiling, hence its name, Sword of Damocles, was the way Ivan Sutherland and his student Bob Sproull built this device in 1968. The first head mounted display connected to a computer instead of a camera which allowed the user to have different view perspectives. The graphics were very rudimentary and the device was not easy to maneuver due to its weight but it still was the first augmented reality display as Steinicke [35] states.

2.2.6 Super-Cockpit

In 1968, the year that the Beatles released their 'The Beatles' album, also known as 'The White Album', Thomas A. Furness III created an interactive system with gestures, speech, sound, movement and tracking for the cockpit of a light combat aircraft. This system was a human computer interaction innovative concept that allowed pilots to train. Furness developed flight simulation prototypes that helped pilots make the best decisions in combat without actually being in combat protecting themselves and expensive material resources as Steinicke [35] and Delaney [13] state.

2.2.7 A name was born

The Visual Programming Lab (VPL) has left an important milestone in the research and discovery of virtual reality devices and have become the first company to sell VR goggles like EyePhone HMD and Dataglove. To be noted that by this time most of the development done in the area of virtual reality happened before the development of the personal computer. In 1985 Visual Programming Lab (VPL) co-founder, Jaron Lanier coined the term Virtual Reality and massified it to the public. From that moment on the research area had a name and could be popularized as Steinicke [35] states.

In an interview given to the WIRED, Palmer Luckey, founder of Oculus VR and designer of Oculus Rift gave his opinion quoted here: 'the people who were most excited about VR hadn't actually tried it. You told them about the content and, because they hadn't seen the reality of what the technology was in the 1980s and '90s, they assumed it was incredible - that it was like The Matrix or The Lawnmower Man'. With this statement it is possible to conclude that films like these helped to viralize the term, Virtual Reality, which has become part of the world's citizen's vocabulary. See also Thompson [37].

2.2.8 Nintendo Virtual Boy

As the ad advertised, 'The first 3-dimensional stereo immersive 32-bit video game system, ever.' came out to the public in 1995 and, undoubtedly, it was a 3D imaging system. This device showed two colors, red and black, which made contrast between them. Nintendo Virtual Boy design lacked motion tracking, which meant that the system was not truly considered virtual reality. Symptoms experienced by users such as headaches and nausea have contributed to the greater commercial failure of nintendo and virtual reality as Zachara and Zagal [42] state.

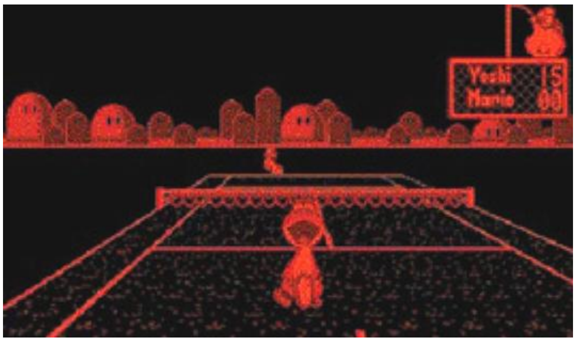

Figure 2.6: Nintendo Virtual Boy Graphics

Figure 2.7: Nintendo Virtual Boy

2.2.9 The Long Long Nose

It is possible to discover similarities between Buxton's [9] example on the mouse and this emerging technology, virtual reality being possible to think of both as symbols of human-computer interaction. As it was written before, in this long nose of innovation, virtual reality has existed since 1929 even though its term was only coined in 1985. Most of the devices described above have their foundation in the military area. No doubt this area is a pioneer in almost all technological advances but in the following chapters more areas will be presented in which virtual reality can grow and triumph. With this, what the reader is meant to understand is that virtual reality is not stagnated here as it will be described in the next chapters and that the tip of the nose is still a few years ahead.

2.3 The break

A very interesting article written by Negroponte [24] puts the question, will virtual reality be an oxymoron or a pleonasm? In other words, are these two words antonyms or synonyms? In the opinion of Negroponte [24] they are synonymous and also a pleonasm since virtual reality makes the artificial become real. The author hoped that in 1993 with the success of virtual reality used in military areas, as it is possible to read in the previous sections, with the Link Flight Trainer of Edward A. Link and the Super Cockpit of Thomas A. Furness III that virtual reality would mostly be used in driving schools to simulate possible environments where future drivers could be tested. The author's hope was that virtual reality would have an astonishing application at a social level. To better understand what led to virtual reality failure, the main reasons will be enumerated and then dissected.

1. Poor graphic quality:

   With the failure of Nintendo Virtual Boy, the area of virtual reality also failed and Negroponte's hopes ended up in smoke. As it was written before it is easy to understand why the Nintendo Virtual Boy failed. Firstly, it only displayed two colors, red and black, and secondly the graphics in all other devices made so far were very rudimentary with poor not very realistic shapes. At last, the system was not actually virtual reality since the user was not immersed in the game and could not have a 360 degrees field of vision as Zachara and Zagal [42] state.

2. Heavy headsets:

   Reasons related to head mounted displays also contributed to virtual reality failure. As it is possible to observe in the Nintendo Virtual Boy images, the headset had to be suspended on a stand in order to be usable which was not very user-friendly as described in Zachara and Zagal [42]. Other reasones regarding comfort are described in Negroponte [24] and are related to the weight of these head mounted displays which are corroborated by devices like Ivan Sutherland's Sword of Damocles being very difficult to maneuver.

3. User's experience:

   Along with the question of the graphics and the weight that made the device unpleasant and uncomfortable was the issue of lag that caused people to report symptoms such as headaches or nauseas during and after using the device as Zachara and Zagal [42] state being the actual problem that as the user moved his head quickly the graphics could not keep the pace with this movement as Negroponte [24] states.

4. Price:

   This technology's price was also a very popular issue despite the fact that the Nitendo Virtual Boy had a friendly price for the average user. Several authors like Steinicke [35], Delaney [13] and Negroponte [24] say that the price was too high for what the product offered to users.

5. Emerging technology:

   Delaney [13] points out another two reasons for the failure of virtual reality, the internet technology, World Wide Web and the age of smartphones which have come to replace the first one in the markets. These two reasons are intertwined and will be important for the revival of virtual reality in today's society.

2.4 The Digital Revolution

Picking up the last point of the previous section, emerging technologies like World Wide Web and the smartphones, it is possible to make a translation of emerging technologies to digital revolution. According to Ramasubramanian [26] and until the year he wrote his book, the Industrial Revolution was divided into four stages. The first, Developing Technologies from 1968 to 1978, the second, Developing Software, Data, and Applications from 1978 to 1988, the third, Being Connected-Anywhere, Anytime from 1988 to 1998 and the fourth and last, Creating Empowered Netizens from 1998 to 2008.

2.4.1 Before 2000

1. Developing Technologies from 1968 to 1978

   Ramasubramanian [26] also states that the technological growth of this first stage was guided mainly by military reasons, a reason that is possible to verify by the model Super Cockpit of Thomas A. Furness III described in previous sections.

2. Developing Software, Data, and Applications from 1978 to 1988

   In this phase, the author reports the emergence of the personal computer and graphic interfaces. Facts that are supported by Microsoft [22] when in 1981 came The IBM 5150 PC that used an Intel 8088 CPU running at 4.77MHz and up to 64KB of RAM and in 1984 came the so famous Macintosh that became the first mass-market computer to ship with a graphical user interface and a mouse.

3. Being Connected-Anywhere, Anytime from 1988 to 1998

   Being brief on the third phase, it is important to remember that it was when virtual reality failed and the World Wide Web emerged in 1989 described in Berners-Lee, Cailliau and Groff [8] and the smartphone that supported calls, email and fax was launched. More fascinating information about this smartphone can be found here Aamoth [1].

2.4.2 After 2000

After 2000, the fourth stage of Ramasubramanian [26], Creating Empowered Netizens from 1998 to 2008, should be extended untill the present. In this phase Bluetooth emerged in 1999, Skype allowed instant video calls worldwide in 2003, Facebook emerged in 2004 that later would play a key role in the area of virtual reality, YouTube appeared in 2005, the Iphone in 2007 and Bitcoin becames the first currency accepted worldwide with cryptocurrency according to Council [12].

It is possible to conclude that technology has evolved a lot throughout this time which has led people to invest in new technologies causing an action reaction mechanism leading more companies to invest more money in innovative products. Undoubtedly, this digital revolution brought people together not only in reality but also virtually which makes it is possible to affirm that the digital revolution is one of the causes of globalization. A statistic by Bank [5] proves that the percentage of Internet users in the European Union reached its peak in 2016 with 80.133% of the population.

According to Steinicke [35] during the first 15 years of the 21st century computers have been part of everyday life for most people because of their computational power and are relatively small and cheap. These mobile technologies have enabled this generation to easily get mobile phones that are increasingly better at the level of software and hardware. One detail that has proved to be fundamental in the area of virtual reality is that these mobile phones used by consumers have gyroscopes and acellarometers which allow users to invest and enjoy the area of virtual reality with a device that is already part of their lives allowing the costumer not to spend money on a more expensive device that will be used few times.

2.4.3 Oculus Rift

From the digital revolution previously discussed, a promotional campaign for Oculus Rift appears in 2012. Oculus Rift is a head mounted display that allows the user to experience virtual environments. The campaign raised 2.4 million dollars and the Oculus Rift was bought by Facebook in 2014, an investment in the area of virtual reality as Ruyg, Teunisse and Verhage [30] state.

Figure 2.8: Oculus Rift - Development Kit 2

Oculus Rift is available to developers as a development kit that the reader can see in the previous image (the second development kit). This Oculus has an OLED display, resolution of 2160 x 1200, refresh rate of 90Hz, field of view of 110 degrees, tracking area of 5x5 feet with two sensors, built-in audio and mic, sensors as accelarometer, gyroscope, magnetometer and constellation tracking camera, an HDMI input, an USB 2.0 and an USB3 3.0 according to the Oculus website. This device, being a desktop platform, also requires a NVIDIA GeForce GTX 960/AMD Radeon RX 470 or greater, an Intel Core i3-6100 / AMD FX4350 or greater, 8GB+ RAM, Compatible HDMI 1.3 video output, 2x USB 3.0 ports and Windows 7 SP1 or newer.

2.4.4 Project Morpheus

In 2014, Sony [31] announces Project Morpheus, a virtual reality headset for playstation 4 being the sense of in-game presence one of the developers' goals.

Figure 2.9: Project Morpheus

The head mounted display works with the Playstation camera. The virtual environment rotates naturally in real time due to integrated sensors, accelerometer and gyroscope that tracks head orientation and movement of the player. This device has a field of view of 90 degrees and a RGB panel resolution of 960x1080 per eye. The connection interface is compound by a HDMI and USB ports. Furthermore, it is possible to observe a representation of the player's hands due to the Playstation motion controller. Morpheus includes display (LCD), audio, tracking, control, ease of use and cotent.

2.4.5 Google Cardboard

In 2014, Google noticed that the existing virtual reality devices were still too expensive for the average user. With this in mind and the fact that mobile phones have sensors such as accelerometers and gyroscopes, Google launches a head mounted display in cardboard that with the help of the user's smartphone was able to reproduce a virtual environment. Sparkes [33] states that it is projected on each half of the mobile phone corresponding to each eye, two images slightly different from each other that reproduced a 3D scene where it was possible for the user to be immersed in a totally virtual environment experiencing a 360 degrees scene.

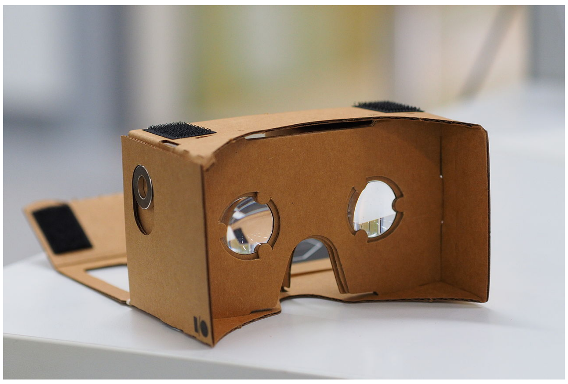

Figure 2.10: Google Cardboard

2.4.6 Samsung Gear VR and Oculus Go

In 2015 Samsung in partnership with Oculus launched Gear VR, another head mounted display. Regarding this device the curiosity is that this headset is only compatible with Samsung's smartphones. As Robertson [28] states this device is the most popular headset ever made since it was the most shipped one with over 5 million units until January 2017.

The Oculus Go have delayed the development process of Gear VR and in opposite to the last one this innovative wireless product does not require a mobile phone to be used. As Robertson [27] states Oculus Go replaced the Gear VR's glass-like lenses with higher-quality fresnel lenses like those in the Oculus Rift which makes it superior to Gear VR as this depends on the display quality of the mobile phone being used. It is also possible to compare other specs of the two devices as the field of view of Oculus Go is unknown while Gear VR's is 101 degrees. The Oculus Go has a snapdragon 821 processor and a 3GB of RAM while Gear VR depends on the phone's processor and has 4 GB of RAM. Both devices have the same sensors, gyroscope, accelerometer and a magnetometer. However the display of Oculus Go is a LCD display, 1280x1280 usable at 72Hz and Gear VR has an AMOLED, 1024x1024 usable at 60 Hz. The positive point of being developed by the same company is that although the Oculus Go seems to have more attention from the developers, Gear VR does not become obsolete because it is compatible with the first one.

2.4.7 HTC Vive

HTC Vive have reached the markets in 2016 being the first headset that allowed the user to move around. Some of its specifications are a display dual AMOLED 3.6' diagonal, resolution of 1080x1200 per eye, a refresh rate of 90Hz and a field of view of 110 degrees according to Vive's website. HTC thought out of the box and incorporated into its headset the ability to make calls, read messages and check the calendar.

Figure 2.11: HTC Vive

2.4.8 Google Daydream

According to Gibbs [15], after Google launching the cardboard in 2014, Google Daydream was launched two years later in 2016. This device is a head mounted display that takes the same principle as the cardboard and depends on a smartphone to work. When it was launched it only worked with Google's mobile phones but nowadays it also works with the best mobile phones from other brands.

2.5 What to choose?

As previously described, and making a brief summary, reasons such as being lighter, cheaper, having more computing power, users having more access to the internet and to smartphones, the technological development that can be seen since the last century and the investment of large companies in this technology, have made these new devices very fond towards the ordinary user.

In order to this case study being done a device needed to be chosen as it is the basis of all the work. Furthermore this case study aims to find the benefits that virtual reality has in education since the last one is the basis of a cultured and conscientious society. With this in mind a strategy has been outlined so that anyone can explore and develop this area for educational purposes.

The line of thought that allowed the device to be chosen began by trying to identify what all people have in common. According to Statista [34], in the United Kingdom 83 percent of mobile phone's users used a smartphone, leaving 17 percent which did not used. It is possible to affirm that in the United Kingdom and generalizing to European Union, the majority of the population owns a smartphone. If the majority of the population have a smartphone it is very likely that it has sensors such as a gyroscope and an accelerometer that are necessary to run applications in virtual reality. Thereby it is possible to base the case study on a smartphone which allows to exclude head mounted displays like Oculus Rift, Project Morpheus or HTC Vive. Regarding Samsung Gear VR it was excluded because it could only use smarphones of the Samsung's brand as it is possible to read in previous sections. Oculus Go and Google Daydream were excluded because they are very recent technologies which could create instability during the development process.

In this way the decision was easy and, without a doubt, economical, Google Cardboard was the device chosen. With abundant cardboard material in the market anyone who owns a smartphone can turn a piece of card into virtual reality. The combination of versatility, low cost and computational power, dependent on the used smartphone, transports the user to a totally virtual environment which is extremely exciting.

3 Virtual Reality in a Learning Environment

Even though it has been on the market for a long time and technology has improved a lot during this time, it is not possible to see Virtual Reality being used massively in education. In 2016, in the United States, based on a survey conducted by Samsung to more than 1000 K-12 teachers, virtual reality was considered a relatively recent technology. K-12 is a designation for primary and secondary education as a whole. According to this survey 86% of teachers said that it is a challenge to keep students focused even with existing technology while 93% said students would be amazed with the use of virtual reality in the classroom and 83% said it would help improving the learning outcomes. This teachers detailed some of the applications where virtual reality could be used in an educational setting. 68% of the teachers said they could use this technology to help students understanding concepts, 72% stated that virtual reality could be used to simulate experiences related to the content taught, 69% said they would use this technology for virtual study tours, and lastly 68% said that this technology could be used to visit inaccessible places. With the numbers presented it is possible to affirm that there is a generalized interest from the teachers to include the virtual reality technology in the educational system.

3.1 Virtual Reality in Schools

According to Christou [11] virtual reality in schools should be divided into two categories. The first is characterized by the students experiencing pre-developed virtual environments while the second is characterized by the students experiencing the development of virtual environments in which they would subsequently be immersed. As Southgate [32] states different virtual environments create different levels of immersion and a sense of presence by being allowed a 360 degrees view and interaction with the virtual environment. By allowing students to be in contact with virtual environments Hu-Au and Lee [17] concluded that Virtual Reality leads to increased student engagement, allows constructivist learning, provides authentic experiences which impact the student's identity, affords new perspective, improves empathy and promotes creativity and the ability to visualize difficult models. However, some safety measures are needed, as Southgate [32] prooved in a previous research that suggests a protocol for students' using virtual reality. One of the measures would be the need of a supervisor to assist the students in the process of placing and removing the head mounted display. Another measure would be that this technology should not be used in the last class due to the fact that many students go home alone and virtual reality when used for a long period can desorientate young children reason why it should be imposed a maximum time during which it can be used.

This protocol should be taken into account in particular with students with special educational needs. According to Buzio, Chiesa and Toppan [10], these students have serious difficulties in school performance and communication which causes them to drop out. As virtual reality promotes multi-sensory learning stimuli and allows students to be immersed in a virtual environment where they are bombarded with repeated sounds and images it facilitates their learning, social and academic skils.

3.2 Virtual Reality in 'Edutainment'

The concept of 'Edutainment' is based on the combination of two words, education and entertainment, which use technology as a tool for interactive learning that aims to educate students with good problem-solving skills and encourage creativity. According to Anikina and Yakimenko [4] the problem that 'Edutainment' tries to solve is that nowadays there is a lot of information that quickly becomes obsolete which makes people easily distracted by so many possibilities. In the traditional system, the knowledge obtained was very rarely applied, whereas with the use of technology in education it is possible to see the knowledge being applied which causes a validation.

The concept of Virtual Reality and Edutainment merge in simulations that promote a controlled, realistic supported learning that allows a thoughtful and cautious management by students in possible real situations as Aksakal [2] states. According to Roussou [29] this application of virtual reality as a tool for 'Edutainment' can be seen in museums being an approach that allows for historic research, simulation, and reconstruction. The visitors live an unique experience where they can see landscapes that no longer exist or are degraded, reconstructed monuments and analyze any kind of materials, beings, monuments, natural phenomena, landscapes, inaccessible sites of different points of view with a feeling of presence that earlier was not possible.

Studies such as Hussein and Natterdal [18] and Fredriksoon and Rodstrom [14] also use virtual reality as an 'Edutainment' tool. In both cases, two educational games were developed, one for virtual reality and another that did not use virtual reality. Both studies conclude that there was a great deal of interest from the groups tested mostly because they had never had contact with this type of technology. Several reports state an increased concetration due to the fact that the surrounding environment does not distract the person from the task goal. In both studies, the groups achieved better results in the virtual reality game.

Although it seems a technology full of advantages it also has some disadvantages. Roussou [29] reports problems related to the locomotion of the user and in the two studies mentioned above in the previous paragraph there are also reports of cybersickness that will be dissected in a future section.

3.3 Virtual reality in Practical Applications

Not neglecting that the points previously discussed are also practical applications, the reader should realize that these practical applications can have severe and permanent consequences within the community. Virtual reality could transform what could possibly be a catastrophe into a controlled and protocolized test.

3.3.1 Simulations of means of Transport

It is extremely fascinating how technology can prevent disasters. Flight simulators can be considered the dinosaurs of the simulations as previously reported with The Flight Flight Trainer and Super Cockpit. It was what Valentino, Christian and Joelianto [38] did, developing a flight simulation that allowed the commercial pilots to train. The advantage of using a simulator is that it allows the pilot to experience unusual scenarios, events that could endanger both the aircraft and passengers, and conditions that rarely occur. In a safe environment, the pilot can gain experience and make the right decision without jeopardizing his or her life or a third party, being better prepared for a real flight.

The simulations of means of transportation do not stop here. An interesting study of Wu, Ashmead and Bodenheimer [41] was done with the aim of evaluating the decision of pedestrians to cross the road in a roundabout. In this case, the simulation was not inside the means of transport, but outside. A concept outside the box that allows shaping the conditions imposed for the action itself in order to evaluate a variety of possibilities not excluding any vicissitude to happen. In this way all the people who did the test did not jeopardize their health condition and it was possible to save resources because of the simulation.

3.3.2 Sciences' Simulations

Continuing in the same line of thought but in the field of medicine, virtual reality can be used in clinical teaching and interventions, empowering real-life situations in a virtual environment. With a massive display of 3D data visualization is facilitated the understanding of concepts and basic anatomy. Pensieri and Pennacchini [25] give the example of an organ that when visualized it is possible to explore it to the smallest detail because it can be analyze it from the side, behind, above, below and even inside. 'Virtual Reality simulators provide explanations of the tasks to be practised and objective assessment of the performance' cited from Pensieri and Pennacchini [25]. This sentence is very important to realize the impact of this technology in the surgical training allowing to operate virtually before performing the surgery on the patient preventing any failure that may occur in the clinical act. In this case a 3D model of body part or even the entire body of the patient is used. The only downside is that it lacked realistic haptic feedback that we will discuss in a future section.

Virtual reality is also used in the treatment of some diseases, including phobias, post-traumatic stress disorder and axiety disorders. By exposing patients to virtual situations that are the mirror of real situations that can be experienced by patients allow them to control their symptoms and overcome the disease that causes them constrictions in their life. This exposure is controlled at the level of quality, quantity and frequency, protecting patients from more severe trauma. Also Pensieri and Pennacchini [25] state that in the area of rehabilitation virtual reality can have a very positive effect inducing the perception of an illusory part of the body that allows a correlation between the touch and the visual effect empowering the patient to gain confidence improving his or her clinical process.

In other sciences like Chemical Engineering virtual reality can play a daring role. Bell and Fogler [6] state that by including virtual reality within a lab it is possible to deliver information through active channels allowing different learning styles. The authors suggested the use of virtual reality to explore the interior of nuclear reactors and microorganism reactions as well as the demonstration of possible consequences for not following proper safety procedures.

3.3.3 Military simulations

It is common sense that technological growth is beneficial to any area. The military area is probably the first to experience these benefits. For the reader to get an idea the United States 2019 defense budget is 716 billion dollars, this money is invested in research that may be beneficial in the future being The Link Flight Trainer, Headsight and Super-Cockpit perfect examples of this investment.

According to Lele [21] Virtual Reality brings to this military area a technological and revitalizing training. The simulations expose the militaries to a mental and physical challenging workout that promotes a space where it is possible to overcome difficulties and tricky events such as bad weather or unexpected scenarios without damaging material and human resources. Of course this technology will not replace training on the spot but it is an extremely beneficial addition to the preparation of the militaries for future missions.

3.4 Collect the evidence

With what has been described previously and collecting the evidence it is possible to give a brief summary about the benefits of virtual reality in a learning environment. Beginning with the interest of students and teachers, this technology brings constructive learning, unique and authentic experiences, explores creativity through multi-sensory learning. By being able to apply the knowledge in different situations the students train and have a sense of validation that empowers their learning. A controlled environment and supported learning allow them to increase concentration and save human and material resources.

Of course there is always the reverse of the coin and virtual reality is not a perfect world. Some challenges that have been identified so far will be dissected in the next chapter in order for the reader to realize what is still missing for this technology to triumph and to be able to be applied in a way that until now was not possible.

4 Challenges in Virtual Reality

Previously, the problems that led to the abrupt decline of virtual reality have been described. The graphics' quality was not the best, the equipment was uncomfortable and heavy, the user experience did not match what was advertised, the equipment was too expensive and the emerging technologies replaced the virtual reality in the public's eyes.

As it was previously noted, some of the reasons that led to the extinction of virtual reality were also the cause of its reappearance in today's society. For instance, emerging technologies have led to the hardware and software development that has overcome some difficulties such as the price, weight and comfort of the equipment.

Obviously this technology still has to overcome some challenges. Challenges that have already been mentioned in the previous chapter but which will now be described in more detail.

4.1 Health and Cybersickness

Cybersickness is probably the oldest and most challenging problem. Reports of cybersickness date since the Nintendo Virtual Boy (1995). To be easier to understand, cybersickness is similar to motion sickness but they differ in the movement because the use of virtual reality is often done in a stationary position. LaViola [20] explains three possible theories for the genesis of the problem but in order to understand each one of them it is necessary to introduce the concept of vestibular system. This system is a sensory system that informs the brain about our motion, head position and spatial orientation being very complex and is located in the inner ear. Another system to take into account is the visual system that transmits to the brain what the eyes see.

The oldest and most accepted theory within the community is the Sensory Conflict Theory. This theory is based on the discrepancy of perceptions of the two systems referred before. As the user is inserted in a virtual environment the visual system has the perception that the user is in movement while the vestibular system knows that the user is in a stationary position which causes a conflict of information that the brain does not know how to deal with.

The second theory called The Poison Theory attempts to explain cybersickness from a point of view of the evolution of the human species. Ingestion of poison caused sensory confusions and the body responded with a survival mode similar to the effects of cybersickness these days. Thereby what this theory tries to explain is that these sensory confusions related to virtual reality are relatively recent and the most similar experience that the body has already experienced is the one from poison ingestion where the reactions are similar. However this theory fails to explain why different people do not react in the same way to the same stimuli and why women are more susceptible to cybersickness.

The third and final theory The Postural Instability Theory argues that unfamiliar situations make it more difficult to maintain our body posture. One of the human species' primary behaviors is to maintain a stable posture within the environment in which the human is inserted being this position maintained by percepting the surrounding environment. When the environment changes abruptly, body posture becomes unstable and when the environment is unfamiliar posture correction strategies are non-existent. This is what happens in a virtual environment which is non familiar and changes constantly. This theory is also corroborated by problems regarding position tracking errors.

These three theories are the most accepted ones around the world. However there are many factors that influence cybersickness. LaViola [20] also argues that aspects like lag, which causes incoherence in what it is supposed to see and what the user actually sees, flicker, which causes eye fatigue, gender, which argues that women are more susceptible to cybersickness, and age, which argues that the younger ones are more susceptible to cybersickness.

The problem in reaching definitive conclusions is that there are few other publicly available investigations into the long term visual consequences of immersion in Virtual Reality systems. Only the short term exposure was examined as Wann and Mon-Williams [39] state. In Steinicke [35] the author himself made an interesting and unique experience in which a head mounted display was used for 24 hours. The author reports that when he experienced cybersickness he only needed to stop and close his eyes for a few seconds so that the symptoms would disappear without having to remove the head mounted display.

4.2 Missing Realistic Visual-Haptic Interaction

Despite the technological advance, the problem of graphics' quality is still remaining being the Nintendo Virtual Boy and Super-cockpit a perfect example of this problem. Virtual environments have improved a lot but it is not yet possible to mistake them with reality. Steinicke [35] states that the human body receives and processes information about the surrounding environment at two levels, physical and perceptual. It is only after the brain has received and interpreted the information that it acts on it being this process necessary for the user to touch an object. As it is perceptible, touching an object that is part of a virtual environment can be an arduous task. These input problems are recent within the domain of virtual reality but they should still be considered problems. Haptic feedback is not the best when using a keyboard as input, but when using a Head Mounted Display with a motion controller to perform simple and small tasks it is possible to obtain a large input panoply that empowers the interaction with the user and makes an appealing experience.

4.3 Inadequate Self-Representation

Continuing with the human body, in virtual reality the representation of the human body is only now being put into practice. In the real world when a person performs a task he or she can see his/her own trunk and limbs. Steinicke [35] gives the example of the Oculus Touch that incorporates two manageable controls that allow the correct representation of the body and manage to transmit to the user simple forms of haptic feedback such as vibrations. The representation of the continuation of the body into the virtual environment is correct because the controllers are able to position and orientate the user's limbs in the correct target position. This is a great challenge for virtual reality because even with this simple representation of an extension of the user's body it lacks the realism that it is possible to experience in day-to-day situations.

4.4 Isolated Social User Experience

So far the virtual reality technology that has been launched only allows an isolated user experience. Steinicke [35] states that this experience disconnects people due to the impossibility of seeing each other realted to the fact that they are immersed in a virtual environment. As virtual reality devices are more affordable and their popularity is increasing within the community more people want to access and buy this type of technology which can become an escape from their real life. This is not negative if the environment is safe and identifies what the user wants to find in it because it can bring happiness and satisfaction that is then transmitted to real life. As humans are highly social beings the demand for more social virtual reality is not surprising. In Gunkel, Stokking, Prins, Niamut, Siahaan and Garcia [16] was reported that the interests related to education's and video conferencing's virtual reality are at the top. The study also reported that people only spent a short time in the virtual environment in the first time experience and afterwards they always got more excited and hopefull for more immersive experiences.

4.5 Every cloud has a silver lining

Virtual reality is a growing area since a long time but it still can and should grow more. The reappearance of virtual reality is due to one of the problems that made it disappear in the 1990s. Now, the new challenges facing this area can help to overcome each other. For example if it was possible to sort out the missing realistic visual-haptic interaction and inadequate self-representation it would be possible to overcome some problems related to health and cybersickness and also, a social user experience could bring more people into the community. All these challenges make this area captivating and by surpassing them it becomes increasingly possible to make people and the community feel comfortable using this type of technology which has benefits in both situations.

5 A Case Study

In order to corroborate what has been concluded previously, both in terms of benefits and in terms of what has yet to be improved, a case study was planned and then put into practice. The plan was simple, bringing together a group of participants of different ages, backgrounds and gender. The game that was developed had in mind the experience that the participants had previously in virtual reality.

5.1 Participants

20 subjects (13 males and 7 females, ages 13-73, with an average of 39 years) participated in this experiment. Participants came from different areas, ranging from students to retirees, from university professors in sociology, civil service workers, shop assistants, home assistants, insurance intermediaries, computer science and marketing students, authority forces and financial officers. All participants had normal or corrected sight. Only one participant had correctly corrected astigmatism. During the experiment two participants wore glasses and no participant wore contact lenses.

Before the development of the game a pre-interview was done to these 20 participants, where only 25% reported having had previous experience with virtual reality. This data will be relevant in the development of the game as it will be possible to outline further ahead. The total time per participant, including pre-questionnaires, accommodation, instructions, the experience itself, the necessary breaks (depending on each participant), the post-questionnaires and the discussion took approximately thirty minutes. It should be noted that the participants used the head mounted display around fifteen minutes. To be noted that the participants were allowed to take breaks at any time during the experience.

5.2 Material

The experiment was performed in a room where the participants had 2m x 2.5m to move within the conditions presented. In the experience Durovis Dive Cardboard was used as a head mounted display that corresponds to google cardboard. This device has a button that works with conductive material which replaces the magnetic button. This button corresponds to the user input. The smartphone used was the OnePlus 6T, which has a Snapdragon 845 CPU, 8GB RAM, 128GB ROM, an AMOLED 6.41 display screen, with the Android version Oxygen 9.0.6. The sensors included in this device are an accelerometer, gyroscope and electronic compass that corresponds to a magnetometer.

An ASUS computer with an Intel Core i7-5500U with 2.40GHz, 8GB of RAM, an NVIDIA GeForce 920M graphics card was used to develop the game. Together with this computer, the game was rendered with Unity 3D Personal with the 2018.2.3f1 version. To make the smartphone into a device capable of playing a virtual reality scene a GVR Android SDK version 1.100.0 was imported allowing to use the input button of the Dive Cardboard. The sound was also considered and the Resonance Audio For Unity version 1.2.1 package was also imported which allowed to set the sound to 3D. The fonts used throughout the game have been extracted from the website *dafont.com.* For accommodation terms and to provide adequate space for each participant a swivel chair was used to facilitate a 360 degree experience.

5.3 Design of the Game

As mentioned previously only 25% of respondents had previous experience with virtual reality which means that 75% had never experienced it before. All this was taken into account and the game thought and developed in a gradual way. The levels of the game and the strategy behind its development will be dissected in the next sub-sections.

5.3.1 Fruit Level

This level, named fruit level, consists of a 360 degree experience that allows the user to interact with fruits. The purpose of this level is to give the participant a first simple contact with virtual reality. In educational terms the goal of this game is to enable a foreigner to learn English. The scenario consists of boxes with a fruit on top of each. In front of the boxes is the name of the fruit in Portuguese and English. The fruit models are from the unity asset store, Fruit Pack - 3D Models by Sevastian Marevoy, supported by unity version 2018.2.2 or higher. The boxes are basic elements of unity. The audio source of the words is from Google. The fruit models present in the scenario are a banana, a watermelon, a pear, an orange, a pineapple, an apple and a lemon. When the gaze input model (the red dot) is on a fruit and the participant clicks the button from the head mounted display an audio source in english is displayed with the name of the fruit. To proceed to the next level the participant just needs to interact with the box that has written *next level*. A preview of the scene can be seen in the next image.

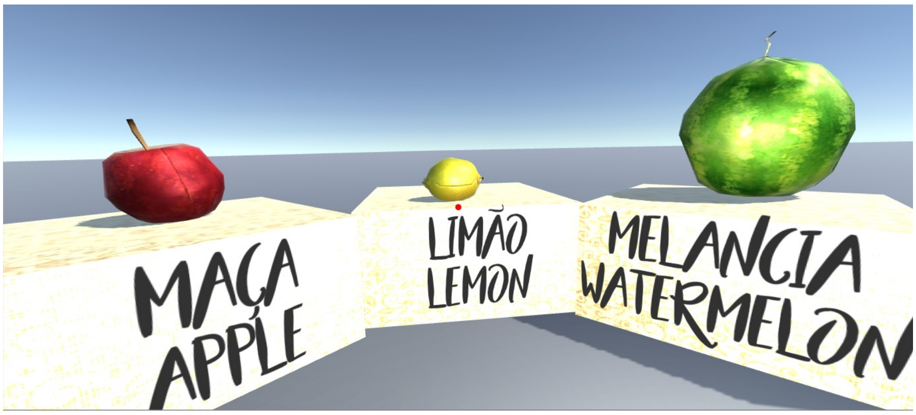

Figure 5.1: Fruit Scene

5.3.2 Room Level

Following the previous level, this one, called Room Level, has the same function, to teach English. As a strategy focused on gradual contact with virtual reality this level offers a level of immersion bigger than the previous one in a way that the participant is in a closed room with furniture labeled in both Portuguese and English and can have a 360 degree experience. The furniture models are from the unity asset store, Big Furniture Pack by Vertex Studio, supported by unity version 4.5.5 or higher. The walls are basic elements of unity. The audio source of the words is from Google. In this level several light points were introduced in order to better illuminate the room. The models of furniture present in the scenario are a bed, a bed light, a wardrobe, a bookcase, a toilet, a shower, a mirror, a washbasin, a table, several cabinets, a sink, a sofa, a chair, a secretary and a lamp. Again, if the participant clicks the button when the Gaze input model is on the furniture, an audio source in English is displayed with its name. To proceed to the next level the participant just needs to interact with the button that has written *next level*. A preview of the scene can be seen in the next image.

Figure 5.2: Room Scene

5.3.3 Memory Level

After the first two levels, the participant is supposed to have already realized how to explore and interact with the scene. By gradually transforming this immersion into a virtual environment, in this third level two very important brain processes, the reasoning and the memory, were introduced. As it is possible to observe in the image below, there is a set of values that participants have to discover and then add up. The reasoning is necessary to solve the part of the calculations whereas the memory is used when the participants have to remember the value of some object or in case they have forgotten it, the place where the clue that takes to that specific value is. In this scenario, the previously mentioned models of fruit and furniture are used. Throughout the scene there are clues to solve the main equation. Arranged below the main equation are three possible outcomes. The participant by clicking on the right result advances to the next level, if the button that the participant chose is one of the wrong ones he/she remains at the same level until the appropriate result is hitted.

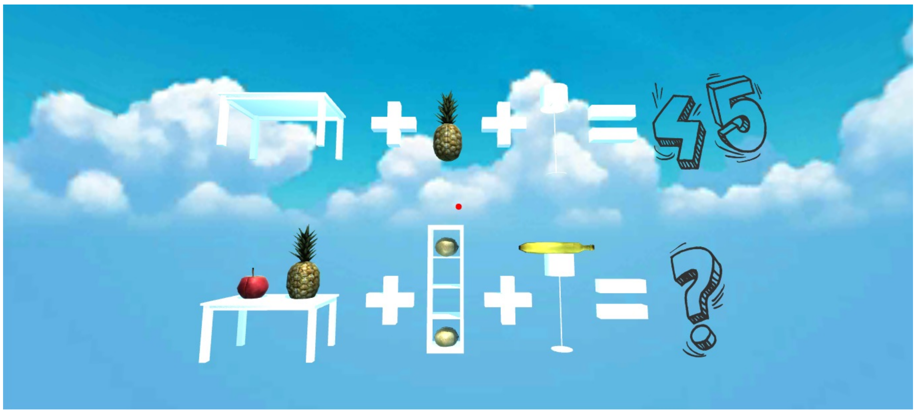

Figure 5.3: Memory Scene

5.3.4 Farm Level

The fourth level has a very simple goal, to introduce movement. At this point, the participant knows how to explore and interact with the scene and the processes of reasoning and memory are no longer foreign to him/her in a virtual environment. As it is possible to observe in the image below, this level contains animals like cows and bears as well as wolves, pigs, chickens, geese, rabbits, goats, deer and scorpions. To give a sense of realism all these animals produce appropriate sounds. The aim of this scene is to introduce movement therefore if the participant tilts the head at an angle greater or equal than 15 degrees he/she begins to walk. As in a farm or zoological garden the participant can explore the whole scene and observe the animals. The basis of the scene is an edited unity terrain. All the models are from the unity asset store, the fences, Mobile Wooden Fences by Jaroslav Grafsjiy, supported by unity version 5.3.4 or higher, the stone walls, Dry Stone Wall with Leafy Vines by Bitsong, supported by unity version 3.5.6 or higher, the trees, Mobile Tree Package by Laxer, supported by unity version 4.5.1 ot higher, the bushes, Yughues Free Bushes by Nobiax/Yughues, supported by unity version 4.3.0 or higher, the rocks, HQ Rock Pack Free by Dnk dev, supported by unity version 5.5.0 or higher and finally the animals models, Animal Pack Deluxe by Janpec, supported by unity version 2017.2.0 or higher. The audio of the animals were extracted from the *freesoundeffects.com* website. In order to proceed to the next level the participant just needed to go against the stone wall.

Figure 5.4: Farm Scene

5.3.5 Maze Level

Finally, the maze level, after the gradual process of contact with virtual environment, this last level encompasses everything that the participants have come to experience until now. A 360 degree immersion where they need to ration and remember the wrong ways (brain trainning). This level is a maze where the goal is to reach the yellow trophy. As the participant approaches the trophy an audio source is played with increasing volume. All elements of this level are basic elements of unity modified to look like the picture below. There is only one way to successfully complete the maze. The audio made available during the maze is the sonic theme song. When the participant arrives at the yellow trophy the challenge has been successfully completed and a congratulatory message is displayed.

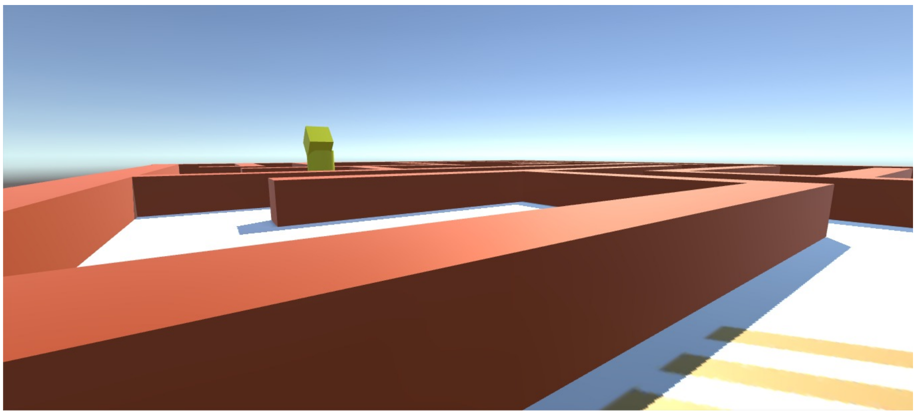

Figure 5.5: Maze Scene

5.4 Experiment

Obviously the experience consisted of experimenting the game detailed earlier. As it was possible to read previously was a gradual experience of contact with several virtual environments in a playful and educational context. Thus, each participant performed the tasks only once. The experience was susceptible to pauses if the participant requested it. To ensure consistency the tasks were presented to all participants in the same order. Prior to the experience, all participants were given detailed instructions so they could perform the tasks presented. Furthermore, all participants completed the Simulator Sickness Questionnaire (SSQ) from Kennedy, Lane, Berbaum and Lilienthal [19] immediately before and after the experiment and also completed a questionnaire with objective answers about the experience, the area of virtual reality and its benefits in educational terms. The results will be analyzed in the next section. As described in previous sections, the participants performed the tasks sitting on a swivel chair that facilitated a deeper immersion and a 360 degree experience. In the following image it is possible to identify a participant, the swivel chair and the space adequate to carry out the tasks, as well as the head mounted display.

Figure 5.6: The Experience

5.5 Results

In this section the quantitative results will be presented, meaning they can be quantified by including yes or no questions and the choice of several options. In a first analysis the answers to the Simulator Sickness Questionnaire are under focus, while in a second analysis the answers to questions about the experience itself and the area of virtual reality are the ones being analysed.

5.5.1 Simulator Sickness Questionnaire

Each participant filled in the Simulator Sickness Questionnaire before and after the experiment. The results were analyzed by gender, age and overall level.

Five groups were defined, from 10 to 20, from 21 to 30, from 31 to 40, from 41 to 50 and over 51 years old. Since no participant was between the ages of 31 and 40, this group in particular was not considered. Starting with the group of 51 or older a SSQ average score of 47.99667 was measured before the experiment and a average SSQ score of 52.36 after the experiment. The next group comprised between 41 and 50 years before the experience had an average SSQ score of 8,228 and after the experience of 29,172. Skipping the group that was not considered, the next ones are between the ages of 21 and 30 where they obtained an average SSQ score of 11.22 before the experience and an average SSQ score of 37.93429 after the experience. Finally, the younger group aged 10 to 20 years had a SSQ score of 7.48 before the experience and 16.83 after the experience. All these results can be seen in an appealing way in the following chart.

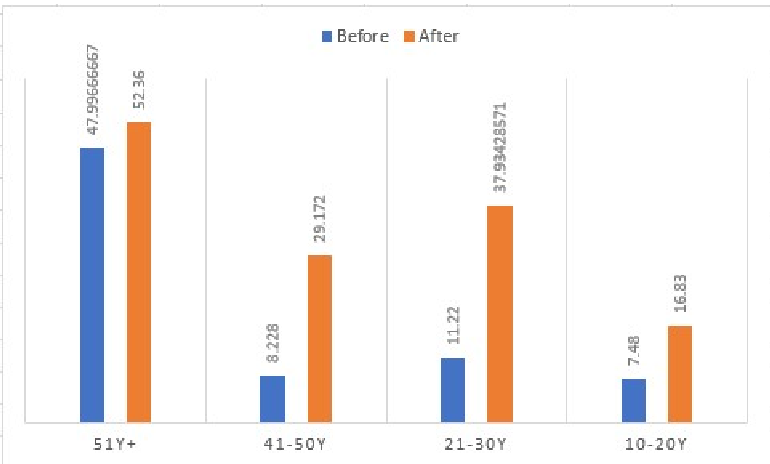

Figure 5.7: Age SSQ score

From the age of 51, the increase is not so significant as there is already widespread malaise unrelated to virtual environments. Therefore, considering the obtained data and visualizing the available graphic it is obvious the increase of simulator sickness in the other groups that leads to cybersickness.

Regarding gender level, two groups were defined, both female and male, in order to understand which gender is most susceptible to side effects from experience virtual reality. The female gender achieved an average SSQ score of 21.90571 before the experience and an average SSQ score of 40.07143 after the experience while the male gender achieved an average SSQ score of 20.71385 before the experience and 36.82462 after the experience. All these results can be seen in an appealing way in the following chart.

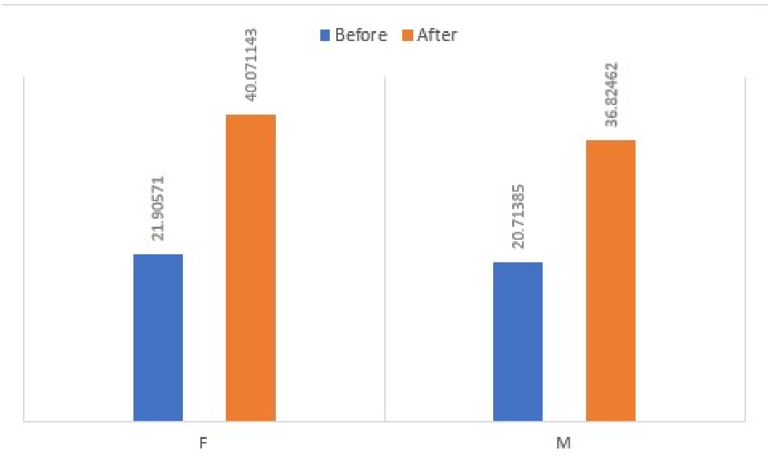

Figure 5.8: Gender SSQ score

It is notorious in the graphic presented an increase of simulator sickness in the two genders. However, it is possible to conclude that the female gender is more susceptible to this type of side effects caused by contacting with virtual environments.

All these variables were also contemplated together and it is possible to notice an obvious increase of simulator sickness. Prior to the experiment an average SSQ score of 21,131 was obtained and after the experience an average SSQ score of 37,961 was obtained.

5.5.2 Experience Questionnaire

For the quantitative results the participants were asked eight questions listed below.

1. *'Did you find the tasks difficult?'*

   17 of the participants answered ***no*** while only 3 answered ***yes***. From this it is possible to conclude that the strategy delineated of a gradual contact with a virtual environment was a good option.

2. *'Were you afraid of colliding with objects?'*

   To this question 10 of the participants answered ***no*** while the remaining 10 answered ***yes***. It is possible to conclude that the lack of experience with this new technology may have led to these results.

3. *'Are you interested in purchasing a Virtual Reality device?'*

   The participants were divided between the answers 10 said ***yes***, 10 answered ***no***. However, it should be noted that all participants younger than 40 years of age answered this question in an affirmative way.

4. *'Did you feel immersed in the various virtual environments?'*

   15 participants answered ***yes*** and only 5 answered ***no***. No unanimity in this question is relative because its content can bring ambiguity and confusion to its interpretation which led not to consider it to the final conclusions.

5. *'What level did you find most difficult?'*

   13 participants answered the memory level, 2 answered the farm level, 4 answered the maze level and 1 participant answered the room level. Here it was to expect that the levels involving locomotion were in the top two but this did not happen. According to the strategy outlined the most difficult level should be the most complex, the maze level however the memory level was pointed as the hardest one. What can be concluded is that locomotion does not add difficulty at the cognitive level and only interferes with simulator sickness.

6. *'Did you feel safe using the application?*

   This was the first question where unanimity was reached. All participants felt safe using the application. It is possible to affirm that the place and the material were adequate for the accomplishment of this experience.

7. *'Did you like this experience?'*

   The second question that was unanimous which means that all participants liked the experience. If they liked it they are open to repeat an experience with virtual reality. These results can help bring more people to the area and increase the virtual community as well as make known to the public what virtual reality is. With this, it is concluded once again that the strategy outlined has been successfully achieved.

8. *'In what areas do you think Virtual Reality can have more application?'*

   Along with the sample of participants the areas of education and entertainment are those in which virtual reality can have more application. Then comes the area of tourism with 18 votes, commerce with 16, industry with 15, and health with 14. The area of sports just obtained 11 votes. A curiosity was that the pioneering area of this technology was penultimate with 13 votes as it is possible to see in the next image.

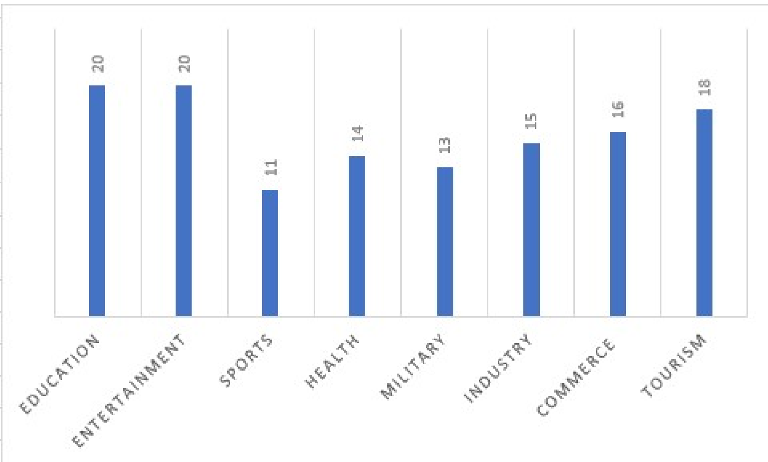

Figure 5.9: Areas of Application

5.6 Discussion

In this section is intended to present not only qualitative results but also the discussion that generated them. Constructive criticisms stated by the participants regarding the game will be presented as well as benefits and opinions on the case study and virtual reality itself.

Beginning with the constructive criticisms all directed to the game, several participants mentioned problems related with the *speed of locomotion* saying that this *could be faster*. However, mentioning the strategy outlined, the aim was to be a gradual and constructive experience that does not become shocking in the perspective of the user. Another criticism directed to the game was also involved with locomotion. This process, as explained earlier, needed a tilt of the head 15 degrees downward, curiously one of the participants mentioned that *when he tilted his head objects were lost in his field of vision* which in the perspective of the author, and making a comparison when someone moves in the car, the landscape around it becomes foggy, distorted and is not possible focus on a certain point other than the way forward. Nevertheless, in order to improve virtual reality, the concept of locomotion initiated by a tilting of the head is a process that must be less used in the future and suggesting something that may be mentioned for future research, it should be replaced by joysticks or hand-held commands that assist in the realization of this process.

Dissecting the positive criticisms, and beginning with the most elementary ones, several participants mentioned that the game was *cool, interesting, well done, enlightening, engaging, captivating, and interactive.* Several participants also mentioned that it was *easier to learn with virtual reality* because it was *attractive*, it was *not a boring way of learning* being *modern* which allowed to be *more focused* on the task they were undertaking because they were immersed in a virtual environment. Some of the participants mentioned that over the time they became used to the virtual environment which means that a period of habituation is necessary for the virtual environment to become natural to the brain and its systems. All the participants mentioned that the place was adequate and facilitated the realization of the experience. Returning to the subject of locomotion, there were also opinions and positive criticism, some participants mentioned that the speed was ideal and that if it was more they predicted some general discomfort. Conclusions that were referred in the previous chapters were also discussed with the participants being these: *A reduced cost of building models, being safe, cost effective and fully controllable, decrease the assets cost in the long run as it solves the problem of acquiring* *training rig/equipment, time and cost restrictions, enhance the opportunity to explore inaccessible or restricted locations such as chemical reactors or the interior of a volcano, make students' learning experience out of ordinary and encourage them to unleash their creativity* were the benefits in which all participants gave their positive endorsement. Other benefits not having the positive endorsement of all participants but still had the consent of the majority were related with climatic impact *the reduction of climatic impact by cutting the wasteful material or eliminating harmful mistakes by learners and reducing the risk of hazardous material in training and teaching environments* were two of these benefits.

Some suggestions were also provided by the partipantes to facilitate the inclusion in the game and in the virtual environment. The simulation of walking, shifting legs and feet up and down while sitting helped in this process and when they felt dizzy and nauseated, it was enough to close their eyes for a few moments to become considerably better.

In terms of areas two of the participants suggested the inclusion of virtual reality in the area of pornography and one suggested the inclusion of virtual reality to facilitate the learning of people with disabilities even going so far as to imagine a bedbound person to experience a learning and interactive experience. To finish a sentence uttered by one of the participants will be quoted here:

'In pedagogics term is motivating and didactic for kids. It is cool and unexpected, I was not expecting a cardboard box to be so good. I thought it was less real and less dynamic.'

6 Conclusion

In this chapter, everything that was discussed previously will be summarized as well as the impact that virtual reality has and may have in the educational area.

Summarizing, the ephemeral fame that virtual reality had in the 1990s is the starting point for a long discussion and overview of this area. A definition is given as well as a comparison with a similar area, augmented reality. Then to be understandable and to contextualize the reader of where this ephemeral fame came the history of virtual reality is analyzed as well as the devices that characterize it.

Beginning in 1929 with the Link Flight Trainer and then going through 1950 and 1960 with the development of Sensorama and Telesphere Mask respectively. After in 1961 the Headsight was developed and in 1965 the description of the concept of Ultimate Display from one of the great names of virtual reality, Ivan Sutherland. In 1968, the sword of Damocles whose name has a fascinating history and Super Cockpit were developed. Then in 1985 the term virtual reality was coined and 10 years later in 1995 during the small fame period of virtual reality the nintendo virtual boy was launched in the market which culminates with a huge failure of virtual reality area. Nevertheless the failure, some benefits had already been completed and corroborated by other researches among them the reduced cost of building models, being safe, cost effective and fully controllable, cutting the wasteful material and eliminating harmful mistakes that could jeopardize human resources and the simulation of hostile environments. Having said this, it is important to understand why such a promising area has failed atrociously being its reasons enumerated and dissected: the poor graphic quality, the weight and dimensions of the headsets themselves, the poor user experience due to the last two reasons as well as the bearing of some symptoms such as nausea and headaches, the price of the devices and the two technologies of the time, world wide web and smartphones.

After this failure came the digital revolution that in the perspective of the author plays a key role in the reappearance of virtual reality these days. With the development of technology computers and smartphones have become more personal, better and user-friendly which allowed the massification of these products making them devices of the day to day. Large companies investments have helped the area of virtual reality allowing the development of cheaper products making them more accessible for users. These products like Oulus Rift, Project Morpheus, Google Cardboard, Samsung Gear VR, Oculus Go, HTC Vive and Google Daydream have been described so it was possible to choose one of them for the case study developed. The device chosen was the Google cardboard and it is easy to see why once the goal was that everyone had access to virtual reality, being this device the apogee of this vision, since it is cheap, affordable, easy to use and every person has a smartphone.

After this the application of virtual reality is explored in learning environments such as schools, edutainment and practical applications, means of transport, sciences and military areas where the reader can have a better perception of where virtual reality can be applied as well as the benefits previously achieved are corroborated. Other benefits mentioned are increased student engagement, constructivist learning, authentic experiences that impact the student's identity, new perspective, empathy and creativity improvement through multi-sensory learning, allowance to visualize difficult models and increased concentration. On top of this virtual reality can also be used in the treatment of some diseases, including phobias, posttraumatic stress disorder and axiety disorders.

Even though this area has many benefits, some aspects can and should be improved reason why four main aspects have been identified which restrict the use of virtual reality. Firstly, health and cybersickness, the biggest problem that has lasted since the genesis of virtual reality. Three theories are discussed being The Sensory Conflict Theory the most accepted within the community. Secondly, missing realistic visual-haptic interaction, thirdly, inadequate self representation and lastly isolated user experience. In the opinion of the author and risking a forecast for the future improvement these aspects will require more research in order to be solved. The contribution of studies and experiences to the area will probably help to improve the user's interaction with the virtual environment as well as the user's own representation can resolve sensory conflicts that cause symptoms of cybersickness.

In order to corroborate all that was stated previously a case study was developed. With the opinion of the participants based on their educational experience and the game outlined for this specific case it was possible to corroborate all the benefits concluded during the investigation process as well as to make the area known to more people who showed a impetuous interest in more experiences like this one where the contact with a virtual environment was possible.

As a personal opinion, the author considers that the area of virtual reality has many benefits being all of them mentioned before. The four big aspects that need to be improved can be so if the technology's development allows a real interaction with a virtual environment as well as an appropriate representation and a social experience which will also reduce the impact of cybersickness. It is obvious that in the near future the use of virtual reality in learning environments will have to be regulated and discussed ethically and deontologically aspects. This study is also intended to help the community to sustain a thesis of progress and apotheosis within the area of virtual reality. Regarding Sutherland and its Ultimate Display the goal is a simulation of reality where it is not possible to distinguish what is real from what is not.

7 Future Research

In previous sections a future research was mentioned several times where the topic of discussion was the forms of input within the world of virtual reality. Of course there are already several companies trying various forms of input but from a personal perspective the author would like to carry out a detailed technical analysis of the various forms of input presented so far and identify their failures to contribute to the progress of this area. Along with this and with the investment of several companies it would be possible to also intervene in the missing realistic visual-haptic interaction problem. These two ideas are linked because the interaction with the scene is still very rudimental. By working and exploring these two fields of virtual reality in depth, it would be possible to give an experience in which reality and virtuality unravel in a thin line in which the user cannot distinguish one from the other which is the ultimate goal of virtual reality.

Further detailing what one intends to do and taking for example the intuitive controls of the oculus rift a detailed analysis of all forms of input so far must be made to identify and perceive what benefits and hexes these forms bring to the area. Once the benefits are clearly identified, a device should be used to not only interact with the scene itself but also to interact with the user by creating a user-scene relationship in which the input form plays a key role in the user's interaction with the scene and also with the feedback that the user will receive by this form of input independently of this feedback being vibrations, opposing movements or even, idyllically, reliefs that can be changed according to the scene itself.

With the evolution of technology this would not only be possible as it could help solving the biggest problem of virtual reality, the cybersickness. This is possible to say because as the experience becames more real and the ultimate goal of virtual reality is achieved cybersickness would not have such a big emphasis within the area that would make virtual reality a ***state-of-the-art*** of technology.

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A Simulator Sickness Questionnaire Results

Before Experience

Sex	Nausea	Oculomotor	Disorientatio	SSQ	Average
F	66.78	90.96	125.28	104.7	
F	0	0	0	0	
F	9.54	37.9	41.76	33.66	
F	9.54	15.16	0	11.22	21.9057
F	0	0	0	0	
F	0	0	0	0	
F	0	7.58	0	3.74	
M	19.08	75.8	55.68	59.84	
M	0	7.58	13.92	7.48	
M	0	0	0	0	
M	0	7.58	0	3.74	
M	9.54	7.58	0	7.48	
M	19.08	30.32	27.84	29.92	
M	28.62	30.32	0	26.18	20.7138
M	19.08	37.9	27.84	33.66	
M	0	0	0	0	
M	0	7.58	0	3.74	
M	9.54	22.74	27.84	22.44	
M	0	22.74	13.92	14.96	
M	28.62	60.64	69.6	59.84	

Age	Nausea	Oculomotor	Disorientatio	SSQ	Average
51+	66.78	90.96	125.28	104.7	
51+	19.08	75.8	55.68	59.84	
51+	9.54	37.9	41.76	33.66	47.9967
51+	0	7.58	13.92	7.48	
51+	9.54	22.74	27.84	22.44	
51+	28.62	60.64	69.6	59.84	
41-50	9.54	15.16	0	11.22	
41-50	0	0	0	0	
41-50	0	0	0	0	8.228
41-50	0	7.58	0	3.74	
41-50	28.62	30.32	0	26.18	
21-30	0	0	0	0	
21-30	0	7.58	0	3.74	
21-30	9.54	7.58	0	7.48	
21-30	19.08	30.32	27.84	29.92	11.22
21-30	19.08	37.9	27.84	33.66	
21-30	0	7.58	0	3.74	
21-30	0	0	0	0	
10-20y	0	0	0	0	7.48
10-20y	0	22.74	13.92	14.96	

After Experience

Sex	Nausea	Oculomotor	Disorientatio	SSQ	Average
F	57.24	90.96	97.44	93.5	
F	19.08	15.16	13.92	18.7	
F	28.62	22.74	41.76	33.66	
F	57.24	53.06	153.12	89.76	40.0714
F	9.54	0	0	3.74	
F	28.62	7.58	13.92	18.7	
F	28.62	7.58	27.84	22.44	
M	66.78	68.22	41.76	71.06	
M	38.16	22.74	83.52	48.62	
M	0	7.58	0	3.74	
M	0	0	55.68	14.96	
M	9.54	0	0	3.74	
M	124.02	106.12	236.64	164.6	
M	19.08	30.32	27.84	29.92	36.8246
M	38.16	45.48	69.6	56.1	
M	0	0	0	0	
M	0	7.58	0	3.74	
M	9.54	7.58	0	7.48	
M	0	22.74	13.92	14.96	
M	57.24	45.48	55.68	59.84	

Age	Nausea	Oculomotor	Disorientatio	SSQ	Average
51+	57.24	90.96	97.44	93.5	
51+	66.78	68.22	41.76	71.06	
51+	28.62	22.74	41.76	33.66	52.36
51+	38.16	22.74	83.52	48.62	
51+	9.54	7.58	0	7.48	
51+	57.24	45.48	55.68	59.84	
41-50	57.24	53.06	153.12	89.76	
41-50	19.08	30.32	27.84	29.92	
41-50	0	0	0	0	29.172
41-50	9.54	0	0	3.74	
41-50	28.62	7.58	27.84	22.44	
21-30	0	7.58	0	3.74	
21-30	0	0	55.68	14.96	
21-30	9.54	0	0	3.74	
21-30	124.02	106.12	236.64	164.6	37.9343
21-30	38.16	45.48	69.6	56.1	
21-30	0	7.58	0	3.74	
21-30	28.62	7.58	13.92	18.7	
10-20y	19.08	15.16	13.92	18.7	16.83
10-20y	0	22.74	13.92	14.96	

Comparation

Sex	Before	After
F	21.90571429	40.07
M	20.71384615	36.82

Age	Before	After
51+	47.99666667	52.36
41-50	8.228	29.17
21-30	11.22	37.93
10-20y	7.48	16.83

All	21.131	37.96