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DEGREE DISERTATION

Industrial electronics and automation engineering degree

Electrical engineering degree

DESIGN OF VR APP APPLIED TO COGNITIVE TRAINING

Volume I

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Resum

En l'actualitat, el món de la realitat virtual (RV) està agafant cada cop més força i s'està expandint en múltiples àmbits del nostre dia a dia. La realitat augmentada va començar a tenir molta repercussió en el món del videojocs ja que aporta a l'usuari una major immersió de l'entorn i, per tant, augmenta l'experiència sensorial del joc a un nivell molt superior. No obstant, la realitat virtual no es va quedar a l'àmbit lúdic sinó que s'ha anat expandint en altres àmbits professionals enfocats a les tecnologies com per exemple les enginyeries, arquitectura, medicina, etc...

En aquest projecte, veurem la realitat virtual enfocada al món de la medicina i els avantatges que pot aportar aquest avenç tecnològic en aquest àmbit. Per aconseguir-ho, es realitzarà el projecte en col·laboració amb l'Hospital Clínic amb el qual es podran fer proves reals amb pacients per veure l'eficacia del projecte i de la realitat virtual en el món de la medicina. També es comptarà amb el suport de l'empresa Visyon 3D que ens proporcionarà els equips i tecnologia necessària per dur a terme el projecte.

El projecte consisteix en la continuació de l'aplicació per tal de millorar-la i refinar-la per fer que l'adaptabilitat, control i jugabilitat de dita aplicació utilitzant la realitat virtual sigui el més fàcil i simple per facilitar l'experiència del pacient i el treball del metge encarregat de l'usuari de l' aplicació. També s'implementaran diverses aplicacions de diferents projectes en una sola per tenir un conjunt global.

La part de la memòria del projecte inclou el llistat de tots els elements, organització i estructura del disseny de l'aplicació i com ha estat programat. D'aquesta forma es presenten les millores que s'han introduït i el resultat final amb les proves del pacients amb els determinats anàlisis.

Per últim s'ha valorat el projecte realitzat amb unes conclusions en la part final amb les quals, també s'ha volgut fer èmfasi en les línies futures en les que es podran treballar de l'actual aplicació.

Resumen

En la actualidad, el mundo de la realidad virtual (RV) está tomando cada vez más fuerza y se está expandiendo en múltiples ámbitos de nuestro día a día. La realidad aumentada comenzó a tener mucha repercusión en el mundo de los videojuegos ya que aporta al usuario una mayor inmersión en el entorno y, por tanto, aumenta la experiencia sensorial en el juego a un nivel mucho más superior. Sin embargo, la realidad virtual no se quedó en el ámbito lúdico, sino que se ha ido expandiendo en otros ámbitos profesionales enfocados en las tecnologías como por ejemplo las ingenierías, arquitectura, medicina, etc…

En este proyecto, veremos la realidad virtual enfocada en el mundo de la medicina y las ventajas que puede aportar este avance tecnológico en este ámbito. Para ello, se realizará el proyecto en colaboración con el Hospital Clínico, con el que se podrán hacer pruebas reales con pacientes para ver la eficacia del proyecto y de la realidad virtual en el mundo de la medicina. También se contará con el apoyo de la empresa Visyon 3D que nos proporcionará los equipos y tecnología necesaria para llevar a cabo el proyecto.

El proyecto consiste en la continuación de la aplicación para mejorarla y refinarla para hacer que la adaptabilidad, control y jugabilidad de dicha aplicación utilizando la realidad virtual sea más fácil y simple para facilitar la experiencia del paciente y el trabajo del médico encargado del usuario de la aplicación. También se implementarán varias aplicaciones de diferentes proyectos en una sola para tener un conjunto global.

La parte de la memoria del proyecto incluye el listado de todos los elementos, organización y estructura del diseño de la aplicación y como ha sido programado. De esta forma se presentan las mejoras que se han introducido y el resultado final con las pruebas de los pacientes con los determinados análisis.

Por último, se ha valorado el proyecto realizado con unas conclusiones en la parte final con las que, también se ha querido hacer énfasis en las líneas futuras en las que se podrán trabajar de la actual aplicación.

Abstract

Currently, the world of virtual reality (VR) is taking more and more strength and is expanding in multiple areas of our day to day. The augmented reality began to have a lot of repercussion in the world of videogames since it brought the user a greater immersion in the environment and, therefore, increase the sensory experience in the game to a much higher level. However, the virtual reality did not remain in the recreational area, but it has been expanding in other professional areas focused on technologies such as engineering, architecture, medicine, etc...

In this project, we will see the virtual reality focused on the world of medicine and the advantages that this technological advance in this field can bring. For this, the project will be carried out in collaboration with the Clinical Hospital, with which real tests with patients can be done to see the effectiveness of the project and virtual reality in the world of medicine. There will also be the support of the Visyon 3D company that will provide us with the necessary equipment and technology to carry out the project.

The project consists of the continuation of the application to improve and refine it to make the adaptability, control and playability of said application using virtual reality easier and simpler to facilitate the patient experience and work of the doctor in charge of the user of the application. Several applications of different projects will also be implemented in one to have a global set.

The part of the project memory includes the list of all the elements, organization and structure of the application design and how it has been programmed. In this way, the improvements that have been introduced and the result with the tests of the patients with the determined analyzes are presented.

Finally, the project has been valued with some conclusions in the final part with which, we also wanted to emphasize the future lines in which the current application can be worked on.

Acknowledgements

In this section we would like to thank all the people who have helped us to carry out this project. We are sure that without their help everything would have been much more difficult.

First of all, we would like to thank Jordi Torné and Francesc Alpiste for giving us the necessary tools to carry out the project. They have been very close to us and have solved all the questions we had. We consider them a fundamental part of the project.

We also want to thank Magda Castellví and Ana Salinero, Hospital Clínic therapists, for their collaboration with the project.

Of course, also thank the volunteers of the Hospital Clínic who tested the application. Their opinion was fundamental for us to finalize the application. Seeing how they played with it allowed us to observe where was necessary a change. It was very useful to improve the application. We really appreciate it.

The company Visyon 3D left us the HTC VIVE and the computer to carry out the project. Thanks to Josep Lorente and Iñigo Gainza for giving us some indications for the application.

Thanks to Adrián Mora, Jesús María, Óscar Ribas and Sergio Sanjorge because they have helped us with some doubt we had about they had done their part of the application.

Finally, we would like to thank our families and friends for all the support they have given us throughout the realization of the project.

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1. Preface

1.1. Project backgrounds

The main idea of the project is to do a virtual reality application which is very helpful for adult people with mild cognitive problems. The VR application won't be an exercise to cure the disease, but it will be a good workout for that people. For that reason, the professors Jordi Torné and Francesc Alpiste and the Alzheimer's unit of the Hospital Clinic decided to carry out this project.

Last quarter, Adrian Mora Pedregosa, Jesús María Merino, Sergio Sanjorge Area and Óscar Ribas Riera started the design of the application with their TFG.

It is important to note that there are several research studies that confirm that these types of exercise are beneficial for patients with mild cognitive problems.

1.2. Motivation

Medical motivation

There are many research studies that explain how virtual reality is a very useful tool for people with cognitive problems. The professionals of the Hospital Clínic thought that it could be very useful medically and they wanted that the UPC students create an application to help their patients. It is important to mention that the idea is not that the application can cure patients. The main idea is to create very useful tool that can reduce the effects of the disease for a while and improve the quality of life of the patients. Therefore, this project aims to provide a small amount of sand to the research work on techniques that can help people with cognitive problems.

Personal motivation

Virtual Reality is a technology that is growing very fast. It has application in very different fields and we are sure that is widely used in the not too distant future.

We really did programming subjects but we had not worked with the virtual reality or the programs that we had to work to do this project. What made us to decide to do a TFG like this was the interest for a type of technology that we do not know. In addition, we believe that in the future this knowledge can be very useful for our professional careers.

Another aspect that we liked about doing this project was the fact of being able to work with companies outside the university. We had the opportunity to work with Visyon 360, one of the best companies providing immersive experiences, and with the Hospital Clínic. Doing the TFG in English was also a great challenge for us.

1.3. Previous knowledge

In order to develop a virtual reality program is necessary to know:

- Programming in C#
- Body representation knowledge in 2D and 3D
- Programming in Unity

2. Introduction

2.1. Project goals

Medical goals

The main goal in this project is create an application to help at the user step up his mental abilities and slow down his degenerative mental illness. We must remember that this type of disease doesn't have a cure. The user only can slow down the process through therapy, drugs or, in this case, using the virtual reality. With this application the patients can be immersed in a virtual reality where they can improve their mental abilities without being exposed to any danger and being controlled by a doctor all the time while he does the activity.

Project goals

During the project we have been acquiring knowledge about C# advanced language while we were doing the scripts for the application. Furthermore, we are learning to use new programs such as Unity 3DS, MySQL or Visual Studio.

The most important project goal has been upgrade the last version of the VR application for cognitive training. For do this, we added new functions in the application and removed others to improve the use of the app and make the player experience as friendly as possible.

2.2. Scope of the project

This project is focused on the cognitive training of patients who have a mild cognitive impairment. This VR application has multiples levels of difficulty to test the patient and see his progress during the therapy. While the patient is using the app all his mistakes, success and end time of the activity will be saved in a database so the doctor will be able to follow up the progress of him and see the evolution of the mental illness.

It is very important that the application will be the friendliest as possible for the user. The controls of the game have to be very simple and easy to use. Also, immersion is an important factor too because the patient must be able to distinguish the different elements of the environment without any confusions.

3. State of art

3.1. Virtual reality

Definition

Virtual reality (VR) is a computer-generated scenario that simulates experience through senses and perception. The immersive environment can be similar to the real world or it can be fantastical, creating an experience not possible in our physical reality. The main goal is to make the user feel that he is immersed in the virtual world and make the experience as credible as possible.

In addition, the software allows the user to be an active element in this virtual world because visual and audible stimuli are used. The person can make decisions and act by obtaining answers from the program; he is not just a spectator.

Characteristics

Below are some of the main characteristics that virtual reality has.

- Interactive: The user and the environment communicate constantly; there is a continual exchange of information.

- Believable: System responses to the user's physical actions help to assimilate the space in a way that looks realistic.

- Realistic: With VR you can make objects and environment very similar to reality.

- Explorable: A VR world needs to be big and detailed enough for you to explore. It's important that the user can move about normally within the confines of the environment.

- Immersive: the artificially created environment looks so much like the real one that it really seems that you are in that environment.

History

Virtual Reality is not a new concept. In fact, it traces its history until before the 50s of the last century, first with illustrations and texts referring to an alternative reality and then with machines that

simulated the costumer's journey to unknown worlds. But of course, the technique limited these experiences a lot.

In 1930, the first flight simulator was created, in order to train inexperienced soldiers to pilot the latest models of aircraft, since otherwise it would not turn out well either of the two parts. This aroused the interest of researchers and designers to develop more and more simulators of higher quality and interaction capacity.

In 1950, Morton Heilig developed a simulator called Sensorama. He saw the theatre as an activity that could encompass all the senses in an effective way, thus preparing the viewer for the activity on the screen. The viewer could visualize 5 small movies while simulating the other senses. He called it "Theatrical Experience". This simulator combined 3D images along with sound, wind and smells to create an illusion of reality.

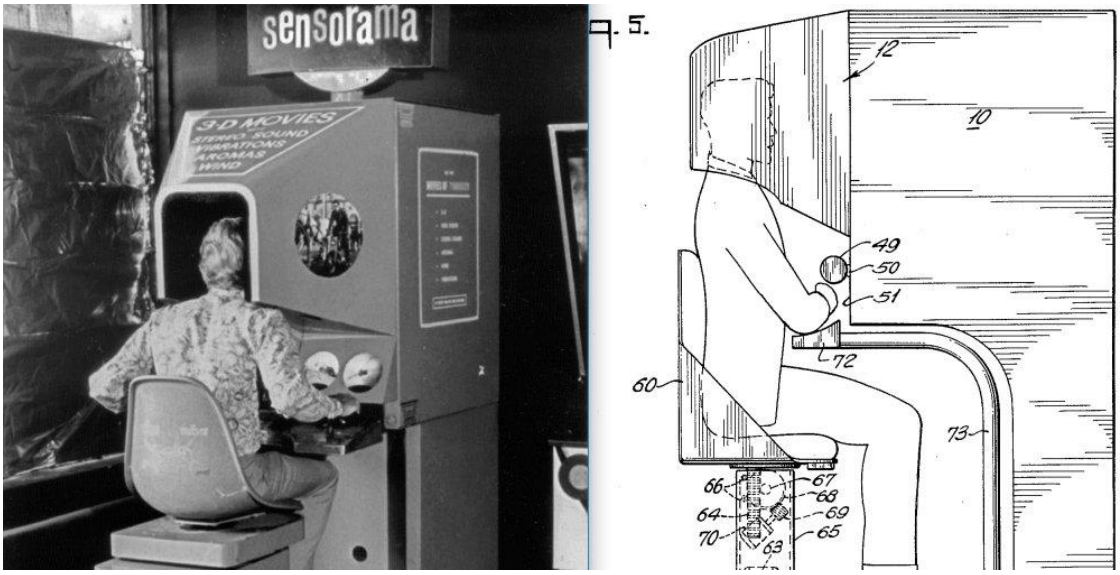

Figure 3.1 The simulator Sensorama (Source: Google Images)

The first truly virtual reality helmet would arrive in 1961, built by Corneau and Bryan, employees of a company called Philco Corporation. The helmet, called "Headsight", incorporates a screen and has a position control of the head. The project was used for military training. Although the element was not connected to a computer, "Headsight" pioneered the practice of leveraging virtual reality technology and training purpose.

In 1965 Ivan Sutherland described the concept of virtual reality with the publication of an article called "The Ultimate Display" in which he explained the concept that scientists had been trying to establish for years. A couple of years later, he and his team at MIT (Massachusetts Institute of Technology) developed a virtual reality device which consists of a helmet attached to a computer.

The helmet and computers used at that time are so big and heavy that the helmet is hung from the ceiling, earning the device the nickname of “Sword of Damocles”.

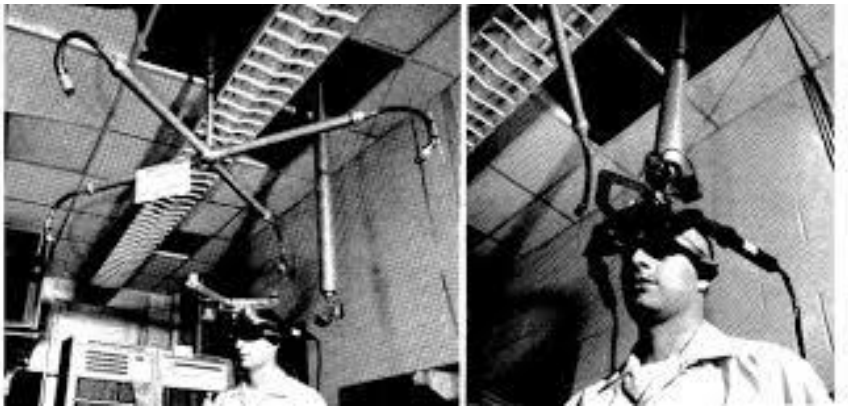

Figure 3.2 The “Sword of Damocles” (Source: Google Images)

In 1982, Jaron Lanier develops Data Glove, gloves with sensors capable of recognizing the movements and position of the fingers. This same year the company SEGA presents the first video game on the market with stereoscopic image, the SubRoc-3D, with some glasses and recreational machine.

It was in the NASA, in 1984, where the first low cost virtual reality glasses were developed, called VIVED (Virtual Visual Display System), by a research group led by Michael McGreevy. With these glasses demonstrations were made oriented to the industry and the university.

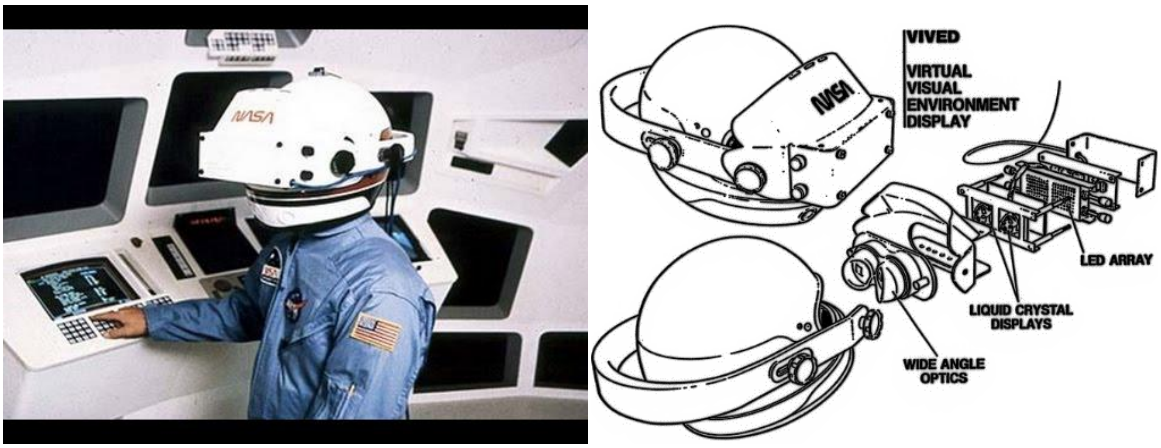

Figure 3.3The VR glasses VIVED (Source: Google Images)

In the 90s, the first commercial launches on Virtual Reality were seen. In 1991, SEGA announced the Sega VR for arcade video games and its Mega Drive console. It used the LCD screen in the viewfinder, stereo headphones and displacement sensors that reacted to the user’s head movements. The model was exposed in several videogames fairs but it never got commercialized due to various problems.

Nintendo, an expert company in the field of innovation, launched on the market "Virtual Boy" in 1995. It was a pair of glasses that used a projector inside to show monochrome 3D through a stereoscopic effect. Although it reached the market with great expectation due to the rise of virtual reality, the console was a true commercial failure. So much that it was not even commercialized in Europe and many consider it one of the worst consoles that Nintendo has given since its inception.

Figure 3.4 The glasses "Virtual Boy" (Source: Google Images)

Palmer Luckey, in 2010, tries to recover almost 20 years after failed projects the idea of a helmet/ virtual reality glasses. Luckey start developing a device that will be the prelude to the Oculus Rift. He made a campaign to get the necessary funding. The campaign was a success. Later, Facebook made a large outlay of 2.000 million dollars and bought the whole project and the Oculus Company. After the birth of Oculus, the big companies from different areas of the technological world started a career and began to develop prototypes of virtual reality glasses. In April 2016, HTC ordered the first HTC VIVE Steam VR helmet units, marking the first commercial launch of a virtual reality system with sensor-based position tracking, allowing free movement of users within a space definite.

Types of RV technologies

Not all types of virtual reality are the same. The categories that exist are immersive reality, semi-immersive reality and non-immersive reality. The truth is that all meet the same objective although the differences between the three categories are big.

- Immersive reality: Is where the user has the sensation of being exploring a virtual world, using different accessories such as glasses or helmets which are the main elements so that the user can teleport to different worlds. Its main advantage over the other two types of immersion is that the person van experiment the virtual reality environment without the need of a computer monitor, a television screen or an overhead projector.

- Semi-immersive reality: It results a balance between both worlds (virtual and real). It is characterized by four cube-shaped screens, three for the walls and one for the floor, which surround the user In them the visual elements are seen in the real environment, a feature that allows us to appreciate an advance of how things will look in the future. They are used mainly for those visualizations where the user is required to keep in touch with elements of the real world.

- Non-immersive reality: The visualization of virtual elements id done through a screen. The interaction is done through accessories such as the mouse, microphone or the keyboard. The user is not the protagonist of the action; there is an avatar that represents the user who is within the reality environment.

3.2. Possible applications

The Virtual Reality emerged in the field of video games and entertainment in general, but due to its almost infinite possibilities has spread to fields and sectors very varied. Here are some of the applications that VR has:

- Medicine: In the medicine field, the uses of VR can be multiple. Currently, it is the sector where their advances are most effective. Within medicine, the most representative applications are carried out in the following areas: simulations for medical training, treatment of psychological traumas, surgery operations and pain management through distractions.

- Military: VR allows to train military professionals in a virtual environment where they can improve their skills and abilities without the risks of training in a battlefield. This environment generated by computer applications is also used in fight simulation for the air army where people train to be pilots. In the same way, virtual driving simulations are used to train drivers of trucks, tanks and all kind of vehicles.

- Leisure and entertainment: Is in the field of leisure and entertainment where Virtual Reality applications are more developed thanks mainly to the video game industry. The industry moves millions of Euros and their public is willing to spend large amounts of money to get all the peripherals to enjoy a total immersion. The immersion and the interactivity with the environment generated are virtually clear differences with regard to traditional video games.

- Architecture: The great advantage of virtual reality in architecture is that through a virtual reality viewer it is possible to immerse in the projects created. It is very helpful because you can perceive proportions or size in a realistic way. The tendency to apply for projects in VR is beginning to grow because when customers put on the glasses they understand the space as they were there.

- Education: The possibilities of virtual reality in the field of education are endless and bring many advantages to students of all ages. The technology has enormous potential in education since it is proven that students process content better when there is a motivational component and virtual reality applications have all the attractiveness and tools to achieve it.

  Here there is an image where we can see a prediction of in what sectors the VR applications will be more important in the future:

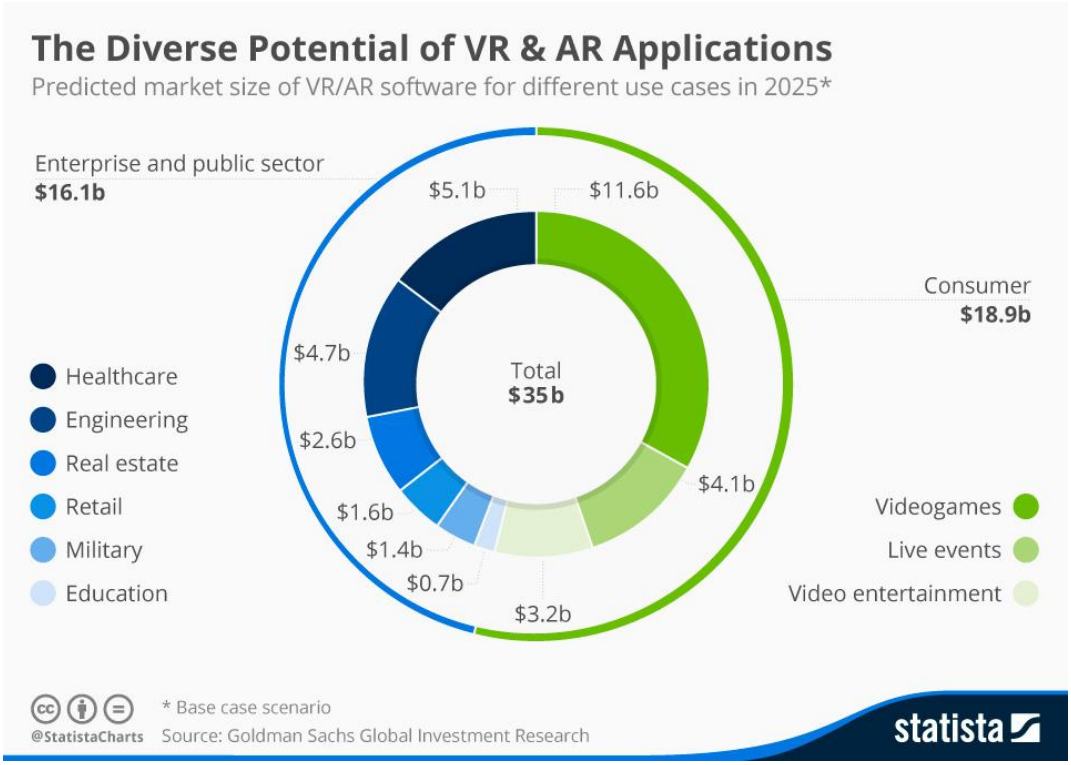

Figure 3.5 The predicted market of VR in 2025 (Source: Statista)

4. Current situations on mild cognitive impairments treatment

Currently, the people affected by Alzheimer's disease have been increasing with the aging. This fact is a consequence of the improvement of life expectancy that allows the population to live longer so they are more probably to generate a mild cognitive impairment (MCD).

This situation leads us to investigate deeply about the cognitive impairment to be able to treat it in the early phases when the patient may suffer response inhibition, cognitive flexibility, and attention switching and planning (Yeh, S. C., Chen, Y. C., Tsai, C. F. and Rizzo, A., 2012). Scientific and medical research are focused to early diagnose of the Scientific and medical research are focused to early diagnose in the Alzheimer's Disease (AD) patients because it can be providing information about the transitional phase between normal aging and dementia (Petersen, R.C., Doody, R., Kurz, A., Mohs, R.C., Morris, J.C. and Rabins, P.V., 2001).

Many National Institutes for Health recommends track all the process of cognitive impairment in the patient to be able to detect problems early. However, they don't have a specific treatment for this disease.

There are two forms to treat the cognitive impairment before it becomes a dementia:

- Using drugs (pharmacological intervention)
- Group or individual therapy (activities, talks)

The pharmacologic method doesn't cure this type of disease, only can slow the process of the cognitive impairment but it is a beneficial way that enhances and improves cognitive abilities (Requena, Maestu, Campo, Fernández y Ortiz, 2006). However, this is not an efficient system because there are many factors that can affect the treatment (age, sex, conditions of the person, etc…). Also, using drugs may carry secondary effects in the patient; therefore, it is normal using therapies and activities (Sitzer, Twamley y Jeste, 2006) to treat the disease without harmful effects but this method has fewer efficacies (Baldelli et al., 1993; Clare y Woods, 2003). Furthermore, this last method can be boring for the patient and even overwhelming.

The first problem to determine a treatment for the Alzheimer's Disease is which criteria is better to choose for each patient. We need to keep in mind that there are different levels of MCD so the first step is evaluating which grade of cognitive impairment has the patient. At the end of task, it is sure to have many different results (in the study we have a group of persons with MCD) because each

patient has a different level of MCD and different difficulties this will make it complicated choose a general criterion to treatment the disease. Also, each patient can response in a different way (secondary effects, physical and psychological conditions) so the results of the treatment may have between other results.

In these last years, the technology field has been growing exponentially because it is always in constant development. Every year the technology evolves and is updated to meet the needs of modern society. These changes have allowed the world of videogames to improve and be used in professional field (engineering, medicine, architecture, etc…). In this case, the virtual reality (VR) is growing towards different areas. Especially the medicine field is using the virtual reality as an aid to research and therapy.

There are clinical studies that affirm the positive results (Farina et al., 2002; Farina et al., 2006) when using ritual reality or videogames in the therapies of patients. These applications can improve the cognitive abilities while being fun and varied (Karlsson, Brane, Melin, Nyth y Rybo, 1988; Ragneskog, Kihlgren, Karlsson y Norberg, 1996) helping to improve the dementia's SPCD (*síntomas psicológicos y conductuales de la demencia*). In addition, this method prevents the patients form having stress and they can do the activities more relaxed (they see the application such as a game, not an exam). All these factors make the treatment of the mild cognitive impairment more optimal and less aggressive for the patient while the application is collecting all data for the doctor automatically.

In the next image, it can be seen the results of diverse treatments. One of these treatments was a videogame called "Big Brain Academy" (BBC) to check the effectiveness of the videogames in mild cognitive impairment front the Integral Psychostimulation Program (PPI):

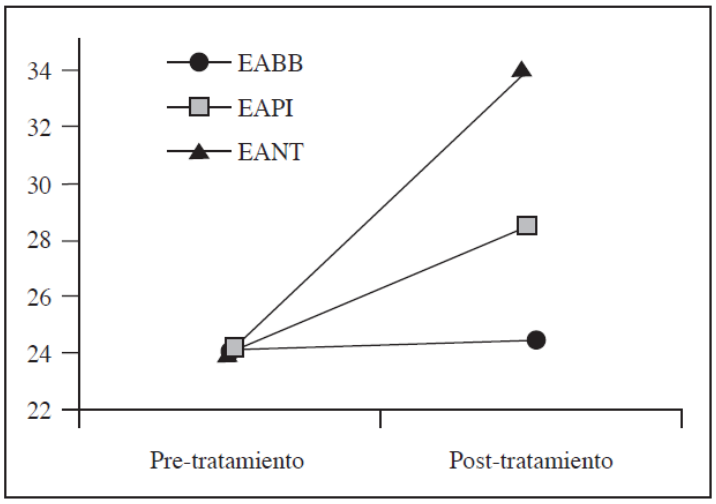

Figure 4.1 Evolution of patients in a test with different treatments (Source: Requena, Maestu, Campo, Fernández y Ortiz, 2006)

The graphic shows 3 results:

- EABB: group of videogames (BBA)
- EAPI: group of traditional therapy
- EANT: group without treatment

We can see that the group of patients who did not have a treatment remains constant in the progress of their abilities. On the other hand, the group with traditional therapy and the group of videogames had an important progress but the group of the patients that played at the BBA had better results.

Finally, the experiment showed that videogames can provide beneficial results for medicine and the treatment and prevention of dementia because they can contribute factors that other methods do not have.

5. Definition of the project

5.1. Objectives of the project

This project is a continuation of previous works based on the design of VR app applied to cognitive training. Our task in the realization of the project has been to fulfill these three fundamental objectives:

- Improve the actual project and update his scripts and functions. This is an important task to do the application friendlier as possible and facilitate control and interaction with the environment.

- Test the application in a real activity. When the project was done, we have gone to Hospital Clínic to do a test with mild cognitive impairment's patients and stored all the results

- Document and organize all the elements that make up the application (game control, gamer, audios, terrains, textures, scripts, game objects, etc.…)

These objectives form our project and allow us to extract a general goal: improve the application for a better use for the patient and store the results of the tests and the configuration of the application so that in the future others can continue with this project to improve it.

We must keep in mind that patients who use the application have an average age of between 45 and 50 years so they are inexperienced people in new technology (virtual reality).

To be careful on this topic we have organized meetings with the Hospital Clínic and our project coordinators to determine what improvements and new functions could be implemented in the application. We also had the support of Visyon360 for solve any question that we had.

From that moment, we have focused on optimizing and improving the patient experience in the game to increase his immersion in the VR while is training his cognitive skills. In addition, it has always been tried that the interface and the controls are as simple and intuitive as possible to rest difficulty in the application and do it friendly.

Finally, we want to remark that the objective of the application is to treat patients with mild cognitive impairment and train their mental skills while patients have a good time without their feeling overwhelmed or examined as if it was a test of control.

For this reason, all our new functions, modifications or changes are destined to reach that goal.

5.2. Methodology and planification

We have planned the project in different important processes:

- Write the project's memory
- Meetings
- Implement and create new functions, levels, and elements in the application
- Debug script's errors
- Test the application and analyze the feedback and results

To do these processes, several meetings were organized among the project coordination to do a periodic review of the state of work. Also, we had meeting with the previous student in charge the application so that he could explain to us what the status was when he finished the project.

On the other hand, other meetings were realized with the doctors of the Hospital Clínic (Magda and Ana) to asked them if they need implement new functions in the project and which type of data are more important to be recorded in the database.

Finally, we had one meeting in Visyon360 with Iñigo to solve a few doubts about programing and design in Unity.

We updated the last version of the project changing structures of the supermarket and his elements (products, meshes, etc.…). We have improved too the gameplay of the application and we have created new menus for the user's interface.

These changes were realized for increase the immersion when the patient is playing and remove any problem such as for example speed of movement, recognize products, locks in environment and poor-quality audio.

Furthermore, this project is the combination of two different jobs, therefore we have put them together in a single project and debugged all the errors during the process. This aspect was an important problem because booth projects are from different person so the structure, interface, gameplay and scripts are totally different. For this reason, before to joint in a single project we had to fix all compatibility errors. We have reviewed all the code and functions of booth applications and have changed the elements that impeded the good operation when we try join them in a single application.

After to improve application and implement modifications, we have tested the VR app in the Hospital Clínic with patients. We have recorded the results and asked them if they had any suggestion or changes for the application.

That day was very important for us because we could see what aspects of the project we could improve to facilitate the patient's experience.

5.3. Gantt diagram

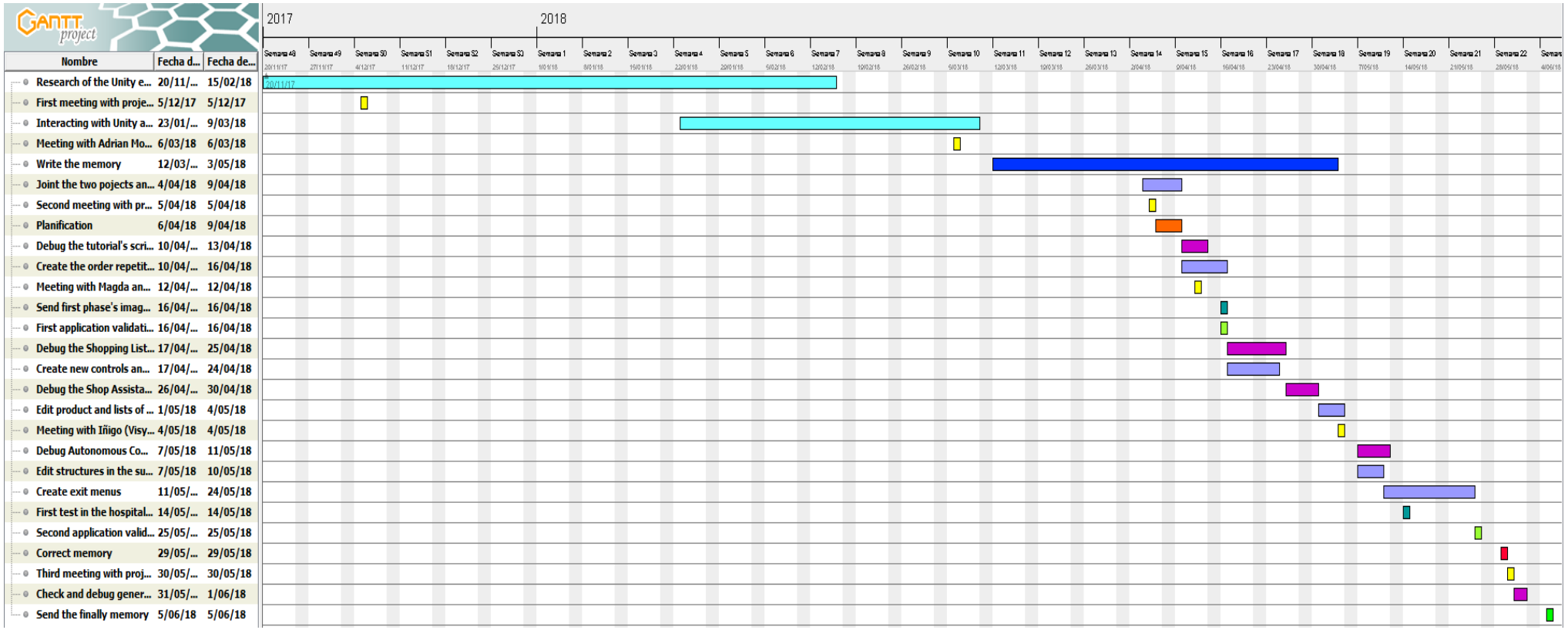

Figure 5.1 Gantt diagram (Source: prepared by the authors)

5.4. Application requirements

During the realization of the project some requirements have been set for the application to be optimal and functional.

These requirements are:

- Different difficulties levels.
- Code and different scripts with a robust structure fail-safe.
- New structure for the controls in the game to facilitate the patient's gameplay.
- Realistic textures and products of the supermarket to make the app more realistic and make easier recognize the elements.
- New supermarket's environment. Fix errors with the light, terrains and walls to get more immersion when the patient is playing.
- Good-quality audios.
- New enter and exit menus to do the interface friendlier and simple to use (only accessible for the doctor).
- New shopping lists with different products.
- Lock the exit option only for the doctor (the patient cannot access at this function).
- Remove all functions, elements and scripts useless to make the application more lightweight.
- Real time data collection.
- Store all the patient's results in a local database (only accessible for the doctor).
- ID for recognizing the patient
- Compatible for VR HTC VIVE

6. Definition of the application

The application "VR Supermarket Experience" has been possible thanks to the collaboration of the Hospital Clínic and the virtual reality company Visyon 360.

Its purpose is to renew and replace the current techniques used in the treatment of mild cognitive impairments through the virtual simulation of an everyday act such as going to a supermarket to make the purchase.

Below are explained the four parts of the application, the menus and what is new compared with other projects.

6.1. Tutorial

Explanation

The first part of the application VR Supermarket Experience is a tutorial to help the patient. It will be useful because the patient can begin to get used the application and know how to relate to the environment. He will use the commands to pass different proofs that will allow the patient to familiarize himself with the mechanics of the application.

First of all, the user will learn to move the head to look around. Virtual reality allows a 360 degrees vision by turning the head and in this first part we want to help the patient realize that.

The user will be in a small room with four walls. In three of them there will be a red sphere that will change to a green colour when it will be viewed from the front. This exercise will make the person turn on itself.

Figure 6.1 First part of the tutorial (Source: prepared by the authors)

Once the three spheres are green, the user will have to look towards the other wall where a door will be found. When the door is facing forward it opens. Behind the door there is a corridor that must be passed using the controls of the commands.

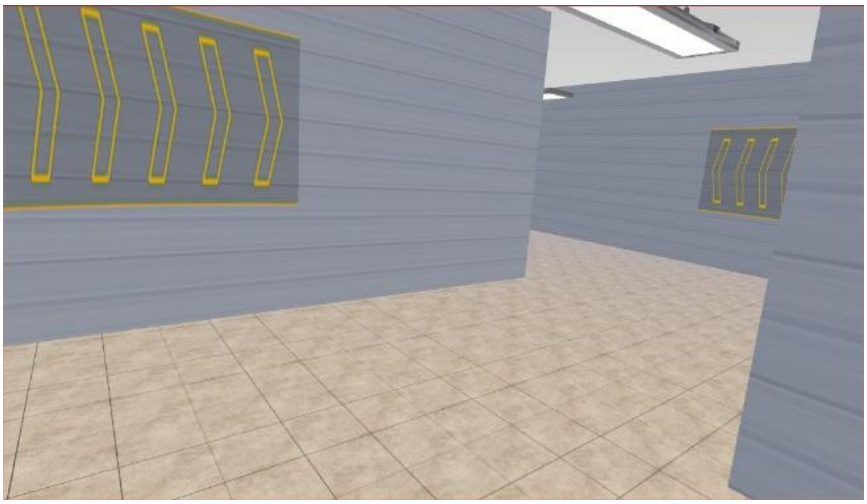

Figure 6.2 The corridor of the tutorial (Source: prepared by the authors)

Once you have covered the entire corridor you will reach the last room of the tutorial. The room has shelves with typical products of a supermarket and a big table in the middle of the room. In this part of the tutorial the patient will learn to take the products and leave them on the shelves.

Figure 6.3 Room with shelves of the tutorial (Source: prepared by the authors)

There are three products on the table (a pack of chestnuts, a package of chickpeas and a packet of salt). Once you have taken each of these products, on the opposite shelf you will be able to see a green silhouette where the corresponding product will have to be placed.

Figure 6.4 Placing the products of the tutorial (Source: prepared by the authors)

Once the three products will be placed in their respective shelves, the patient will be congratulated and the tutorial will be finished.

Then, the patient will go to a supermarket to practice the movements learned in the tutorial. In the supermarket the user will be able to catch the products that he wants and put them in the basket. It is a scene for the patient to become accustomed to the environment in which they will later have to unwrap.

Figure 6.5 Test Scene (Source: prepared by the authors)

Objects

In this section of the project the objects created to elaborate the tutorial are explained.

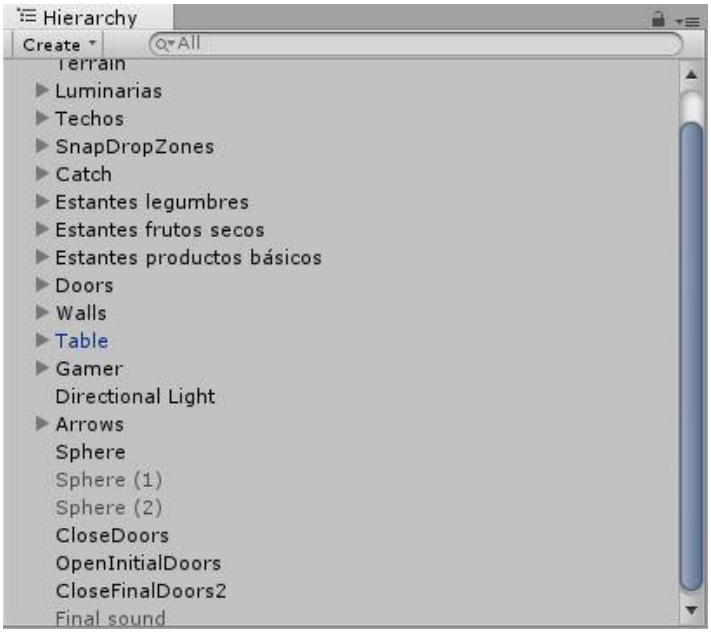

Figure 6.6 Objects of the tutorial (Source: prepared by the authors)

There is a terrain with a texture to do it more realistic.

Figure 6.7 Terrain of the tutorial (Source: prepared by the authors)

There are also ten luminaries hanging from the ceiling.

The SnapDropZones are the areas that the product occupies at the end of the tutorial. There are two SnapDropZones for each product. The first one is the zone on the table where the product is before it is caught by the user. The other one is the area in the shelf where the patient has to put the product. The SnapDropZones are useful for the patient because in this way it is easier to see where each

product must be placed. The colour of the area is green because it is an easy colour to distinguish between the other products.

Here there is the example of the chestnuts.

Both SnapDropZones have a script of Snap Drop Zone with the object of the chestnut and the colour of the silhouette.

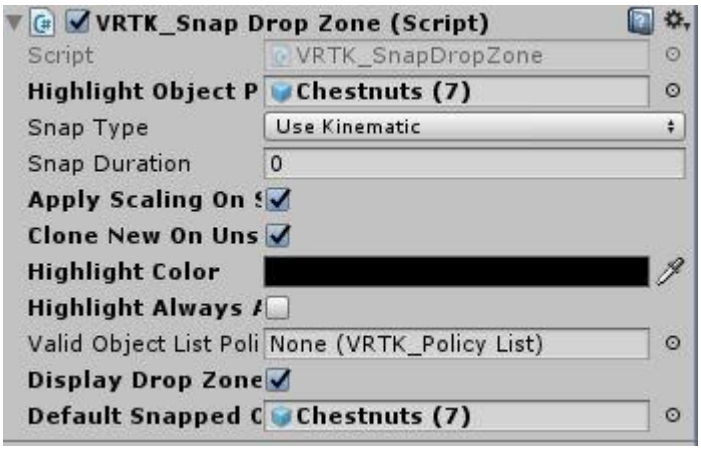

Figure 6.8 Snap Drop Zone Chestnut 1 (Source: prepared by the authors)

Figure 6.9 Snap Drop Zone Chestnut 2 (Source: prepared by the authors)

As we see in the figure 6.9 there is a policy list to control that the chestnut is in the correct area.

The SnapDropZone 2 has a unity event which makes that the next object appears on the table once the chestnuts are placed correctly.

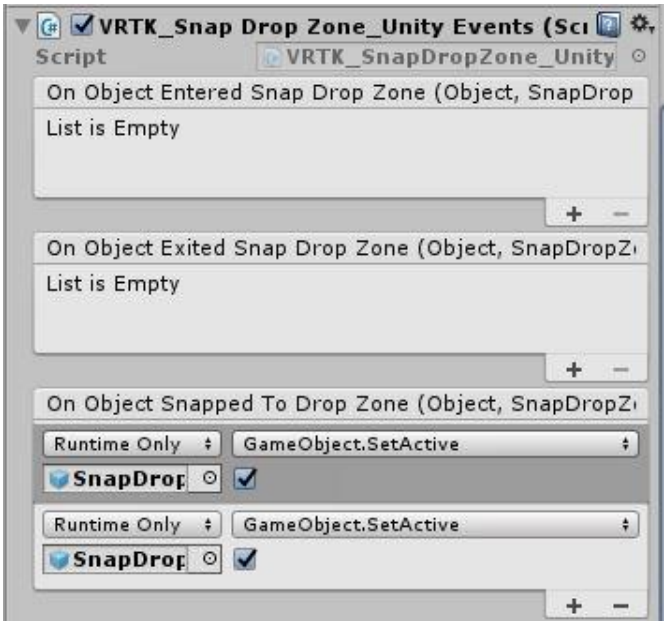

Figure 6.10 Snap Drop Zone Chestnut 2 Unity event (Source: prepared by the authors)

In the object Catch there are the three objects that the patient has to catch and put it in the corresponding shelf. There are chestnuts, salt and chickpeas.

There are three shelves in the last room of the tutorial. The legumes shelf contains lentils, chickpeas, beans, rice, flour and macaroni. The patient must put the chickpea which is on the table in this shelf.

Figure 6.11 The legumes shelf (Source: prepared by the authors)

There is the nuts shelf where the user must put the first object, the chestnuts; this shelf contains almonds, pistachio, hazelnuts, chestnuts and peanuts.

Figure 6.12 The nuts shelf (Source: prepared by the authors)

The last shelf, the basic products shelf, contains vinegar, salt, pepper, eggs sugar and oil. In this shelf the patient must put the salt which is on the table to finish the tutorial.

Figure 6.13 The basic products shelf (Source: prepared by the authors)

There are two doors; the first door is in the initial room and the second one is in the last room. The two doors are made from aluminium.

There are walls during the tutorial; in the initial room, in the corridor and in the final room. There is a material in each wall to do it more realistic.

There is a table in the centre of the final room in which the object that must be placed on the shelves are appearing.

The gamer is the most important object of the application. It controls the camera and the movements. It has five important objects inside that are explained below.

Figure 6.14 Gamer (Source: prepared by the authors)

In the VRTK_SDK Manager we can control the camera and the controllers and we can relate them to each other. Inside the VRTK_SDK Manager there is the SteamVR and inside the SteamVR there are the CameraRig and the VRSimulatorCameraRig.

Figure 6.15 Gamer extended (Source: prepared by the authors)

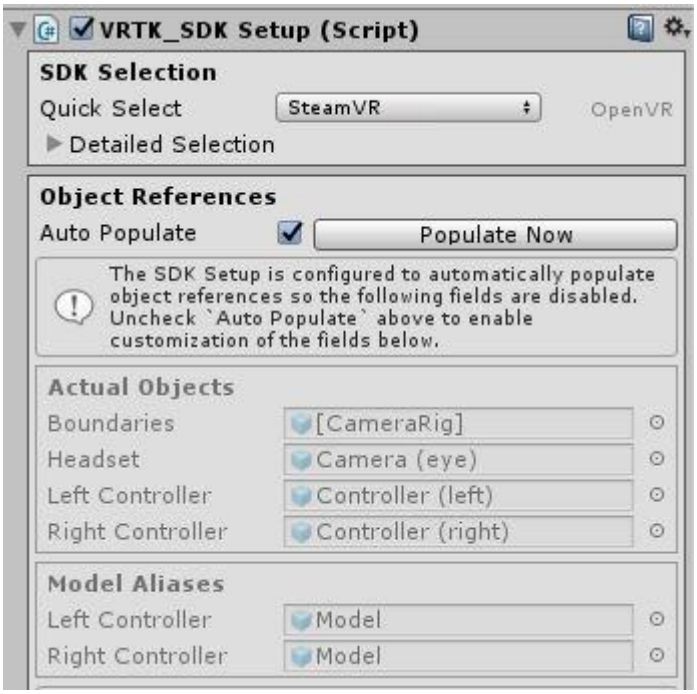

Figure 6.16 Steam VR (Source: prepared by the authors)

Inside the CameraRig there are the controller left, the controller right and the camera head. Inside the Camera head there are the camera (eye) that contains the script that controls the audios, the camera (ears) that contains the audio source of the ambient music and the menuFollower that contains all the videos that are shown during the tutorial to do the comprehension easily.

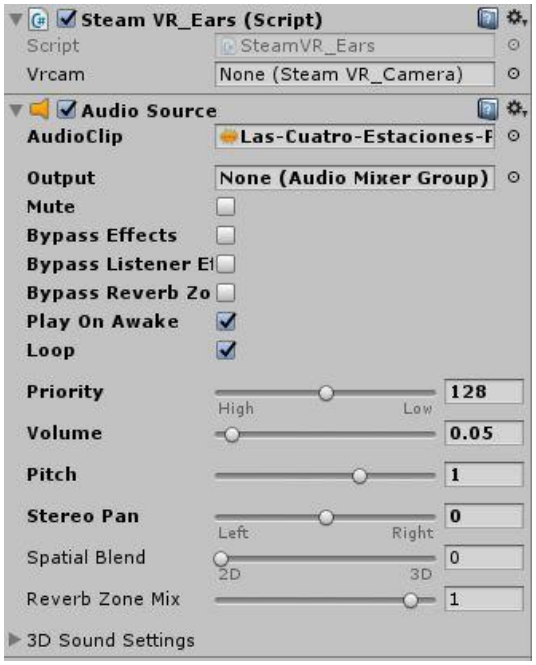

Figure 6.17 Camera ears (Source: prepared by the authors)

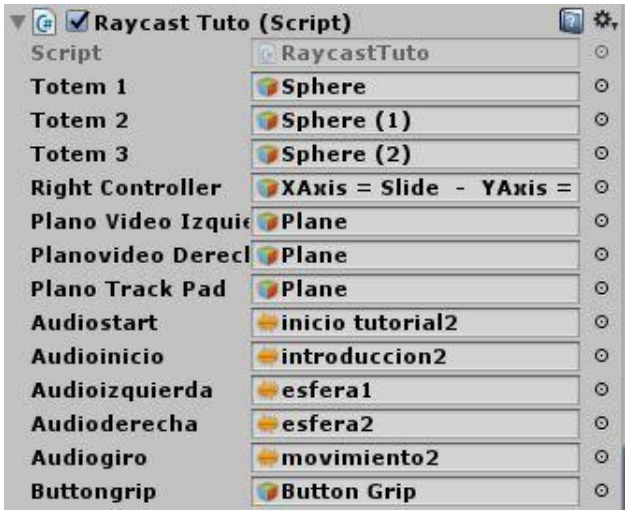

Figure 6.18 Camera eye (Source: prepared by the authors)

In the VRTK_Scripts there are the controls of the right and left controls. Here you can change the way the user can move with the commands and the speed of the movement. In this application the controls are very easy and the speed is slowly because the game is thought for old people that are not used to use this type of technologies.

Here there is the example of the right controller.

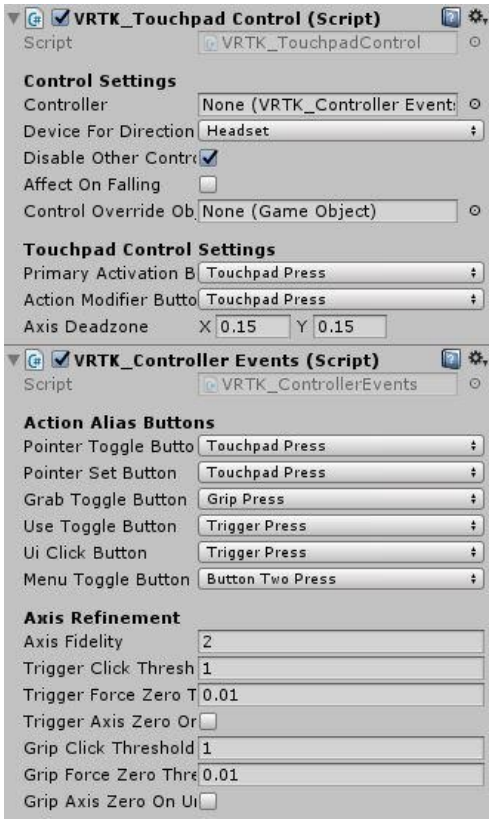

Figure 6.19 Right Controller (Source: prepared by the authors)

The PlayAreaScript is the area by which the user can move.

The eventSystem controls all the events that there are in the system.

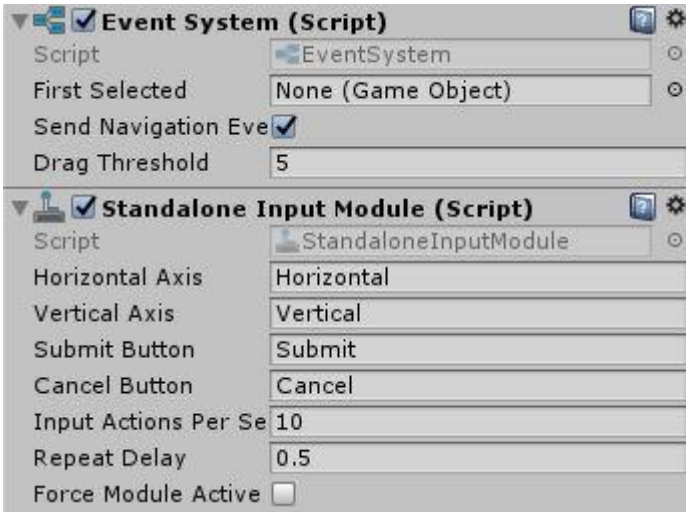

Figure 6.20 EventSystem (Source: prepared by the authors)

The directional light is the light that the patient will see during the tutorial. It can be changed the type, the colour and the intensity of the light.

During the corridor there are arrows to indicate where the patient has to go.

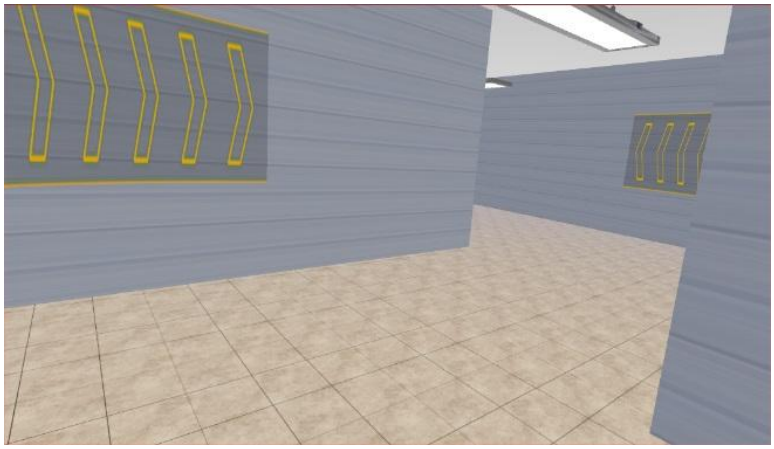

Figure 6.21 Arrows in the corridor (Source: prepared by the authors)

In the initial room there are three red spheres in three different walls.

The object OpenInitialDoors is the object that contains a script that allows open the initial door. When the patient has completed the three spheres and he looks the door the door opens.

Figure 6.22 Open Initial Doors (Script) (Source: prepared by the authors)

The object CloseDoors is the animation that allows close the initial doors where the patient is in the corridor and the audio had sounded.

Figure 6.23 Close Initial Doors (Script) (Source: prepared by the authors)

The object CloseFinalDoors2 is very similar to the object CloseDoors. This object contains a script that allows close the final door when the user is in the last room and the explication of what he has to do is sounding.

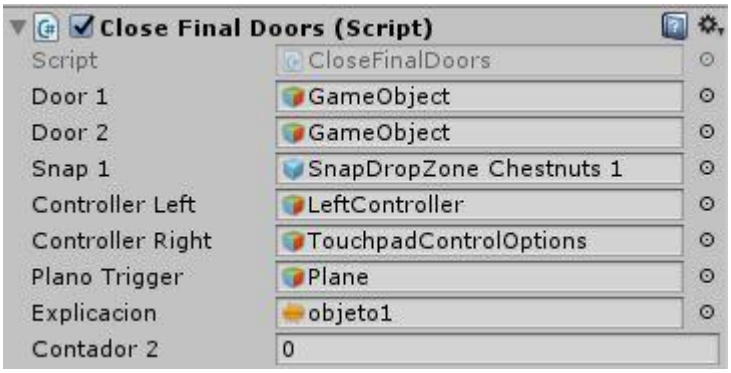

Figure 6.24 Close Final Doors (Script) (Source: prepared by the authors)

The last object, the final sound, is a script which consists in when the last object is well put on its shelf sounds a congratulatory audio.

6.2. Shopping list

Explanation

In this part of the application there are 3 levels and 2 videos. The first video explains what do you have to do in the level 1 and the second video explains what you will find in levels 2 and 3. The videos provide tips for a better understanding of the application.

In this part of the application the patient is in the supermarket and a shopping list appears on the screen. The patient has to take these products from the supermarket and put them in the basket. The user can take the products he wants but the objective of the application is to take the products that are only on the list.

Levels have a growing difficulty as the user progresses. In the first level the shopping list will always be visible. In the levels 2 and 3 the shopping list will be visible for a stipulated time. The differences between level 2 and level 3 are that in the level 2 there are five products in the list and in the level 3 there are seven products. The display time of the shopping list is also higher in level 2. During both levels you can consult the shopping list by pressing a button.

To increase the difficulty, some distractions for the user have been included in levels 2 and 3. These distractions consist in that the supermarket replenishment will go to the user and will tell him something. In level 2 there is only one distraction. On the other hand, in level 3 there are two distractions.

Figure 6.25 Distraction levels 2 and 3 (Source: prepared by the authors)

Figure 6.26 Distraction level 3 (Source: prepared by the authors)

The products entered in the basket will appear on the screen. When the user thought that he has finished the purchase, he must leave through the exit door.

Situation of the products in the supermarket

In the supermarket there are different products which are located according to the type of products that they are.

In the supermarket there is a fruit section where the buyer can find apples, bananas, peaches, pineapples, pears, melons, oranges, lemons, red peppers, radishes, watermelons and coconuts.

Figure 6.27 Fruit section (Source: prepared by the authors)

In front of the fruit section there is the vegetables section where we can find potatoes, asparagus, cucumbers, carrots, tomatoes, garlic, onions, aubergines, kiwis, cauliflowers, endives and avocados.

Figure 6.28 Vegetable section (Source: prepared by the authors)

In the supermarket there are two fridges and a freezer. In the first fridge the user can buy chickens, trouts, steaks, mushrooms, cherries and strawberries.

Figure 6.29 First fridge (Source: prepared by the authors)

In the second fridge there are butters, cheeses, yogurts, lettuces, grapes and blackberries.

Figure 6.30 Second fridge (Source: prepared by the authors)

In the freezer the patient can buy pizza, ice cream, lasagne, green pies, frozen potatoes, prawns, fish sticks and sweet corn.

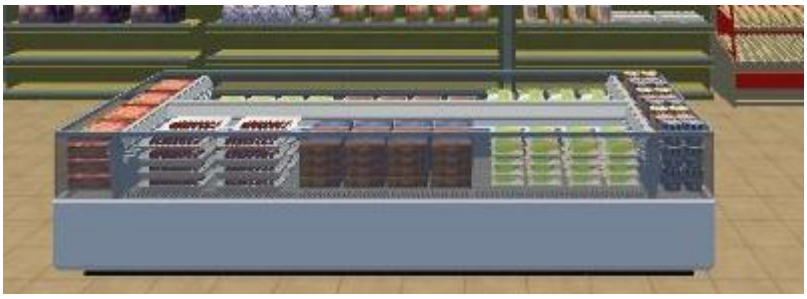

Figure 6.31 Freezer (Source: prepared by the authors)

Near the fridge there is the bakery section where we can find bread and Bimbo bread slices.

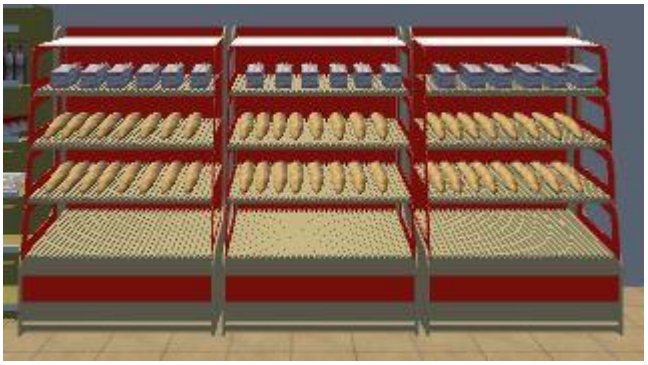

Figure 6.32 Bakery section (Source: prepared by the authors)

Next to the bakery section there is the basic products section where we can buy oil, vinegar, salt, pepper, eggs, sugar, milk, coffee, honey, tea, chocolate, marmalade and cereals. The cleaning products are located next to the basic products. The cleaning products that are available in this supermarket are tampax, shaving gel, toilet paper, toothpaste and deodorant.

Figure 6.33 Basic and cleaning products sections (Source: prepared by the authors)

There is a legumes shelf which contains lentils, chickpeas, beans, rice, macaroni and flour. There is a nuts section next to the legumes shelf where the patient can buy almonds, chestnuts, pistachio, hazelnuts and peanuts. Next to the nuts the buyer can find a varied assortment of chips.

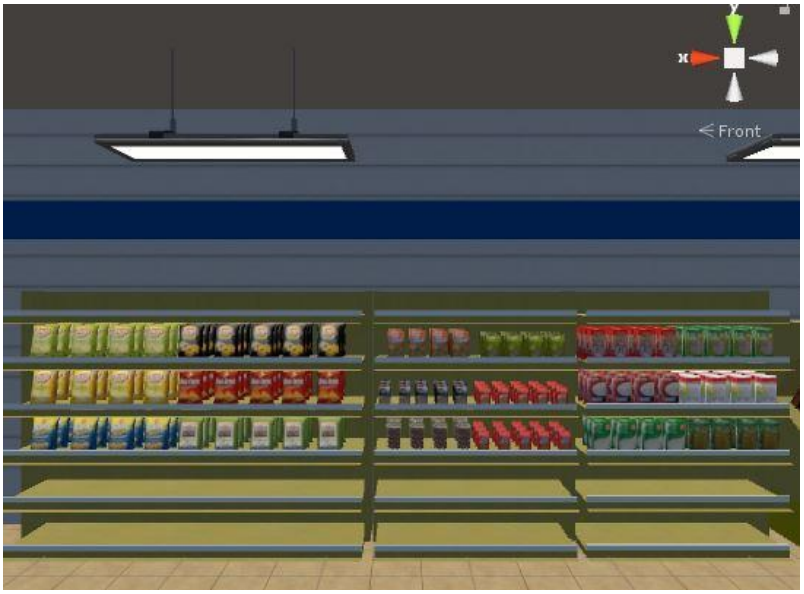

Figure 6.34 Legumes, nuts and chips sections (Source: prepared by the authors)

Below there is an overview of the supermarket to see where is each section located and where the user can buy the product they want.

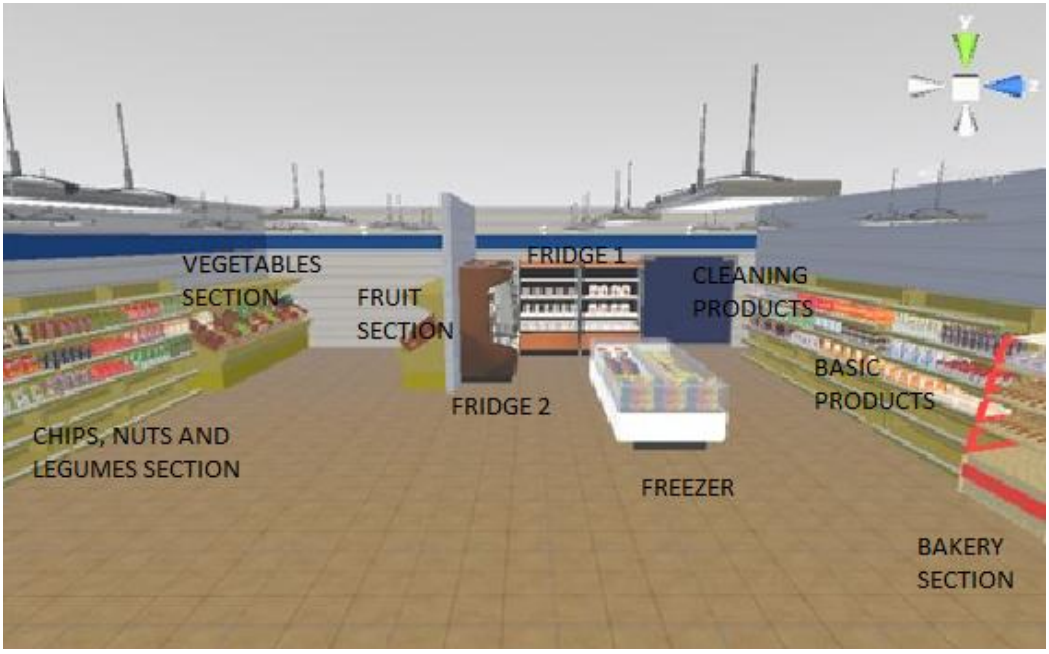

Figure 6.35 Different sections of the supermarket (Source: prepared by the authors)

In the supermarket there are two checkout counters, an entrance door and an exit door.

Figure 6.36 Checkout and doors (Source: prepared by the authors)

Objects

There are explained the objects that there are in the level 3. In the levels 1 and 2 there are fewer objects than in level 3. All the objects that can be found in levels 1 and 2 are also contained in level 3, so they will also be explain in this section of the project.

Figure 6.37 Objects in main sceneL3 (Source: prepared by the authors)

There is a Game Control to control the data of the application. It is explained more detailed in the section 7 of the project.

The stand is where the shop assistant is in the second distraction. It is done to do the distraction more realistic

It has and the same terrain as the tutorial. There are also twenty luminaries hanging from the ceiling.

In the basket there is the object of the blue basket which is on the left control.

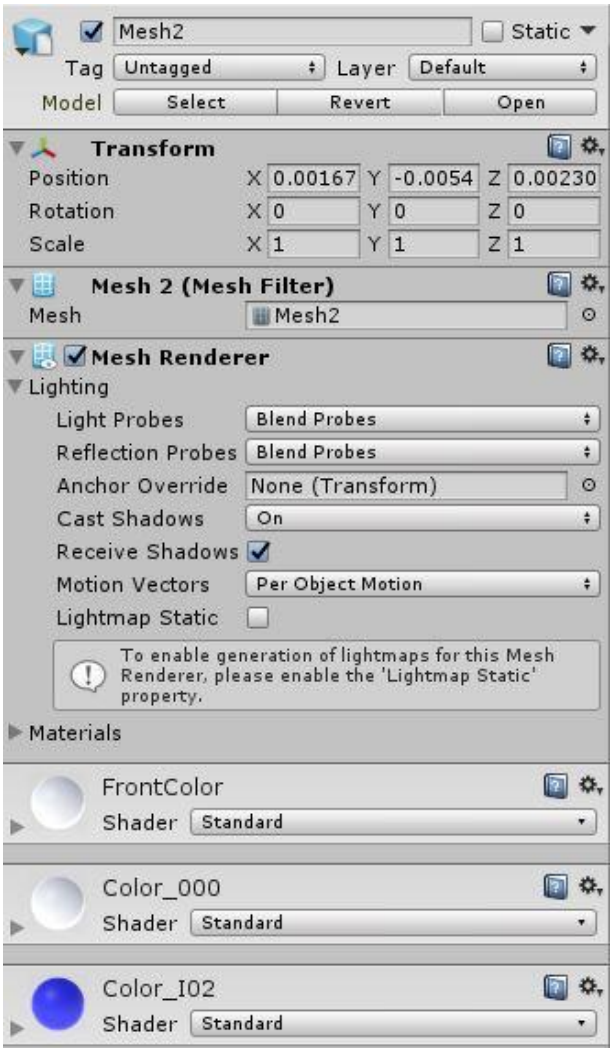

Figure 6.38 Basket (Source: prepared by the authors)

There are also the different scripts that allow the user catch objects when he has the object selected with the right control.

Figure 6.39 Script Stop Gravity 7 in Basket (Source: prepared by the authors)

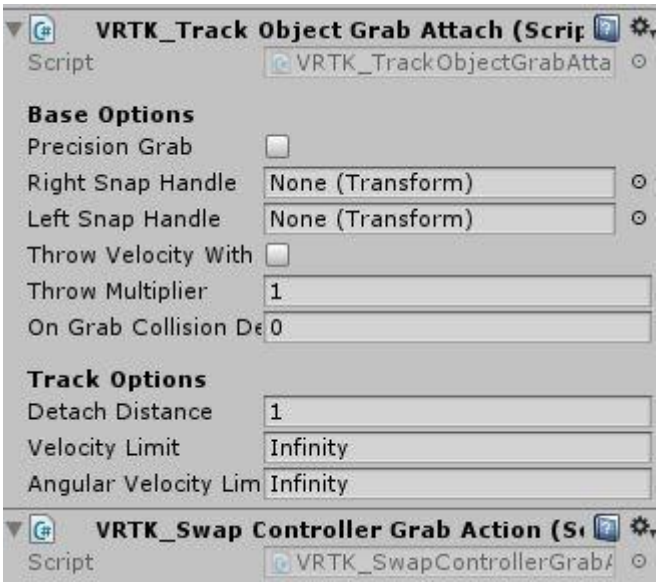

Figure 6.40 Scripts Track Object Grab and Swap Controller Grab Action in Basket (Source: prepared by the authors)

In the object *Supermercado* there is created the structure of the supermarket. There are all the objects related to the supermarket except the market products and their shelves.

The market products are explained more detailed in the section 6.2.2 of the project. In that section are explained which products are in the supermarket and what is the distribution of the different sections.

The colour, the type and the intensity of the directional light is the same as the tutorial.

The gamer is the same as it is explained in the section 6.1.2. The movements and the camera are the same as the tutorial.

The object *Final juego* is a script to leave the Main SceneL3 when the exercise is finished and it goes to the scene Final Main SceneL3.

The object Script is used to control the time.

Say Hi (1) is the object that does the first interaction with the user. It is in levels 2 and 3. It consists of an audio source that is what the shop assistant say and an animator with an avatar that is the animation that has to do the shop assistant.

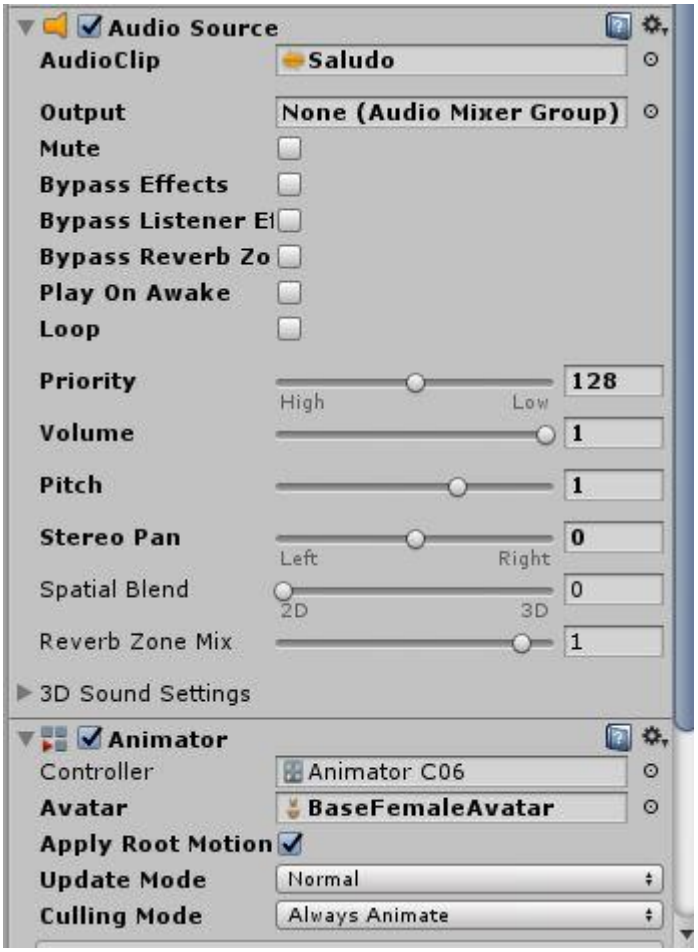

Figure 6.41 Say Hi (1) (Source: prepared by the authors)

The object *Inicio Animación* is very important and it is related with the object Say Hi (1). It is a script that indicates when has the shop assistant start to walk and do the animation. The time of waiting until start walking is 15 seconds. The shop assistant is 3 seconds greeting and the time of movement is 6 seconds. This three times can be modified but we think that in this way the system goes very well.

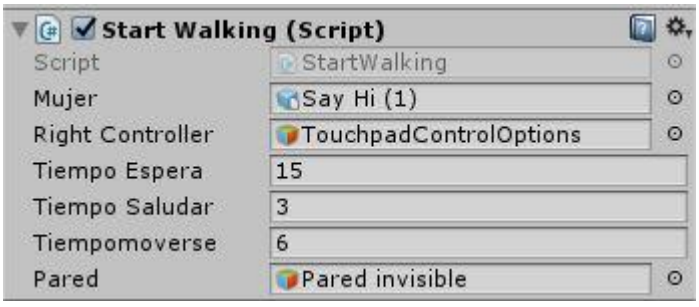

Figure 6.42 Inicio animación (Source: prepared by the authors)

Say Hi Distrac 2 is the object that contains the audio source and the animator for the distraction in level 3.

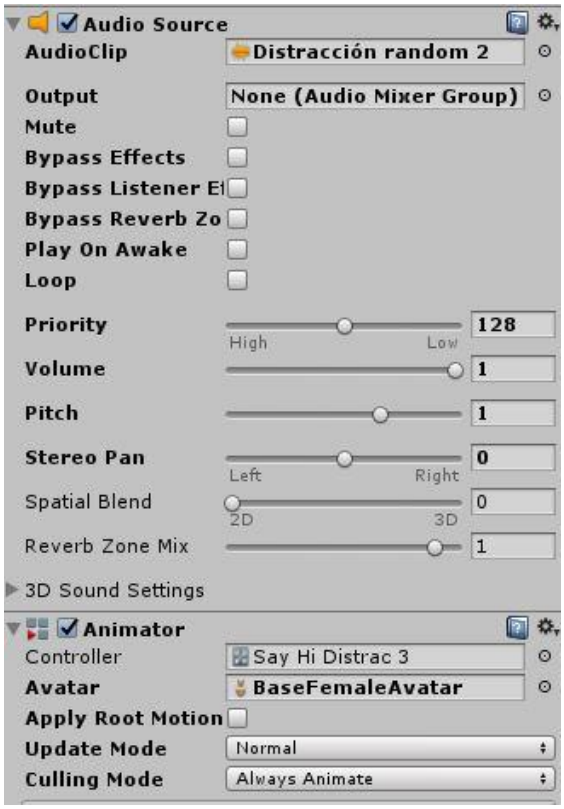

Figure 6.43 Say Hi Distrac 2 (Source: prepared by the authors)

The object Inicio Start Talking is very important and it is related with the object Say Hi Distrac 2. It is a script that indicates when has the shop assistant start to talk and do the animation. It is programmed that the animation starts when the patient is near the shop assistant.

Figure 6.44 InicioStartTalking (Source: prepared by the authors)

The last object of the Hierarchy is *Pared invisible*. It is done to not disturb the shop assistant in her first distraction. It is a wall that allows the shop assistant to do the animation without the user being bothered in the middle of her trajectory.

6.3. Shop assistant

Explanation

In this activity the patient can play another different role. He becomes a shop assistant and his objective is returning a different market product at their correct place.

The products are on a table that it is in the center of the market. The patient must identify the objects and find in which section must be the product.

The environment is the same that the List Products activity and the products of the shelves are in the same place too. Also, the controllers and game objects are very similar than the other activity to reuse resources and save working time.

This activity has three levels:

- Level 1: the patient must return 3 products.
- Level 2: the patient must return 4 products.
- Level 3: the patient must return 6 products.

All the results of the levels will be stored in the same database used in other activities.

Objects

LEVEL 1

In this level the patient must replace three objects. In the next image we can see the game objects in this level.

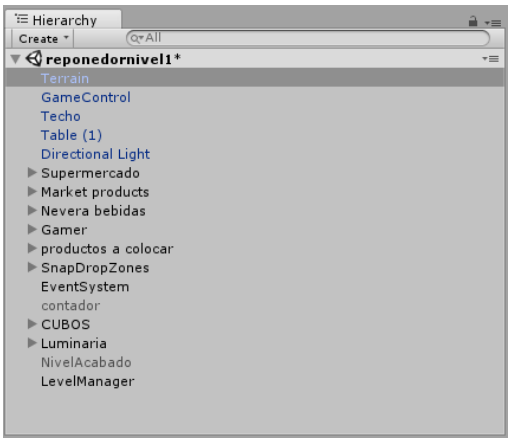

Figure 6.45 Objects reponedornivel1 (Source: prepared by the authors)

As can been seen, the structure is very similar at the other activities.

The level has the next more important elements:

- The supermarket structure (walls, terrain, light, products, shelves).
- Game control to store the results in a database.
- Gamer: it has the controllers and cameras that let at the user plays in first person mode.
- Products to replace.
- Snap drop zones: the places where the objects are replaced.
- Blocking wall.
- Counter: count the successes.
- Timer: count the time to finish the level.
- An object called *NivelAabado*.

As we have commented previously, the Game Control let at the doctor stores all the data of the patient to extract later a result. This game object has been used in other activities and different levels.

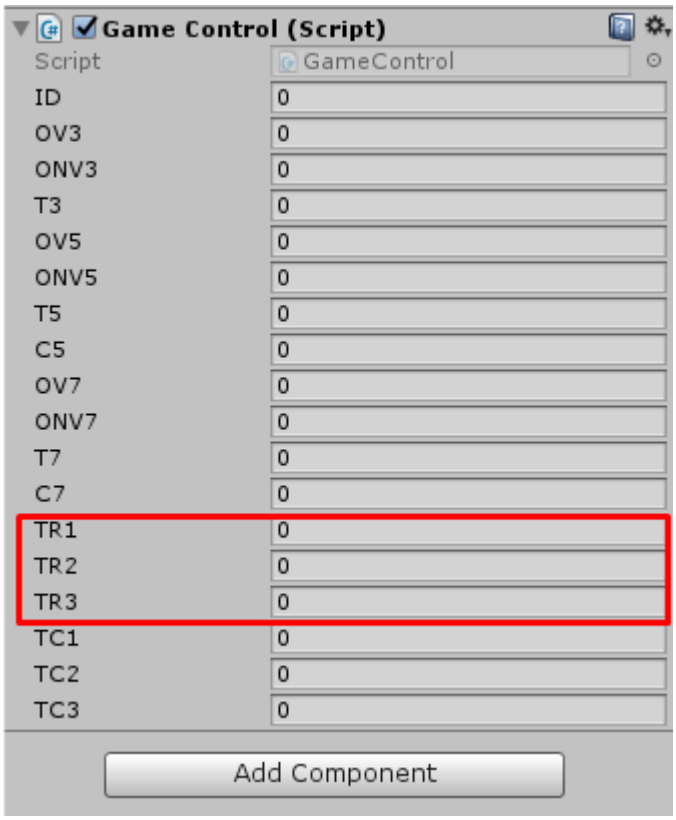

Figure 6.46 GameControl level 1 (Source: prepared by the authors)

These three parameters store the patient's time to realize the objective. The parameter TR1 is the time in Level 1, TR2 for Level 2 and TR2 for Level 3.

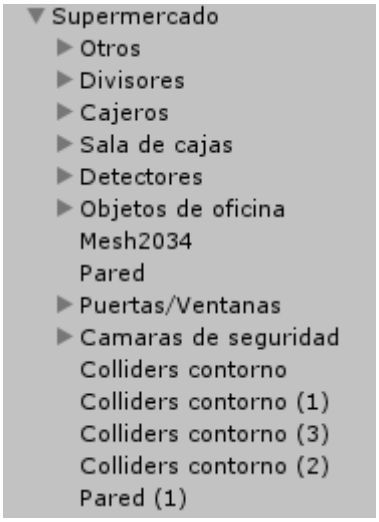

Figure 6.47 Supermercado objects level 1(Source: prepared by the authors)

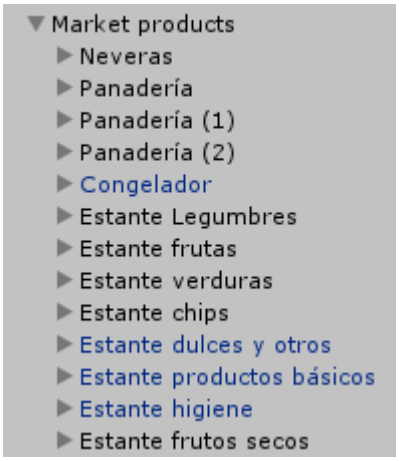

Figure 6.48 Market products level 1 (Source: prepared by the authors)

In these images we can see the structure of the supermarket and his products (inside the object shelves we can find the products).

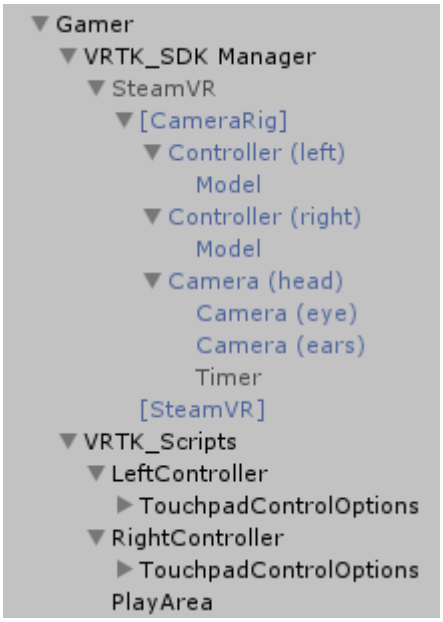

Figure 6.49 Gamer level 1 (Source: prepared by the authors)

The game object Gamer has the controllers of the movement and the cameras to let at the user seethe environment. Also, we can find inside this object other important elements:

- Camera (eye): it has the environment music and let control the volume with the component Audio Source.

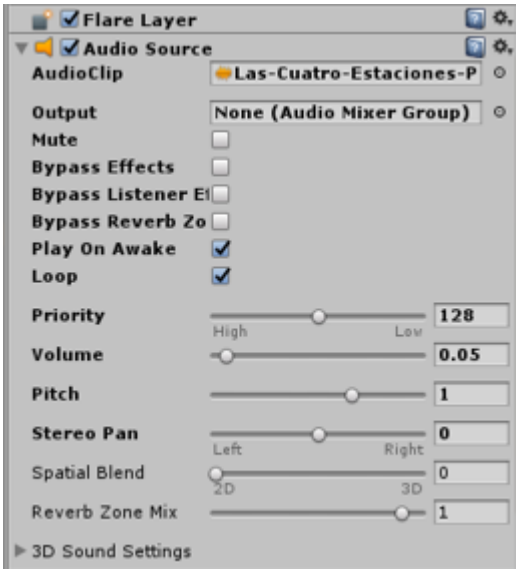

Figure 6.50 Camera (eye) level 1 (Source: prepared by the authors)

- Camera (ears): it has an Audio Source and script.

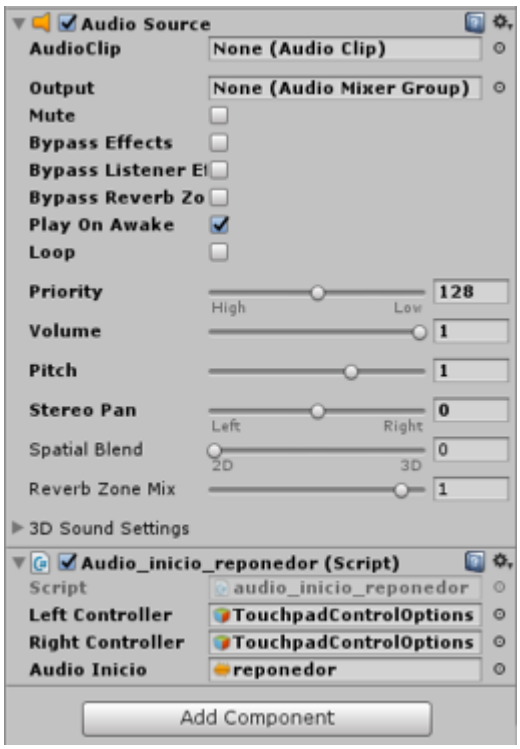

Figure 6.51 Camera (ears) level 1 (Source: prepared by the authors)

```
public class audio_inicio_reponedor : MonoBehaviour
{
    public GameObject LeftController;
    public GameObject RightController;
    AudioSource audiosourceinicio;
    public AudioClip AudioInicio;
    // Use this for initialization
    void Start()
    {
        audiosourceinicio = GetComponent<AudioSource>();
        audiosourceinicio.clip = AudioInicio;
        audiosourceinicio.Play();
        LeftController.SetActive(false);
        RightController.SetActive(false);
        StartCoroutine(tiempoaudioinicial());
    }

    IEnumerator tiempoaudioinicial()
    {
        yield return new WaitForSeconds(AudioInicio.length);
        LeftController.SetActive(true);
        RightController.SetActive(true);
    }
}
```

Figure 6.52 Audio Inicio reponedor Script

The Camera (eye) starts the application with an introduction audio (it needs the component Audio Source) and active the controllers when the audio has finished.

- Timer: this object let store in the database the time to realize the level. For do this, it need the next script.

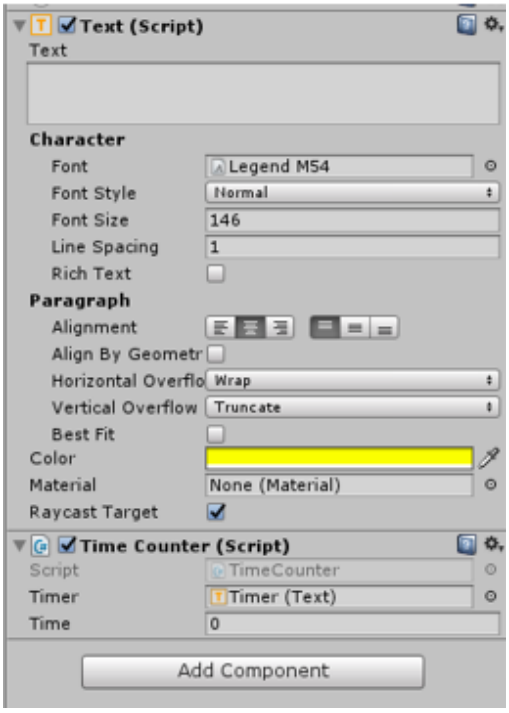

Figure 6.53 Timer level 1 (Source: prepared by the authors)

```
public class TimeCounter : MonoBehaviour {
    public Text Timer;
    public float time= 0.0f;
    // Use this for initialization

    void Start () {

    }

    // Update is called once per frame
    void Update () {
        time += Time.deltaTime;

        var minutes = (int)time / 60;
        var seconds = time % 60;
        var fraction = (time * 100) % 100;

        Timer.text = string.Format("{0:00} : {1:00} ", minutes, seconds);

        //Timer.text = string.Format("{0:00} : {1:00} : {2:000}", minutes, seconds, fraction);
    }
}
```

Figure 6.54 Time Counter Script

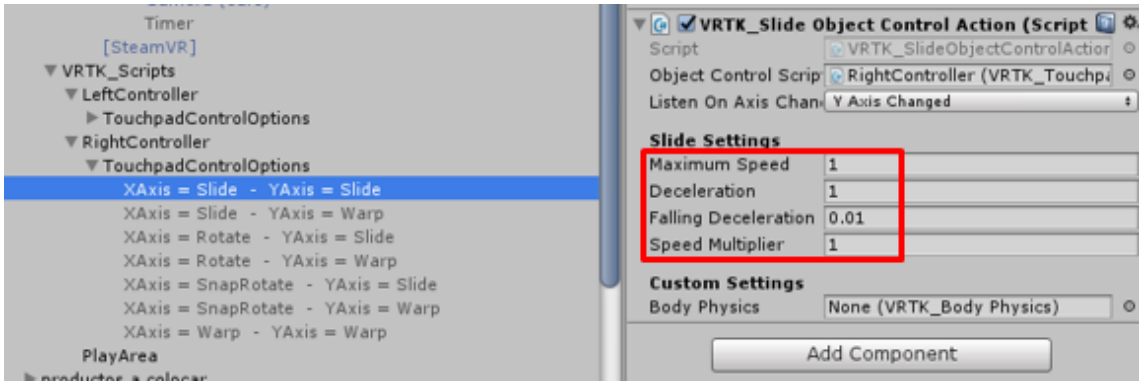

Figure 6.55 Right controller level 1 (Source: prepared by the authors)

In the image, we can see the parameters of our controllers. In this case the right controller shows the parameters to modify the speed of the movement.

Other important factor to see is that in this activity (just like the Autonomous Communities) the functions of the controllers have changed. In the left controller there is no function or event that it will execute.

All the activity can be done only with the right controller.

The next images show the products to replace in the Level 1.

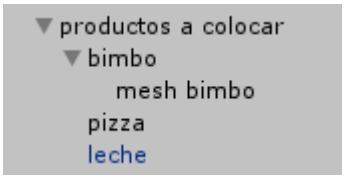

Figure 6.56 Products to replace level 1 (Source: prepared by the authors)

Figure 6.57 Products of level 1 (Source: prepared by the authors)

These products have various parameters so in the next images we can see the most important.

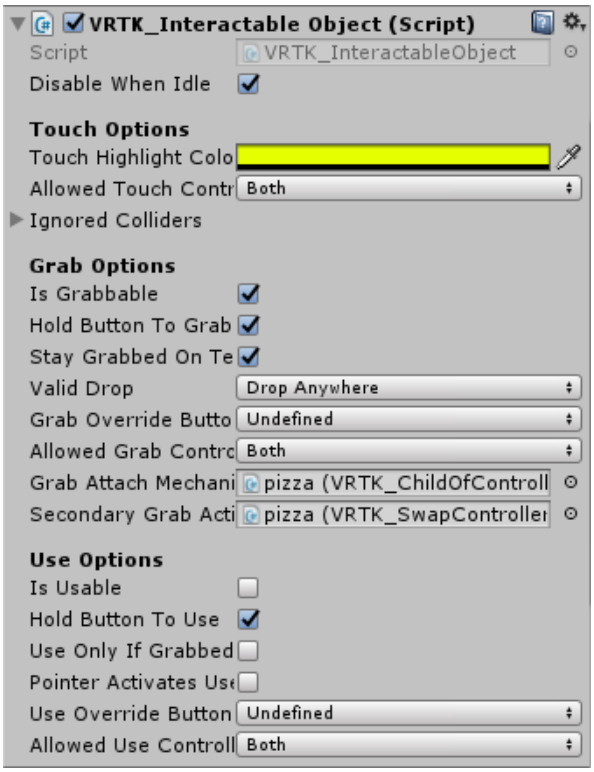

Figure 6.58 Script objects to replace level 1 (Source: prepared by the authors)

This component light the product in color yellow when the controller is near of him. Also, it makes to the product a grabbable element.

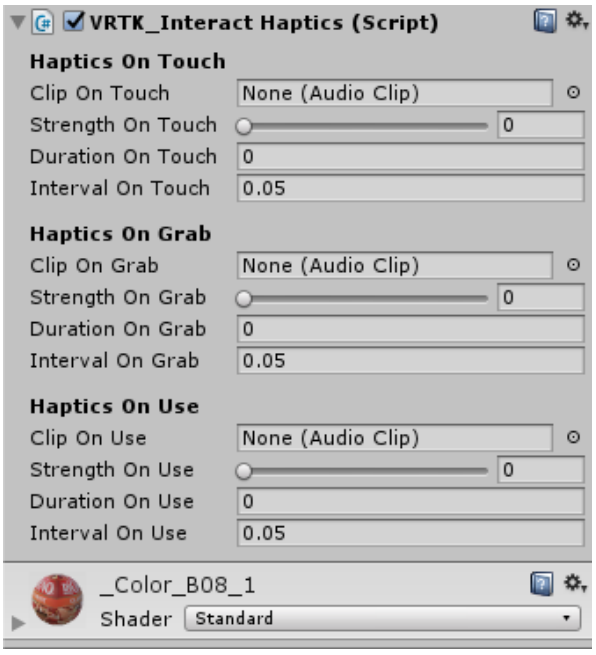

Figure 6.59 Texture products level 1 (Source: prepared by the authors)

In this component we can put the texture that we want for him.

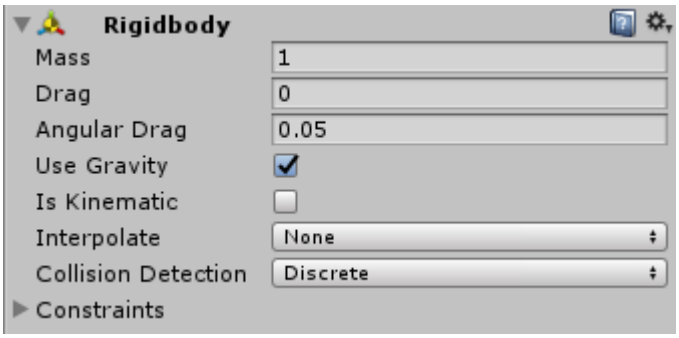

Figure 6.60 Rigidbpdy products level 1 (Source: prepared by the authors)

The last component let at the product have gravity and introduce his mass and weight.

Figure 6.61 Snap Drop Zones level 1 (Source: prepared by the authors)

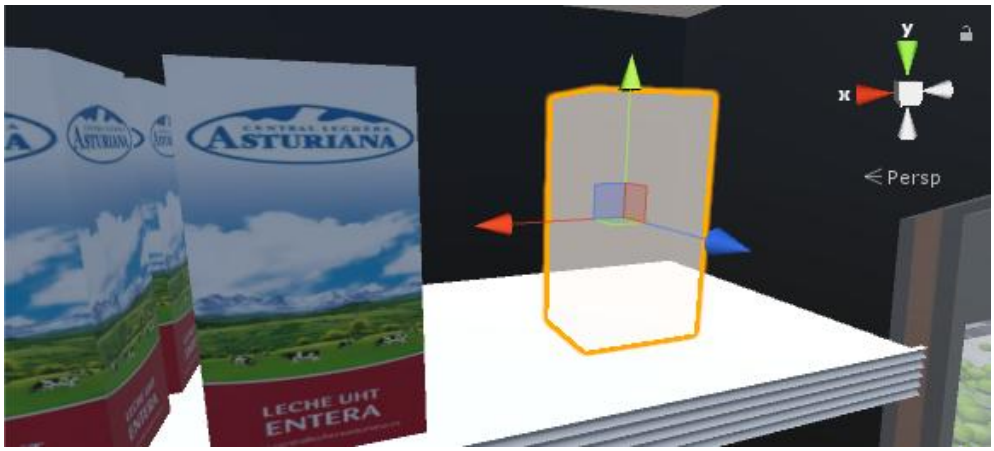

Figure 6.62 Snap Drop Zones of Milk level 1 (Source: prepared by the authors)

In this image we can see snap drop zone. This object is the place where the patient will put the product. The snap drop zone has various parameters.

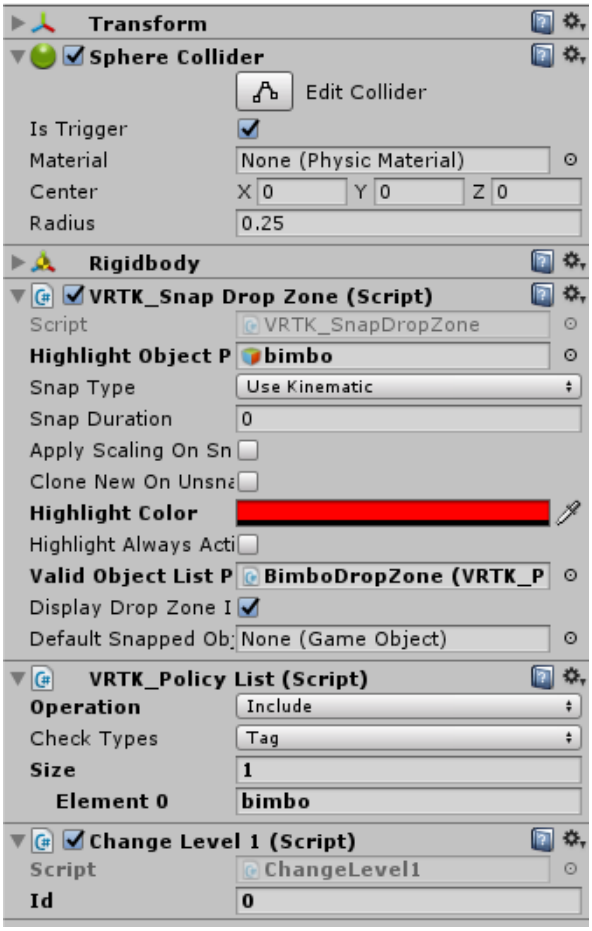

Figure 6.63 Snap Drop Zones parameters level 1 (Source: prepared by the authors)

We can see that the snap drop zone let determine his color that it shows when the correct product is near of him. Also, this component introduces the product that it is referred.

Other element very important in this activity is the object called *Productos a colocar.*

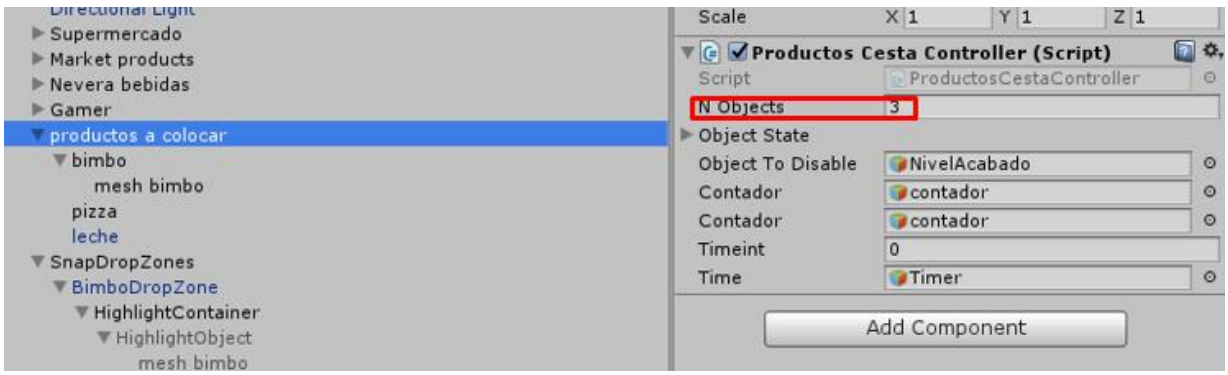

Figure 6.64 Script Productos Cesta controller level 1 (Source: prepared by the authors)

It has a script that counts (thanks at the object *contador*) the correct products that the patients replace. When all products are in their correct place (you can put the number of products that the patient needs to replace) the object stop the time and active the object *NivelAcabado.*

```
private void Start()
{

    Contador _contador = contador.GetComponent<Contador>();

    Contador.SetActive(false);
    ObjectToDisable.SetActive(false);

    objectState = new bool[nObjects];
    for (int i = 0; i < nObjects; i++) {
        objectState[i] = false;
    }

}

public void SetObjectTrue(int id) {
    objectState[id] = true;
    Debug.Log("Set Active" + id);
    naciertos++;
    Contador _contador = contador.GetComponent<Contador>();
    _contador.Aciertos(naciertos);
    CheckAllState();
```

Figure 6.65 First part Script ProductosCestaController (Source: prepared by the authors)

```
public void CheckAllState()
{
    all = true;
    for (int i = 0; i < nObjects; i++)
    {


        if (!objectState[i])
        {
            all = false;
        }
    }

    if (all)
    {
        ObjectToDisable.SetActive(true);
        Contador.SetActive(true);
        time.SetActive(false);

    }
    else
    {
        ObjectToDisable.SetActive(false);
        Contador.SetActive(false);
    }
}

void Update()
{
    timeint = (int)time.GetComponent<TimeCounter>().time;
}
```

Figure 6.66 Second part Script ProductosCestaController (Source: prepared by the authors)

We have to keep in mind that this script is the same for all the levels of the Shop Assistant activity and the Autonomous Communities activity.

Also, we can see the script of the counter object.

```
public class Contador : MonoBehaviour {


    private float contador = 5.0f;
    int aciertos = 0;
    string escena;
    string levelname;


    public void Aciertos(int valor)
    {
        aciertos = valor;
    }

}
```

Figure 6.67 Script of the counter object (Source: prepared by the authors)

Finally, this level has the object *NivelAcabado.* This object is in all the levels of the Shop Assistant and the Autonomous Communities.

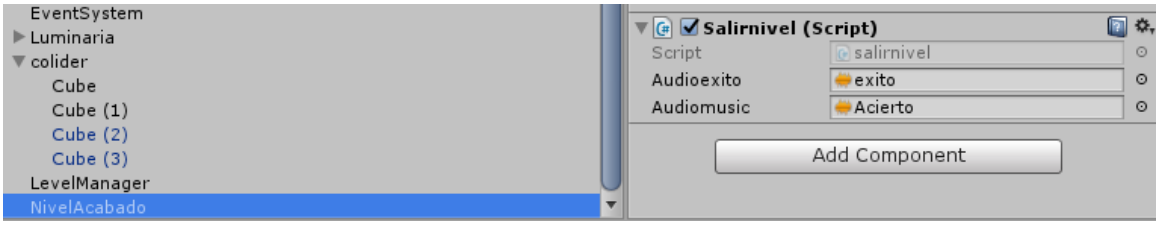

Figure 6.68 Object NivelAcabado (Source: prepared by the authors)

It has two audios to advice at the user that he has complete successfully the level (it song an audio music and a message of congratulations).

The only change in this object between levels is the script annexed inside him.

```
public class salirnivel4 : MonoBehaviour {
    AudioSource audiosourceexito;
    public AudioClip Audioexito;
    AudioSource audiosourcemusic;
    public AudioClip Audiomusic;
    // Use this for initialization
    void Start()
    {
        audiosourcemusic = GetComponent<AudioSource>();
        audiosourcemusic.clip = Audiomusic;
        audiosourcemusic.Play();
        StartCoroutine(exito());
    }

    private IEnumerator exito()
    {
        yield return new WaitForSeconds(Audiomusic.length);
        audiosourceexito = GetComponent<AudioSource>();
        audiosourceexito.clip = Audioexito;
        audiosourceexito.Play();
        StartCoroutine(salida());
    }

    private IEnumerator salida()
    {
        yield return new WaitForSeconds(Audioexito.length);
        SceneManager.LoadScene("Final Reponedor 1");
    }
}
```

Figure 6.69 Script SalirNivel4 (Source: prepared by the authors)

As can been seen, when the audios finished, the script load the next scene (in this case *Final Reponedor 1*). These scenes change if the level is different.

In the supermarket we can find blocking walls to limit the space of the environment using cubes with collider components.

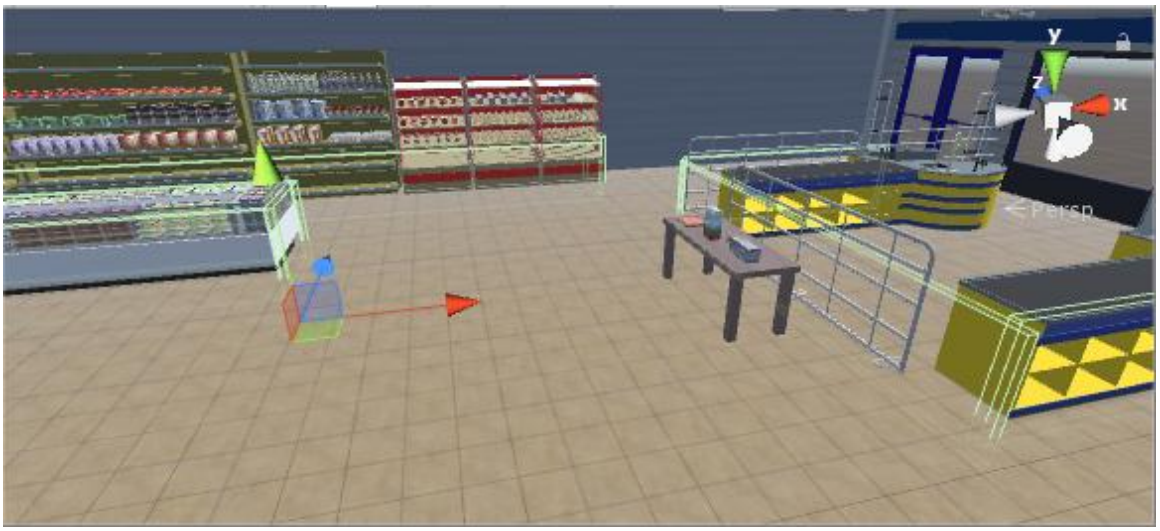

Figure 6.70 Blocking walls (Source: prepared by the authors)

LEVEL 2

This level has the same 3D structure and objects that the level 1 with little changes:

- The number of products to replace is 4.

Figure 6.71 Products of level 2 (Source: prepared by the authors)

- In the database the time is the parameter TR2.
- We must to introduce 4 products in the object *Productos a colocar.*
- The object *NivelAcabado* loads the scene *Final Reponedor 2.*

LEVEL 3

Just like the level 2, the level 3 have the same changes:

- The number of products to replace is 6.

Figure 6.72 Products of level 3 (Source: prepared by the authors)

- In the database the time is the parameter TR3.
- We must to introduce 6 products in the object *Productos a colocar.*
- The object *NivelAcabado* loads the scene *Final Reponedor 3.*

6.4. Autonomous communities

Explanation

This activity is based on the recognition of some products and relates them to their corresponding region.

The patient must choose the product and replace it in the corresponding region trying to do the fewer mistakes as is possible.

The structure and objects of this activity are very similar that the Shop Assistant.

Objects

LEVEL 1

In this activity and levels, we can find similar objects that are like the last activity:

- Timer object.
- Counter object.
- Game Control.
- *NivelAcabado* object.
- Camera (eye).
- Camera (ear).
- Controllers.
- *Productos Cesta Controller* script.

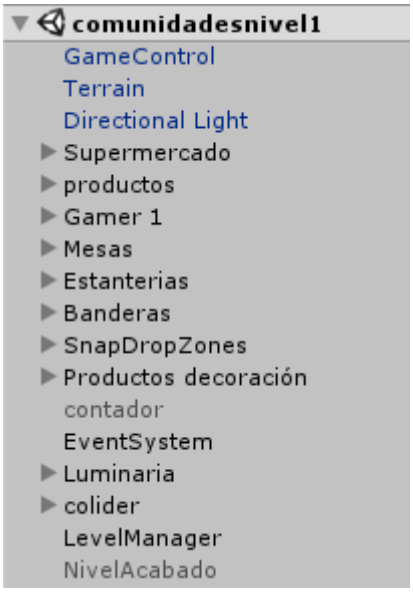

Figure 6.73 Objects Comunidadesnivel1 (Source: prepared by the authors

As can been seen, this activity has the same Game Control to store the results in the database.

In this case, the parameter that it will send in our database is the time (TC1). In the levels 2 and 3 it will store the same parameter (TC2 and TC3).

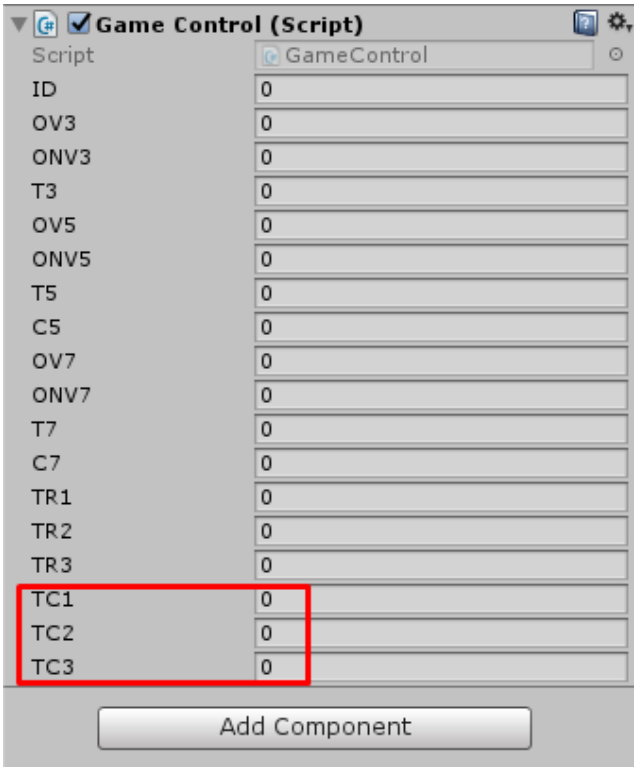

Figure 6.74 Game Control level 1 (Source: prepared by the authors)

In this activity the patient will be in another zone in the supermarket. However, the objects are the same because this zone has too walls, light, terrain, products, shelves and other decoration elements.

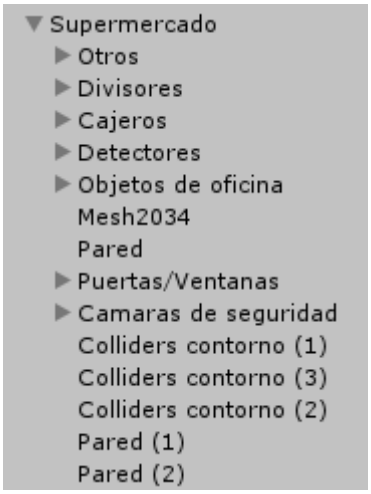

Figure 6.75 Objects of Supermercado (Source: prepared by the authors)

The principal difference in this level is that the user needs to replace 3 products.

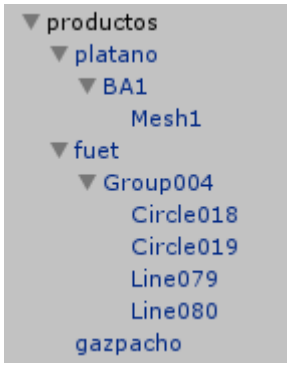

Figure 6.76 Products of level 1 (Source: prepared by the authors)

Figure 6.77 Products to replace of level 1 (Source: prepared by the authors)

Also, in the next image we can see the different communities and the snap drop zones.

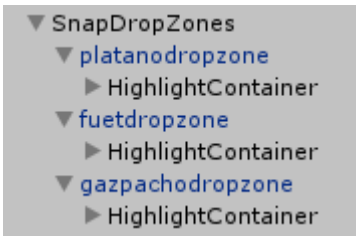

Figure 6.78 SnapDropZones of level 1 (Source: prepared by the authors)

Figure 6.79 Products and the shelves of level 1 (Source: prepared by the authors)

In the Gamer object it is possible find some difference in the Camera (ears).

Figure 6.80 Audio Inicio Reponedor of level 1 (Source: prepared by the authors)

This image shows that we have reused the script of the Shop Assistant but we have changed the introduction initial audio.

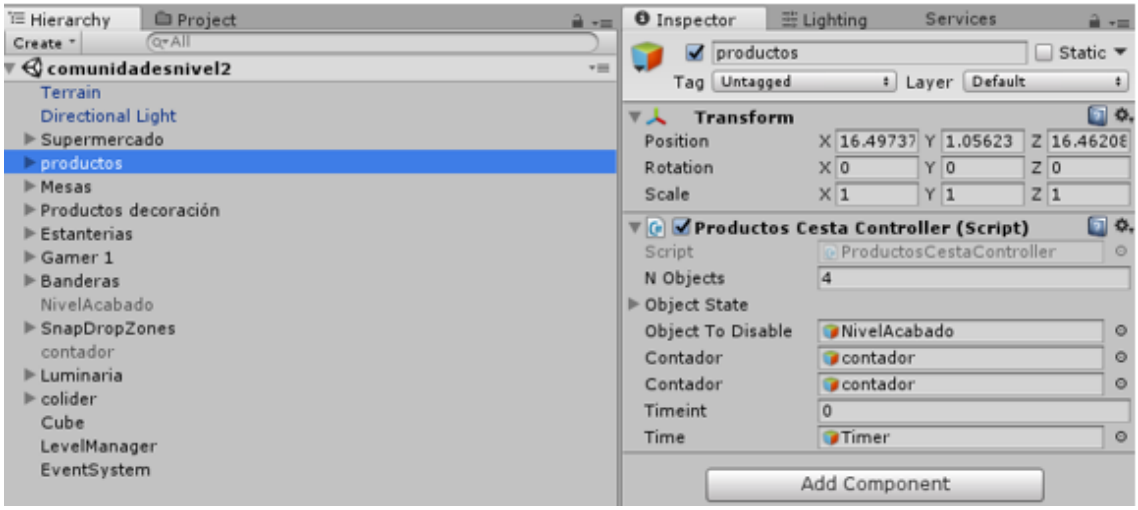

Figure 6.81 Productos Cesta Controller (Source: prepared by the authors)

In this image we can see that the *productos* object contain have the *Productos Cesta Controller* script.

We have modified the scene load in the *NivelAcabado* object. The script annexed inside the *NivelAcabado* changes if the level is different. The audios that the script plays are always the same but when the audios have finished, the script loads different scenes.

In this case it loads the *Final Comunidades 1* scene.

Also, we can find in this zone of the supermarket blocking walls to limit the movement of the user in the environment.

These walls are cubes with colliders.

Figure 6.82 Collider walls (Source: prepared by the authors)

LEVEL 2

This level has the same 3D structure and objects that the level 1 with little changes:

- The number of products to replace is 4.

Figure 6.83 Products level 2 (Source: prepared by the authors)

Figure 6.84 Communities of level 2 (Source: prepared by the authors)

As can been seen, in this level has a trap shelf to confuse the patient.

- In the database the time is the parameter TC2.
- We must to introduce 4 products in the object *productos.*
- The object *NivelAcabado* loads the scene *Final Comunidades 2.*

LEVEL 3

Just like the level 2, the level 3 have the same changes:

- The number of products to replace is 6.

Figure 6.85 Products level 3 (Source: prepared by the authors)

Figure 6.86 Communities of level 2 (Source: prepared by the authors)

- In the database the time is the parameter TC3.
- We must to introduce 6 products in the object *productos.*
- The object *NivelAcabado* loads the scene *Final Comunidades 3.*

6.5. Menus

The menus are used to distribute the application. They are in 2D and they are made to be the doctor who handles them. We think that it is easier if it is the doctor who selects the the game modes and the patient does not do it.

The different menus are explained below.

ID menu

In the ID menu the doctor puts a number in “Número de Identificación”. This number will be the ID of the patient. It is done in this way to maintain the patient’s anonymity.

Once the ID is set, the doctor must click on “Introducir” to go to the different game modes. On the other hand, if the doctor presses “Salir” the application will be closed.

Figure 6.87 ID Menu (Source: prepared by the authors)

While the doctor is entering the ID in this menu, the patient sees the shop assistant in the supermarket adding fruits to the fruit shelf.

Main menu

In the main menu the doctor can select one of the four game modes that there are in the application.

The doctor has the possibility to change the user clicking “Cambiar usuario” or to leave the application clicking “Salir”.

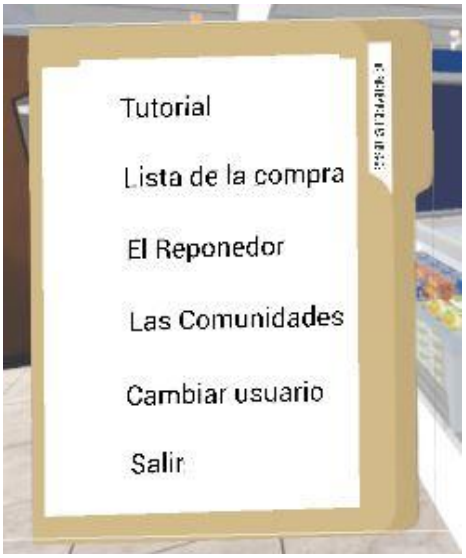

Figure 6.88 Main Menu (Source: prepared by the authors)

While the doctor is choosing the game mode, the patient sees the shop assistant in the supermarket adding oil bottles to the shelf.

Main scenes menu

Where the doctor selects “Tutorial”, the tutorial starts playing automatically. When any other game mode is selected, the main scenes menu appears. In that menu the doctor can choose which level the patient will do from the three available levels. If the doctor selects “Volver” it will go to the Main Menu.

Figure 6.89 Main Scenes Menu (Source: prepared by the authors)

In that menu the patient sees, as the Main Menu, the shop assistant in the supermarket adding oil bottles to the shelf.

Final menu

When the patient completes any level of any game mode the Final Menu appears. In it, the doctor can decide whether to repeat the level or return to the Main Scenes Menu.

Figure 6.90 Final Menu (Source: prepared by the authors)

In that menu the patient sees the shop assistant in the supermarket going around the fridge.

6.6. Commands

In this section are explained the different commands that are used in the application. There are only 4 buttons because the application is done as easy as possible because the users will be old people that are not accustomed to use this type of applications.

When the instructions are sounding there are some videos in the screen showing the button that is referring the instruction to try to do it easily and that the patient could understand the instruction perfectly.

Below there is an image of the commands and the explanation of what does every button.

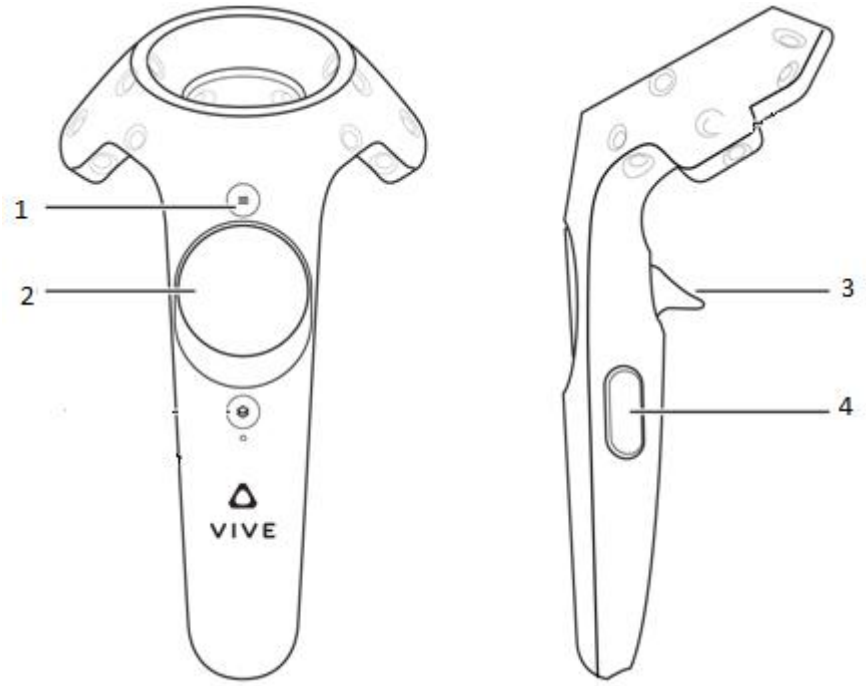

Figure 6.91 Commands (Source: prepared by the authors)

Number 1: this button is only used in the levels 2 and 3 of the Shopping List part. It is used to consult the list. When the button number 1 of the left command is pressed the list appears 15 seconds. The number of times that the button number 1 is pressed in the levels 2 and 3 will appear in the database.

Number 2: It is the Trackpad button. It is always in the right command and it is used to modify the direction of the user. When the user presses the left part of the Trackpad he moves to the left. When he presses the right part he moves to the right. When the patient presses the up part of the Trackpad he goes forward and when he presses the down part of the Trackpad he goes backwards. It is used in all the parts of the application.

Number 3: It is the Grip button. It is used in the four parts of the application. It is used to catch the different products. When the Grip button of the right command is pressed and a product is selected the user catches the product.

Number 4: This button is only used in the tutorial. When the button number 4 of the right command is pressed the last instruction is repeated. It is useful at the beginning because the patient can be nervous and he can lose some important information of the instruction.

6.7. Improvements and changes in the application

- Implementation of both projects in a single project (tutorial, list shopping, shop assistant and autonomous communities)
- Speed adjustment on all levels for greater handling
- The problem of the colors of some objects has been solved (for example the banana). Now everyone has a realistic color, greatly enhancing their distinction without confusion.

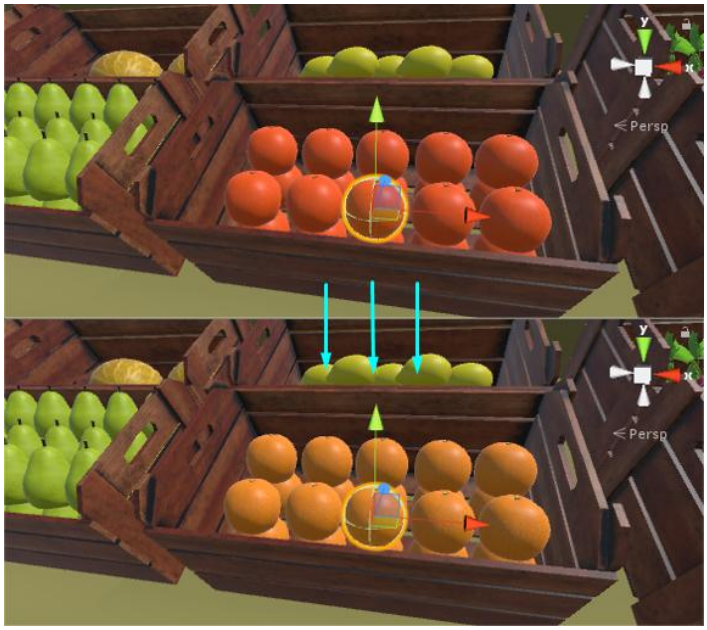

Figure 6.92 Colour differences (Source: prepared by the authors)

As can been seen in the image, the orange had a similar red color. This problem was in the textures because it had an extra color on the texture product.

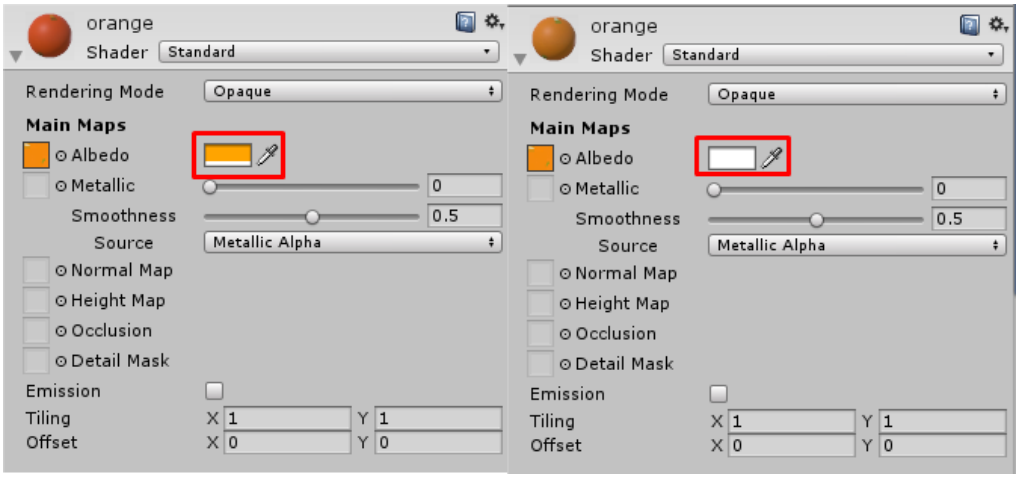

Figure 6.93 Orange's texture (Source: prepared by the authors)

- In the list of objects that the user had to put in the basket, those that were difficult to distinguish (endive, avocado, etc.) have been removed. In addition, we have improved the lists putting more variety of products and avoid that they are repeated so that the game is not so monotonous and intuitive.
- We have also created new combinations of products that were not in the same shelf so that the activity is not so simple.
- To place objects in the basket, the system has been simplified and improved. Now you only need to press a button (trigger) of the right controller to pick up the object you want and just bring it closer to the basket.
- In the tutorial the system of audio repetition has been implemented.
- The start menu has been updated. Now they include the activities of shop assistant and autonomous communities with their different levels.
- In the game of the shop assistant, the shopping cart that contained the objects has been removed. It has been considered that the shopping cart had many problems to take the objects inside because it was difficult to access them and many times you were stuck inside him. Instead, a small table has been replaced.

Figure 6.94 Before and after in the Shop Assistant (Source: prepared by the authors)

- New audios have been made. There are more explanatory and they are heard more clearly.
- In the levels of shop assistant and autonomous communities a terrain has been added since the objects and even the personage fell to the emptiness.
- The limits of the environment where the player moves have been modified to prevent cross the walls or other surfaces.
- We have colored areas of the supermarket that don't have any color or change wrong textures.
- We have fixed the problem in the tutorial that activated several audios at the same time.

- The database system has been implemented and tested and works correctly. Collect the errors and time of the activity.
- The timer of the screen has been removed in all the levels (internally it continues working for the database). We have removed it because the doctors said us that the timer could stress the patient.
- We have removed all the unusable elements and functions. Now, the application is more lightweight.
- In the tutorial, we have change the color of the snap drop zones. They had different colors but the doctors said us that the patients can't recognize very well some colors. For this reason, we changed all the snap drop zones to the green color (the colors that the patient can recognize easily are red, green and blue).
- The paused menu has been removed in the button of the controller because the patient enters at the menu unintentionally. Also, the doctor must be the only person who can stops the application (not the patient).
- When the patient finishes the level, he doesn't need to press any option in the menu to load the next level. The application loads the scene automatically and the doctor chooses the level.
- All levels have environment music to relax the patient.
- In the Shop Assistant activity, we have added an exit poster in the supermarket to indicate at the patient where the exit is.
- We changed the successful message that it appears when the patient completes the level. The message has been replaced for two audios that give the congratulation at the user while it songs a music.
- We have created all the exit menus in the different levels of the Shop Assistant activity and Autonomous Communities activity.
- Initially, the user could move with the touch pad controller (touch panel) but this configuration is for advanced gamers because it requires more experience and skills in the games. However, the patients are inexperienced people in the world of the games, therefore we have changed the touch pad controller for the press pad controller (axis buttons) to make easier the movement in the game.
- We have fixes some object errors in the application: floating objects, invisibles walls, no-reproducing audios.

7. Database

One of the most important things about the application is the collection of data. It is very important for the doctor to have a follow-up of each patient's progress.

The database is done with the program MySQL. It is a very popular program to do a database and it is developed by Oracle and Microsoft SQL Server. The database can be read with the program DB Browser.

First of all it is necessary to introduce a list of the variables that will be in the database indicating what type of variable it is. Here it is an example of a list of variables:

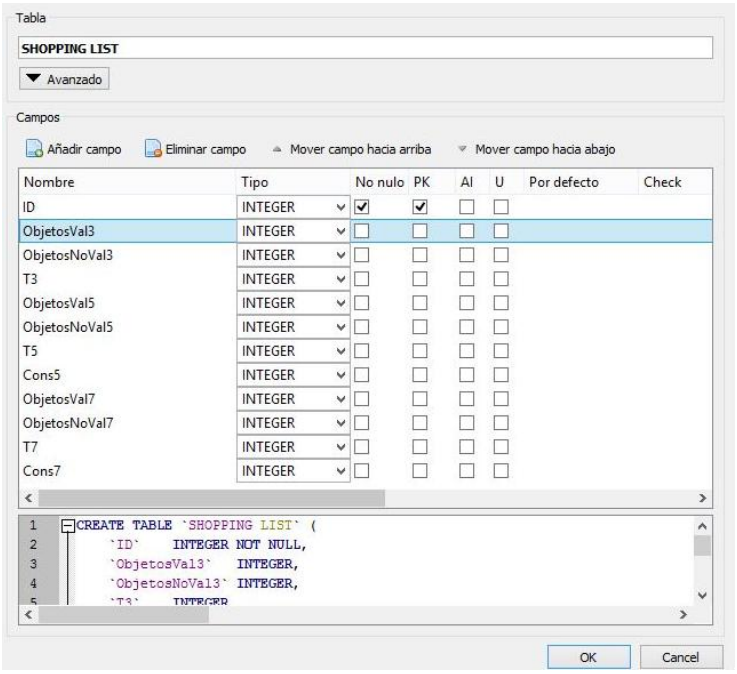

Figure 7.1 List of variables for the Shopping List (Source: prepared by the authors)

To connect it with the application is important to create an object (in our application its name is Game Control). There is a script in C# in the Game Control to collect the data.

The data is collected in the Game Control while the patient is performing the exercise. Once the doctor presses "Salir" in the Final Menu the data is stored in the database.

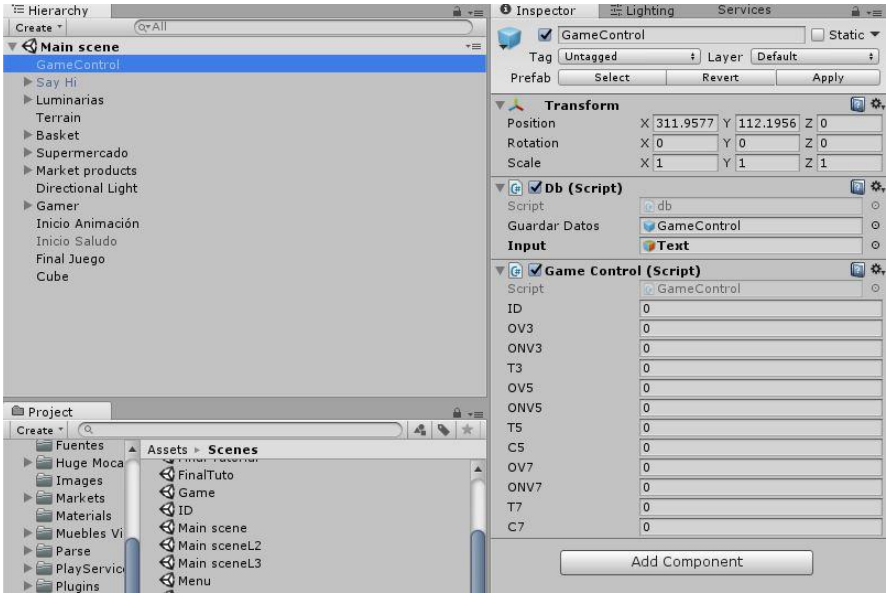

Figure 7.2 The Game Control and the Data collected (Source: prepared by the authors)

7.1. Data collected

All the data collected in the application are those that the doctors of the Hospital Clínic told us it would be important to have collected.

In the tutorial there is not any type of data collected because the intention of the tutorial is to learn the movements and the environment of the supermarket.

In the Shopping List the data collected are:

- ID: it is a number to maintain the anonymity of the patient.
- ObjetosVal3: the products put in the basket correctly in the first level. The maximum are 3 products.
- ObjetosNoVal3: the products put in the basket incorrectly in the first level.
- T3: it is the elapsed time from the beginning of the exercise until the patient leaves the exit door in the first level.
- ObjetosVal5: products put in the basket correctly in the second level. The maximum are 5 products.
- ObjetosNoVal5: the products put in the basket incorrectly in the second level.
- T5: it is the elapsed time from the beginning of the exercise until the patient leaves the exit door in the second level.
- Cons5: it posts the number of times the user consults the shopping list in the second level.

- ObjetosVal7: products put in the basket correctly in the third level. The maximum are 7 products.
- ObjetosNoVal7: the products put in the basket incorrectly in the third level.
- T7: it is the elapsed time from the beginning of the exercise until the patient leaves the exit door in the third level.
- Cons7: it posts the number of times the user consults the shopping list in the third level.

In the Shop Assistant the data collected are:

- ID: it is a number to maintain the anonymity of the patient.
- TR1: it is the elapsed time from the beginning of the exercise until the patient puts the three objects in their correct shelves in the first level.
- TR2: it is the elapsed time from the beginning of the exercise until the patient puts the four objects in their correct shelves in the second level.
- TR3: it is the elapsed time from the beginning of the exercise until the patient puts the six objects in their correct shelves in the third level.

In the Autonomous Communities the data collected are:

- ID: it is a number to maintain the anonymity of the patient.
- TC1: it is the time that the user needs to put the products placed on the shelf correctly in the first level.
- TC2: it is the time that the user needs to put the products placed on the shelf correctly in the second level.
- TC3: it is the time that the user needs to put the products placed on the shelf correctly in the third level.

Here there is an example of what sees the doctor after the users had done the exercises.

Estructura de la Base de datos | Navegar Datos | Editar Pragmas | Ejecutar SQL

Tabla: SHOPPING LIST — Nuevo registro — Borrar registro

	ID	ObjetosVal3	ObjetosNoVal3	T3	ObjetosVal5	ObjetosNoVal5	T5	Cons5	ObjetosVal7	Ol
	Filtro	Filtro	Filtro	Filtro	Filtro	Filtro	Filtro	Filtro	Filtro	Filt
1	0	3	0	44	4	3	88	5	7	3
2	1	3	2	56	2	2	90	5	6	5
3	2	3	0	64	5	0	105	2	7	0
4	3	0	0	0	0	0	0	0	0	0
5	4	2	3	75	3	4	154	9	5	10
6	5	3	1	56	5	1	87	6	6	5
7	6	1	2	87	4	4	99	5	6	5
8	7	3	0	75	5	1	115	6	7	5
9	8	2	2	45	4	5	69	1	5	5
10	9	3	0	58	4	2	98	2	7	0

1 - 10 de 10 — Ir a: 1

Figure 7.3 Data collected of Shopping List (Source: prepared by the authors)

These are the data collected in the Shopping List. There are 10 users that had done the three exercises. It is possible to add more users.

In this first image, the data are sorted by order of ID although they can be sorted according to some other data. Here there is an example of the data ordered from less to more time.

Estructura de la Base de datos | Navegar Datos | Editar Pragmas | Ejecutar SQ

Tabla: SHOPPING LIST

	ID	ObjetosVal3	ObjetosNoVal3	T3
	Filtro	Filtro	Filtro	Filtro
1	3	0	0	0
2	0	3	0	44
3	8	2	2	45
4	1	3	2	56
5	5	3	1	56
6	9	3	0	58
7	2	3	0	64
8	4	2	3	75
9	7	3	0	75
10	6	1	2	87

Figure 7.4 Data collected of Shopping List ordered form less to more time (Source: prepared by the authors)

Doctor has the possibility of looking for some type of concrete data writing it where puts “Filtro. It is useful to search all the results of a specific patient. For example, if you write 7 in “Filtro” below ID the data base will show you all the results of the patient number 7.

8. Chosen technology

8.1. Hardware

To create the application, we need to keep in mind that the virtual reality needs a special hardware to use.

This hardware is normally a virtual reality glasses that let at the user have more immersion during the game.

Currently, this type of technology has been advancing and modernizing so that with the passage of time has come on the market new versions of this hardware.

For this reason, we can find different virtual reality glasses for choose with advantages and limitations among them.

In our case, we did not have to choose the technology because this project is the continuation of others. During the project we have used the VR HTC VIVE for the application.

As we have commented previously, in the market is a different type of virtual reality glasses. Therefore, the next study market shows the characteristics between the different hardware:

The Google Cardboard is a virtual reality platform developed by Google on the basis of folding cardboard that works from mounting a smart mobile phone with Android or IOS. If you look up, the image continues up, if you look to the left, the image continues to the left, etc… This creates the illusion of the immersion. The lenses are to give the feeling of depth. The fields of vision for the right and left eye are delimited by a strip of separating cardboard in the centre of the glasses. The crystals create a magnifying glass effect, so it is quite important that the phone has a rather high concentration of pixels per inch to use Google Cardboard.

Its graphics are considerably lower and immersion is not as sophisticated, but it has some advantages over its competition. Google Cardboard is impressively cheap. Thanks to its low cost is spreading the concept of virtual reality among the population. Secondly, it is very practical to use and you already have the screen (your telephone). To use it you just put it on the device. Another positive factor is that Google Cardboard already has more than 1000 applications in the Play Store.

Figure 8.1 Google Cardboard (Source: Google Images)

The Google Cardboard is a very simple hardware limited for the mobile platforms. His price is very cheap (5€) and it doesn't have any controllers or movement sensors. These factors let the Google Cardboard an accessible hardware for everyone, but it has a low immersion.

The Samsung Gear VR is totally wireless, lightweight and has a relatively low price in their segment. Its interface is intuitive and is relatively convenient to use. It needs a smart phone to work and only some Samsung phones are compatibles with the glasses.

The virtual reality experience that it offers is still below what the net systems that use computer and consoles offer. The field of view is only of 96 degrees. In addition, the ecosystem still lacks the quality and variety of content to really take advantage of it.

Figure 8.2 Samsung Gear VR (Source: Google Images)

Th Samsung Gear has the same problem that the last hardware because it only works in mobile platforms. It has a simple controller for playing and his structure is more robust. His price is 129,99€ and it has a low immersion too.

The PlayStation VR (PS4) is more expensive (299,95€) but offer at the user more immersion thanks at his camera to capture all the movement. Furthermore, it has special controllers to improve the game experience. However, it is limited because only can use in PlayStation platform.

Figure 8.3 The PlayStation VR (Source: Google Images)

The Razer OSVR let at the user use this hardware in different platform without limitation. It has a similar price that the PlayStation VR (315€) and offer more immersion. On the other hand, it doesn't any controller so it difficult the playing with him

.

Figure 8.4 The Razer OSVR (Source: Google Images)

The Oculus Rift is a virtual reality helmet that is being developed by Oculus VR. Rift's integrated 360 degrees spatial audio takes the power of immersing virtual reality to another level. The graphics are much better, although a computer with minimum requirements is required.

The Oculus Touch controls incorporate impressive hand and finger movements as well as physical buttons for traditional games. Motion tracking lacks the full room scale of the HTC Vive.

Figure 8.5 The Oculus Rift(Source: Google Images)

The Oculus Rift is considered a very good hardware for the virtual reality. It has good immersion thanks at his movement sensors and let at the user play with universal controllers (for example XBOX's controllers). It can use in PC platform and his price is 499€ but Oculus Rift was conceived to play sat down.

The last is the HTC VIVE (the hardware we have used). It is one of the best virtual reality glasses in the market. It has two laser towers that capture all your movements and special controllers to make easier play with this hardware. However, it has high PC specifications and high price (699€).

The HTC Vive is virtual reality glasses manufactured by HTC and Valve. A powerful computer is necessary for the correct functioning of HTC Vive. The device is designed to use space in a room and immerse in a virtual world in which the user is allowed to walk and use drivers to interact with virtual objects. Facts, hand tracking and physical movement makes the experience able to get fully into that virtual world.

The front camera allows detecting any object, static or moving, in the area. This function also serves as a security system, showing the real world to prevent users from colliding with objects.

Figure 8.6 The HTC VIVE (Source: Google Images)

8.2. Engine development

As we have commented previously, this project is the continuation of others so for this reason the engine development was already chosen.

We have used Unity3D, but we can find other engines for example Game Maker or Unreal Engine. In the next table it is possible to see the characteristics of these three engines:

Properties	Unity3D	Game Maker	Unreal Engine
Free version	YES	NO	YES
Compatible with windows	YES	YES	YES
Compatible with HTC VIVE	YES	NO	YES
3D design program integration	YES	NO	NO
3D support	YES	NO	YES
VR support	YES	NO	YES
VRTK (virtual reality toolkit)	YES	NO	NO
Help forums	YES	YES	YES

Table 1 Engine development

As can been seen the Unity3D engine is the best option to do a 3D application. It is compatible with windows and HTC VIVE. Also, using this engine we can contact with Visyon360 to obtain support of them.

The engine Game Maker it's obviously discarded because it doesn't have compatibility with HTC VIVE and not be a free engine.

On the other hand, Unity3D and Unreal Engine are compatible and free engine, but Unity takes advantage because this engine has a lot of repositories and documentation for learning and solve problem for beginning users.

Other important factor is the coding language. While Game Maker use C++, Unity3D use C# which is an easier language for programming to use for beginner users.

Finally, all the factors make Unity3D the best option for the project because his characteristic do the design of the application friendlier for users that never have created a 3D project, use Unity or use advancing programming.

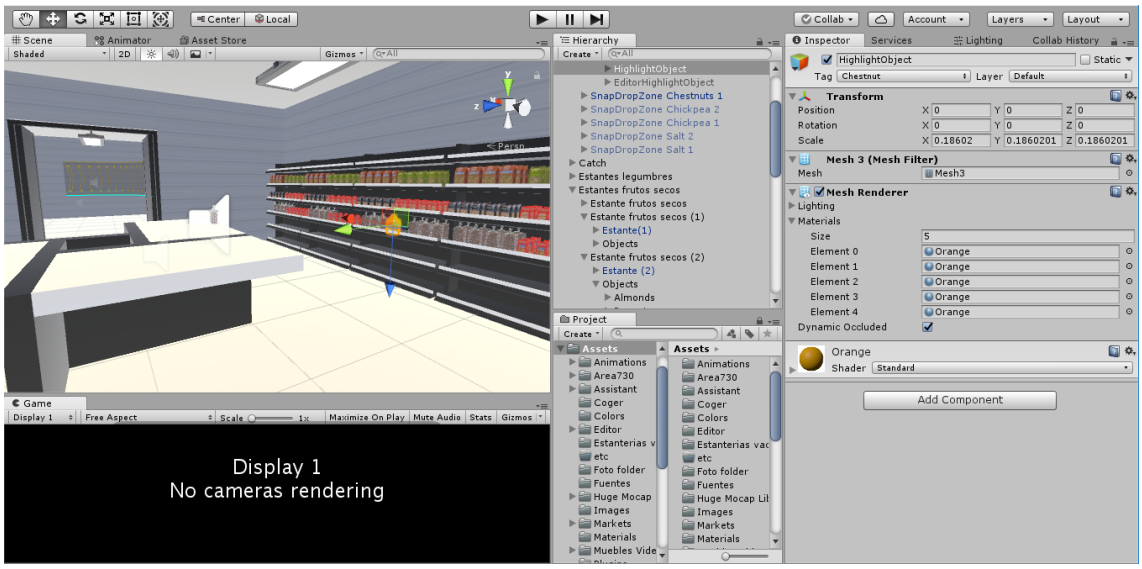

Figure 8.7 Unity interface (Source: prepared by the authors)

8.3. Programming software

To carry out the programming of the various scripts necessary for the operation of the application it has been decided to use the Microsoft Visual Studio software, although the Unity comes by default the MonoDevelop has decided to work with Visual Studio.

Visual Studio is an integrated development environment (IDE) developed by Microsoft, it is a very versatile application with which you can edit almost any code and for different platforms such as iOS, Windows, Android or web, it has been decided to use this IDE, because it has a more advanced development environment, offering aids that MonoDevelop does not offer as intelligent autocomplete; it also offers syntax coloring help, code schematization or pop-up descriptions of the code element you select, among other things.

This programming software admits different coding languages: C, C++, C#, Python or other.

For this reason, we use Visual Studio because we can program in C# so, as we explained before, is easier to use at the beginning.

8.4. Extra resources

This project needs to use other resources in addition to Unity, HTC VIVE or Visual Studio.

We used different tools to carry out our project and all of them are explained in this part:

SKANECT: is a scanning program that let us capture new textures and structures to do new objects in the application.

GANNT PROJECT: this application helps to organize and structure our objectives and goals during the time that we are doing the project.

MYSQL: is a database management program. We have used this database to store all data during the game to make easier to the doctor extract a result.

VOICE RECORDING: we use our mobile phones to record the audio used in the application. After to record the audio, we need to convert these type of files (MP4 format) to MP3 format.

9. Design

The part of the design of the supermarket is basic to be able to make our application. Designing the supermarket and the products that are in it as realistic as possible helps the user to complete the exercises.

The most important part of the design was done in the others TFGs but we think is very important to explain it to understand the way that the entire project is done. What we do in the design part is to change some textures in some parts of the supermarket and in the products of the supermarket to do it more realistic. In this way, the patients will recognize the different products easily and quickly.

9.1. Unity 3D tools

The program Unity allows downloading different types of assets. The majority are free and they are very useful to design the supermarket. The Asset Store of Unity allows downloading different type of animations too.

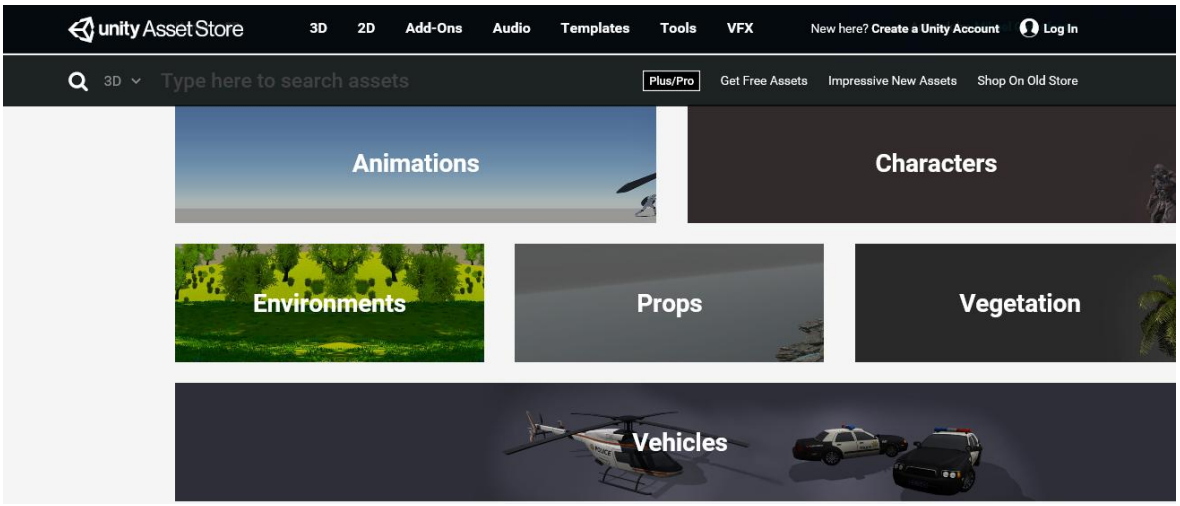

Figure 9.1 Unity 3D tools (Source: capture of Unity Asset Store)

There is the possibility to build the objects with different forms directly from the Unity program. Once the object with the desired shape is created, it is possible to add a certain texture and colour so that the created object is as close as possible to the real object.

9.2. Websites

Sometimes there is not the possibility to use the Unity assets because they are not free or the assets that you are looking for are not in the Unity assets.

There are some websites in Internet to download different type of assets.

During the project the websites that have been used are Sketchup.com and Archive3d.net. Both have been used to import assets into our project. The advantage that Sketchup has over the other pages is that it allows us to clean the assets of possible imperfections.

9.3. Skanect

Skanect is a useful program to scan different objects for an easy design. In the project we have used Skanect in the videos of the tutorial to show to the patients the way to move the head in the first room.

We thought that if the patient is looking a video of the movements when the instructions are sounding the comprehension is easier.

Figure 9.2 Animation of movement (Source: Prepared by the authors)

10. Results

The 14th of May we went to the Hospital Clínic to do a test with real patients.

The first idea was to do the test with our laptop but we tried to see if it could support the application and load the game without lag. However, the laptop couldn't work running the application and the performance was very slow. Therefore, we carry the PC and the VR HTC VIVE device to the hospital for the test. When we were there; we start to connect the PC and devices to do the test.

The first problem was that the laser towers of the HTC VIVE didn't be in the same place as in the university so the towers didn't capture well the movements of the patients. We solved the problem using books and boxes to elevate the laser towers to increase the vision range.

The first patient was a woman. She played the tutorial and the level 1 of the Shopping List activity.

When she finished said that she had a good time because the application is very amused and easy to play. She didn't feel dizzy but she told us that the system of the controllers to grab objects and put them in the basket is so difficult. Also, she couldn't find the exit door.

The second patient was a woman too. She played the tutorial and the level 1 of the Shopping List activity.

During the game she has some problems to control the movement and she hit on the walls and shelves. Furthermore, the application had a design problem: if you are very close an object, this product puts automatically in the basket (this problem was solved). For this reason, when she hit on the shelves, she put the products in the basket. However, she told that the application is amused.

The third and last patient was a man. He played at the same levels than the other patients.This patient didn't stop to move in the room (in the reality) because the game causes an effect that can confuse a little the perception of the patient.

We tried to sit down on a chair to see if the application could work in this position but the results was negatives because when the patient is sit down, he loses mobility and immersion. Also, he couldn't find the exit door.

When he finished he said that the game is very real and has a good immersion.

Finally, we extracted the next results:

- The application fulfills the requirement of being fun and entertaining the patient.
- The system to put the objects in the basket was wrong. It made the application very difficult to play.
- The speed of the movement had to decrease a little.
- We had to fix the error in the basket when the patient is close to one object.
- We learnt the importance of the HTC tower's place.
- When the patient is sit down the immersion during the game is less then if the patient is playing stand up.
- We needed to signpost the exit door.

The patients, doctors and coordinator projects were pleased to see that the application works well and the patients feel so good when we were playing.

This factor made us to continue working hard to improve more and more the application to make it efficient and entertaining.

MEETING MINUTES

Place: Campus Diagonal-Besós

Date: 12/04/2018

Start time: 15:30

ASSISTANCE:

List of attendees:

- Francesc Alpiste

- Jordi Torner

-Magda Castellví

-Ana Salinero

- Isarn Ardanuy

- Xavier Riera

Explanation of what happened in the meeting:

Magda and Ana came to the university to test the application. They wanted to see if it can be useful for patients.

We tested all the parts of the application to verify that there were not errors. First, Isarn and Xavi did a demonstration of the different parts and then Magda and Ana tested it.

After Magda and Ana had tested the application we draw some conclusions.

Conclusions:

The application is well done and it can be useful for patients.

The movement speed is too fast. This can lead to dizziness.

It is recommended to change the instructional audios because they are heard so softly and there will be some instructions that will change their content. It will be a good idea to change the background music to a classical music.

It is necessary to change the colour of the products that there are at the last part of the tutorial. It can confuse the patients.

It can be useful that the patients have the possibility to repeat the audio pressing a button.

A good way to practice the movements and to adapt to the environment can be to do a test scene at the end of the tutorial where the patient could move around the supermarket and could catch the products that he wants.

MEETING MINUTES OF THE PILOT TEST

Place: "Hospital de dia del Raval de Barcelona", Reina Amàlia Street number 37-39

Date: 14/05/2018

Start time: 9:00

ASSISTANCE:

List of attendees:

- Francesc Alpiste

- Jordi Torner

-Magda Castellví

-Ana Salinero

- Isarn Ardanuy

- Xavier Riera

Explanation of what happened in the meeting:

A pilot test was done with three volunteer patients. They tried the application one by one. First of all we explain them how the application works and we did a demonstration. Then, they tested the scene that is at the end of the tutorial in which you can move around the supermarket and you can catch the products that you want. After a while, when they felt comfortable and we saw that their handling was already good, they prove the level 1 of the shopping list.

After the patients had finished the test and had explained their feelings about it, we made a meeting to draw some conclusions.

Conclusions:

The patients have felt comfortable and they have not rejected the application; rather, they have enjoyed the time they have been handling the application.

The speed is adequate. The patients do not felt dizzy.

It is very important to do a "session 0" to introduce the patient to the environment of the application.

We have to take off the exit menu because it is not useful and it bothers patients.

It is important to change the way to put products into the basket because it is not practical and it is difficult for them.

It is a good idea to change the colours of some products to do it more realistic. The products that can cause identification errors should be removed from products list.

We have to change the place where the corridor's audio is because depending the place where the patient is situated, it starts in a wrong moment.

When we do the sessions with patient is important to go to the place where the session will be the day before because we spent a lot of time to have everything ready to start and to calibrate the sensors to the test room.

11. Regulations

Our product must follow all the applicable rules and regulations. The regulation that is applied to it is that of a computer program for medical purposes. Our product is part of the Health Technology that covers a wide range of health care products and, in one way or other, is used to diagnose, monitor or threat each disease or condition that affect humans.

Regulatory framework in Spain:

- Law 14/1986, General Health
- Law 16/2003, Cohesion and Quality of SNS (Sistema Nacional de Salud).
- Royal Legislative Decree 1/2015, the revised text of the Law on Guarantees and Rational Use of Medicines and Medical Devices is approved.
- Royal Decree 1591/2009, regulates health products.
- Royal Decree 1616/2009, regulates active implantable medical products.
- Royal Decree 437/2002, establish criteria for the granting of operating licenses for manufactures of customized medical devices.

Regulatory framework in Europe:

- Directive 90/385/CEE, regulates active implantable medical products.
- Directive 93/42/CEE, regulates health products.
- Decision 2010/227/UE related with European Database on Health Products.
- Regulation (EU) number 207/2012, about electronic instructions on Health Products.
- Directive 2011/24/UE, about the rights of patients in cross-border healthcare.

Conclusions

This project has consisted in the design of a Virtual Reality Application applied to cognitive training. This application has been compared with the traditional treatments to test his efficiency thanks at the technology that the app has.

This modern method let at the patients with mild cognitive impairment train their mental and cognitive skills while they have a good time. This new technique is less monotonous and more effictive and fun than the traditional treatments (with pencil and paper).

Furthermore, the patient doesn't feel overwhelmed because during the game he can disconnect and enter in the virtual reality where he is immersed in a new world with different activities that let him slow down the dementia progress without feeling examined.

We have achieved our objectives during the process of the application to the help of Hospital Clínic, Visyon 360 and our project coordinators.We have improved the application to make it easier and friendly to use for the patient while we learnt new knowledge of 3D Design. Thanks, at the project we have known how to solve problems in Unity and fix scripts errors that before are unknown for us.

On the other hand, this project opens our eyes to the reality and we have been aware that currently, the people that are affected by any mental illness are increasing so research treatments to cure or slow down this illness can be the new future in the field medicine.

Finally, we feel very proud and grateful to see the patients finish the activity of the application with a smile in their face and when they sold us that the game is very real and amused. This factor proves that we can achieve the most important goal in this project:

Helping a person with a disability while having a good time and forgetting for a moment his worries.

We want to show the next experiences that this project has contributed us:

- Learn to design in 3D with Unity.
- Train our advanced programming skills.
- Organization and companionship during the project.
- Autonomous learning.
- Become aware of mental illness.
- Train our English.
- Interact with professionals and patients.
- Constancy and patience bring great gratification.

- Train our English.
- Interact with professionals and patients.
- Constancy and patience bring great gratification.

Future lines

Currently the application is very developed and is already prepared to be used by patients with mild cognitive problems. In the future, it will be very interesting to do the tests with different groups of patients to see the benefits that the application produces on them.

In order to control the advances of the patients, a good idea that could be made in the future would be to make a broader database in which doctors could have more information about the patients. For example, the results of any patient with the average values of the others could be compared.

Some initial ideas for the project could also be incorporated into the application in order to have more data to control the patient's progress. An initial idea was that before leaving the supermarket in the Shopping List part, the patients would have to pay for the products that were in the basket. The shop assistant would tell the patient the price to pay and the user would have to choose between some coins that would appear on the screen which ones he could use to pay for the products. Another idea was to do the same exercises but changing the place. Do the exercises in a house instead of a supermarket with usual objects that are in a house.

The idea is to do different type of exercises to train different parts of the memory. We think that the ideas are very good but they can probably be part of a totally different application. It can be designed another application to train the semantic memory and language, another to train the episodic memory and other exercises to train exercises of attention and executive functions.

Budget

In this section the detailed costs derived from the realization of the project are presented. At the time of carrying out the calculations it has been taken into account that the project started on 23/01/2018 and it ended on 05/06/2018, which adds 96 days of work.

Direct cost

Salary

SALARY				
	Number	Time (h)	Cost /hour (€/h)	Cost (€)
Worker	2	576	30	34560
TOTAL				**34560**

Table 2 Salary

Social Security

Taking into account that the cost of Social Security is 23.60% of the contribution base, we obtain the following calculation of the cost of social security for the two workers.

SOCIAL SECURITY				
	Number	Salary (€)	Contribution base (%)	Cost (€)
Worker	2	34560	23.60	8156.16
TOTAL				**8156.16**

Table 3 Social Security

Equipment

	Number	Cost/unit (€)	Total Cost (€)
Computers	3	1000	3000
Unity 3D	3	0	0
Visual Studio	3	0	0
DB Browser	3	0	0
HTC Vive	1	600	600
Skanect	3	0	0
	TOTAL		**3600**

Table 4 Equipment

Indirect cost

Installations and the associated expenses

	Months	Cost/month	Cost (€)
Rent	5	400	2000
Internet	5	50	250
Water	5	10	50
Light	5	40	200
Gas	5	20	100
	TOTAL		**2600**

Table 5 Installations and the associated expenses

Total cost

TOTAL COST	
	COST (€)
DIRECT COST	**46316.16**
Salary	34560
Social Security	8156.16
Equipment	3600
INDIRECT COST	**2600**
Installations and the associated expenses	2600
TOTAL COST	**48916.16**

Table 6 Total cost

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