

Virtual Reality experience for home automation system

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TITLE	
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ABSTRACT	This thesis is about developing a VR experience for a technological company in Valencia. The idea of this project is to have an experience and a better understanding of home automation system before buying it. The result is two different VR platforms: mobile application for Samsung Gear VR and computer version for Oculus Rift.
	La tesis está basada en el desarrollo de una experiencia de realidad virtual para una empresa de domótica en Valencia. La idea del proyecto es entender el funcionamiento y poder experimentar con el sistema de domótica antes de adquirir el producto. El resultado final son dos plataformas diferentes de RV: una aplicación móvil para Samsung Gear VR y una versión para ordenador con Oculus Rift.
KEYWORDS	Virtual Reality; Home automation system; Application; 3D design
	Realidad Virtual; Sistema domótico; Aplicación; Diseño 3D
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1. INTRODUCCION

I have started this project while doing my internship in Baintex Technologies in Valencia, Spain. Baintex Technologies is a technological and innovative company which is working on home automation systems. My job was to show the function of devices which produces the company through the short animated videos. Then, I realized that if this is an innovative company, the advertisement must be unusual. Thus, we have started our new virtual reality research.

It was not my first virtual reality project. I have done my bachelor degree thesis in 2016 about virtual reality in architecture. Though during last two years the technologies have changed a lot in the virtual world.

The idea of this project was to launch a virtual reality advertisement. Nowadays there is a huge amount of various types of artificial reality and devices to use. Thus, in my thesis I would like to show the way we have developed our idea and the results that we have reached. This work was made with the help of my coworker Adrián Ciborro Montes (Software Engineer), all coding part of the project was made by him.

Consequently, this thesis consists of data about what is virtual reality, types of it, the market of headsets for nowadays, VR in marketing and useful tips how to design for VR. Then the most important part is the project, there is information about the differences in designing for VR mobile application and VR for computer platform. Moreover, the difficulties I have faced with and solutions. Furthermore, the important part of this research was testing the applications. At the end, the final project with a new version of Unity 3D 2018 with more realistic render and effects in virtual reality.

2. BACKGROUND INFORMATION

2.1. WHAT IS VR

“There is huge hype about virtual augmented and mixed reality. Facebook, Sony, Microsoft, Google, HTC and others are investing billions of dollars. 2016 sees the VR industry entering the mass market for consumers. Immersive media create an impressive reality, surrounding the user completely.” – Joerg Osarek (Virtual Reality Analytics 2016).

Virtual reality definition: “Inducing targeted behavior in an organism by using artificial sensory stimulation, while the organism has little or no awareness of the interference.” - Steven M. LaValle (Virtual Reality 2017).

According to Steven M. LaValle, the first experiment which showed a 3D effect of stereopsis was made in 1838 by Charles Wheatstone. Later, in 1930s a portable version was made and it is known as View-Master (Fig. 1). Then, it was converted to Sensorama machine, which included motion pictures, vibration, wind, sounds, and smells (LaValle, 2017, p. 30).

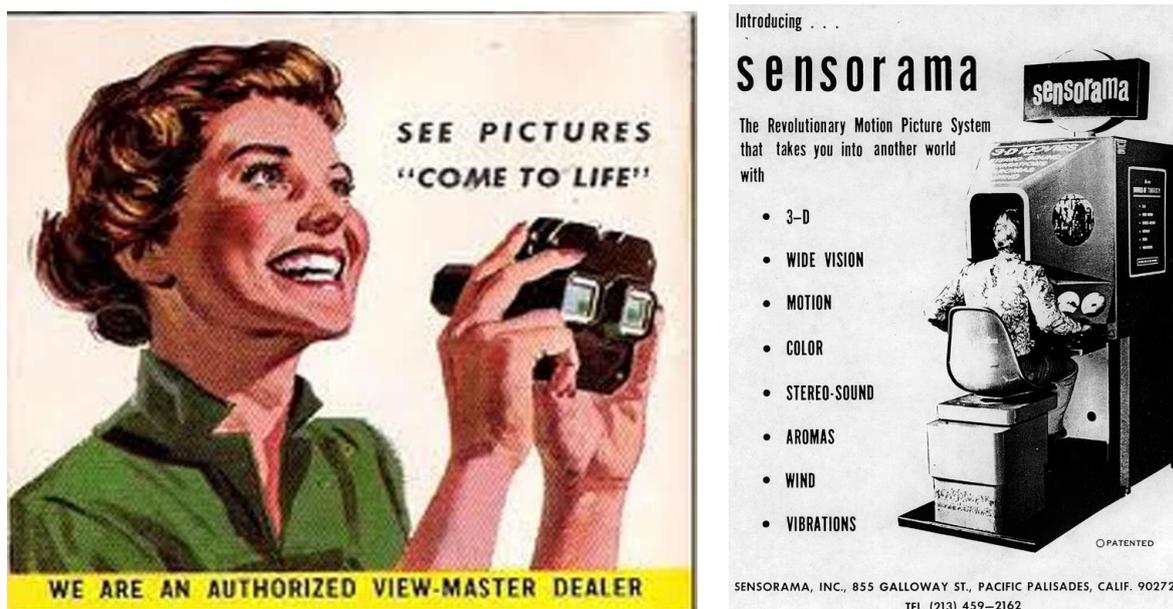


Figure 1. View – Master and Sensorama posters. (<http://proyectoidis.org>)

Nowadays there are three main types of artificial reality:

- Augmented Reality (AR)

- Virtual Reality (VR)
- Mixed Reality (MR)

According to Joerg Osarek, AR is a kind of artificial information which is projected on top of the real world. VR means total immersion into a virtual world, without seeing the real one. MR is virtual information and objects which are placed correctly into 3D space in real time. Therefore, “we can sum up the relevant technologies VR/AR/MR as xR” (Osarek, 2016, p. 13).

2.2. VR HEADSETS

After studying the market, I have divided headsets to three categories:

- Simple headsets like Google Cardboard
- Medium level headsets such as Gear VR and Daydream
- Professional headsets like Oculus Rift and HTC Vive

The first two categories are for mobile phones. The difference between them is that the cardboard version (Fig. 2) is the cheapest kind of goggles for nowadays. Besides, almost any type of mobile phones can be used for this type of glasses. Nevertheless, they can be used just to watch 360° videos.



Figure 2. Google Cardboard (<https://vr.google.com/cardboard/>)

Gear VR (2018) by Samsung and Oculus (Fig. 3) and Daydream by Google (Fig. 4) are quite similar in characteristics and price. Both of the models have controllers. These goggles have much more options and applications than cardboard glasses. The difference between them is that Gear VR works only with certain models of Samsung which support VR option.

Daydream works with more phones which have Android platform though they should also support VR mode. Another difference is virtual reality platform. Gear VR uses Oculus platform and Daydream uses Steam VR. This means that there are some differences in coding.



Figure 3. Gear VR
(<https://www.oculus.com>)



Figure 4. Daydream
(<https://vr.google.com/daydream/>)

	Gear VR	Daydream
Optical Lens	101-degree field of view	90-degree field of view
Display	2560 x 1440 pixel Super AMOLED	Depends on device
Refresh Rate	60 Hz	Depends on device
Sensor	Accelerator, gyrometer, proximity	Accelerator, gyrometer, proximity
Focal Adjustment	Focus adjustment wheel	N/A
Physical UI	Touchpad, Back button, volume key, and Gear VR controller (included)	Motion controller (included)
Connection	USB Type-C and MicroUSB	Wireless connection
Dimensions	201.9 x 116.4 x 92.6 mm	166.8 x 4.18 x 3.88 mm
Weight	310 grams	220 grams

Table 1. Gear VR and Daydream technical characteristics
(<https://www.digitaltrends.com/virtual-reality/>)

At the moment of choosing headset Oculus Go has been announced but has not been on the market yet. It uses the same platform as Samsung Gear VR, but without any extra devices and

cables. There is no need in mobile phone because the headset already includes a small computer inside.

The last category is Oculus Rift (Fig. 5) and HTC Vive (Fig. 6). This kind of glasses are professional headsets which work only with computer or laptop that supports VR option. Thus, they are almost the most expensive in the market. The characteristics of these headsets are very similar, both of them includes controllers and movement sensors, the angle of view is 110 degrees. The biggest difference that they have is design of the goggles and of controllers, size of tracking area and VR platform. Oculus has their own platform and HTC uses Steam VR.



Figure 5. Oculus Rift
(<https://www.oculus.com>)



Figure 6. HTC Vive
(<https://www.vive.com>)

	Oculus Rift	HTC Vive
Display	OLED	OLED
Resolution	2160 x 1200	2160 x 1200
Refresh Rate	90Hz	90Hz
Platform	Oculus Home	SteamVR, VivePort
Field of view	110 degrees	110 degrees
Tracking area	5 x 5 feet (two sensors), 8 x 8 feet (three)	15 x 15 feet
Built-in audio	Yes	Yes
Built-in mic	Yes	Yes
Controller	Oculus Touch, Xbox One controller	Vive controller, any PC compatible gamepad
Sensors	Accelerometer, gyroscope, magnetometer, Constellation tracking camera.	Accelerometer, gyroscope, Lighthouse laser tracking system, front-facing camera

Connections	HDMI, USB 2.0, USB 3.0	HDMI, USB 2.0, USB 3.0
Requirements	NVIDIA GeForce GTX 960 / AMD Radeon RX 470 or greater Intel Core i3-6100 / AMD FX4350 or greater 8GB+ RAM Compatible HDMI 1.3 video output 2x USB 3.0 ports Windows 7 SP1 or newer	NVIDIA GeForce GTX 970 /AMD Radeon RX 480 equivalent or greater Intel Core i5-4590 equivalent or greater 4GB+ of RAM Compatible HDMI 1.3 video output 1x USB 2.0 port Windows 7 SP1 or greater

Table 2. Oculus Rift and HTC Vive technical characteristics

(<https://www.digitaltrends.com/virtual-reality/>)

The headset, which is not inside the classification is HTC Vive Pro. The reason is that at the moment of choosing the goggles, the release date still was not announced. Another reason is that I have worked with other headsets and this one is something completely new and I can compare only searching characteristics in the internet. In theory it should be the most powerful headset for this year, however, the price is double comparing to other professional goggles. The strengths of Vive Pro are: better resolution 2,880 x 1,600 (615 PPI), bigger tracking area (33 x 33 feet), dual front-facing cameras and it should have wireless adaptor. Thus, it means that there will not be irritating cables between the headset and computer. Thought it requires more powerful PC than others headsets, for instance, the graphic card should be Nvidia GTX 1060.



Figure 7. HTC Vive Pro (<https://www.vive.com/>)

2.3. EXAMPLES OF VR IN MARKETING

Nowadays a great quantity of famous and big companies use VR for advertisement. For instance, McDonalds in Sweden made a special edition of Happy Meal from which you could do “Happy googles” (Fig. 8) and play a simple VR game. Not only is it a VR experience, but also recycling point.



Figure 8. Happy googles (<http://www.happygoggles.se/en/>)

One more interesting example is Marrell – a shoes company. To promote their new advanced hiking shoes they have used 4D experience with Oculus Rift (Fig. 9). Thus, a customer could try and “use” the shoes before buying them.



Figure 9. Marrell VR experience (<https://optitrack.com/about/press/20150317.html>)

The field which makes the biggest effort in the VR applications as advertisement is car industry. A huge amount of prototypes and new models are presented with the help of virtual reality showrooms. I would like to pay more attention on applications which are available in Oculus store for Gear VR.

In my own point of view, the most interesting application for now that is available for downloading is “BMW i Samsung Virtual Reality Experience”. The graphics of the app are

really nice and soft, very pleasant for the eyes. The scene consists of high quality renders, photos, videos and two 3D models of hybrid cars (Fig. 10). Consequently, the creators have used mixed solution for the scene. A user can move from one part to another part of the scene but can not “walk” through. At the end there is a 360° video, which simulates driving experience with a car.



Figure 10. BMW i Samsung Virtual Reality Experience screenshots

Another example which is available for the owners of Gear VR is “The new Jaguar E-pace virtual reality experience”. This application is a bit less realistic than the one by BMW (Fig. 11). In my opinion, it is due to real time rendering and 3D scene with animation, no photos or videos are used. This means that there could be more interaction and a possibility of walking through the scene with the controller, but unfortunately it is not like this. It is possible that the developers have thought that not all Gear VR headsets include controllers. Only the new version of 2018 has a controller. Thus, the application is more like a 360° animated movie.



Figure 11. The new Jaguar E-pace virtual reality experience

There are more examples of VR apps in car industry, for instance, collaboration of Lamborghini and Samsung. Lamborghini Huracán Virtual Reality Experience for Geneva Motorshow 2015. A user could experience driving Lamborghini Huracán with 360° video and sound effects.

A similar project Volvo Reality was made by Volvo to promote a new car XC90. A possible client can experience driving the car with Google Cardboard headset. The application is available for both platforms Android and IOS. However, there was no chance to try it because it was written that this application is not available in the territory of Spain. It seems that application was made only for US users.

One of the most interesting examples as virtual reality in marketing is IKEA. The company has various applications for different types of headset. The simplest one was made with Gear VR for the 30th IKEA anniversary in United Kindom (Fig. 12). As far as I understand, the scenes are 360° renders with some interaction like popup information windows. On the one hand, this type of applications is easiest to make and to present. There is no need to have a computer you just need a mobile phone. Moreover, there are no cables around the user. On the other hand, the quality of the scene is not that realistic and there is no interaction inside the app.



Figure 12. IKEA VR with Gear VR (<https://www.youtube.com/watch?v=8dOEK0GR1Tk>)

In further examples professional headsets such as Oculus Rift and HTC Vive were used. Thus, the projects are much more interesting due to possibility of user interaction with objects and more realistic scenes. The first example is IKEA Virtual Reality Showroom (Fig. 13). Although there is no possibility to walk through the scene, user has a chance to interact with the objects. For instance, change colours of the walls, change materials, fabrics, put day or night mode and at the end give a feedback.



Figure 13. IKEA VR Showroom (<http://demodern.com/projects/ikea-vr-showroom>)

In the next example you can imagine yourself as a designer and a chef on IKEA kitchen (Fig. 14). There are many options like “walk” around the kitchen, change colours and materials, cook some food etc. Subsequently, this application is more like a game, however, the point is that a client can see the functions of the kitchen which is made by IKEA.



Figure 14. IKEA Virtual Reality Kitchen

(https://www.ikea.com/ms/en_SG/this-is-ikea/ikea-highlights/Virtual-reality/index.html)

The last project, which I would like to review is IKEA VR shopping. The experiment took place in 3 countries: Kuwait, Jordan and Morocco (Fig 15.). The idea was to do shopping without entering to the real store. The customer could choose different types of furniture, colours, see the final design of the space. Moreover, at the end of the video, as a statistic, it is said that those days more furniture was sold.





Figure 15. IKEA VR shopping (https://www.youtube.com/watch?v=5_znFPj5Lis)

To sum up, with professional headsets it is possible to get better quality, more interaction between a user and the products. However, more free space is required for this type of VR experiences and the cost of the project will be more expensive. With portable headsets is easier to show a VR experience in different places, moreover, there is a possibility that a potential customer can try it at home. Nevertheless, there will be challenge between quality and level of interaction of the application.

2.4. DESIGNING FOR VR

“Accordingly creators of VR content have a great responsibility. But they will not be able to avoid all VR accidents, just as the car industry cannot avoid people having accidents in cars.” (Osarek, 2016, p. 15)

The first thing to note before starting to plan the scene for virtual reality is that the user should feel comfortable inside the virtual scene. There is a high possibility to have motion sickness. If a person does not feel good with VR headset on, it is important to take it off immediately.

The biggest problems which I faced with testing some VR applications were incorrect high position of the person inside the scene and bad navigation system. For instance, when you turn to the left with the controller and your scene turns to the right. Despite the fact that design of the scene was very beautiful and realistic, these kind of mistakes made VR experience awful.

There are some basic useful tips that I have found very reasonable. For instance, the angles of view (Fig. 16). It is important to remember that maximum field of view with head turn is 204°. Not only is it useful if the user is sitting on the static chair, but also in other occasions, because fast 360° rotation can provoke sickness. Forward field of view in VR is more or less 94°. However, if the main part will be going on only in this 94° degrees, there is no sense in virtual reality, because the user is not going to move his had around. In conclusion, the most comfortable field of view in VR is 154 °.

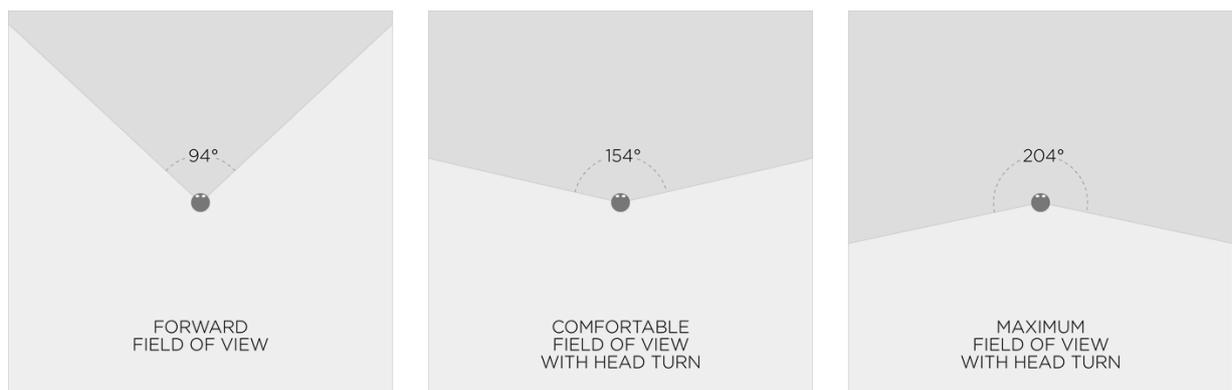


Figure 16. Comfortable head rotation ranges in VR.

(<https://virtualrealitypop.com/storyboarding-in-virtual-reality-67d3438a2fb1>)

In the online magazine *The Marketers Guide To Virtual Reality & Brands*, David Francis, head of sales APAC at Zappar, said some interesting facts, which later I have proved during the project testing:

“Allow the user time to settle in. It takes time for someone to understand 360-degree content. Don’t start the ‘virtual roller coaster’ until they can get their bearings.

Understand nausea. 70% of women, for example, experience nausea in VR. Know the ins and outs of avoiding sudden edits, camera tilts and moving the user through the virtual space too fast.”

One more thing which is important to decide before starting to do your VR project is what kind of scene and interaction the user will have inside the virtual reality. There are three options:

- Pre-rendered 360° scene or video
- 3D scene in real time

- Hybrid option

The first option means that there is a restriction of moving inside the scene. The user will have only two degrees of freedom like rotating and tilting the head. Although there is no possibility in moving, this kind of scene is the easiest to make. There is no need in coding due to programs like YouTube VR, which has a special converter, which will do everything for you and it is free. Thus, you need to do only a video in 360 degrees.

The second option is to have a 3D scene in real time rendering. Consequently, the user has 6 degrees of freedom. This means that the user can move inside the virtual world due to positional tracking. However, this types of projects are more complicated to do. Normally a game engine and coding are required for this task. (Osarek, 2016, p. 19)

The last one is a hybrid solution. This is a combination of renders with more degrees of freedom. Subsequently, the user can move from one part to another of the project but can not walk through the scene. The user does not have as much freedom as in 3D scene in real time, as a result he is following the storytelling line.

To sum up, all three options use individual techniques and have different meanings. It depends on the factors such as for which kind of audience you are doing the VR application, in which context you are going to use it, for which headset and so on.

3. PROJECT

3.1. THE IDEA

The first idea was to do some 360° videos based on the short animations which I have done before for the company. It was done more to convince the owner of the company to start to work with virtual reality.

It did not take too much time due to the previous projects were done in Unity 3D. Unity 3D is a game engine that you can use to create 2D or 3D games or applications for different platforms such as Android, Windows etc. Moreover, there is a possibility to develop applications for AR and VR. The reason why this game engine was chosen is because both of us (Software engineer and I) had experience in this program.

Subsequently, to make a test it was just necessary to change normal camera inside the scene to camera 360. Then, YouTube has a special converter where a 360° video can be adapted to a spherical video or VR version.



Figure 17. Testing 360° videos.

There are three options to watch this types of videos:

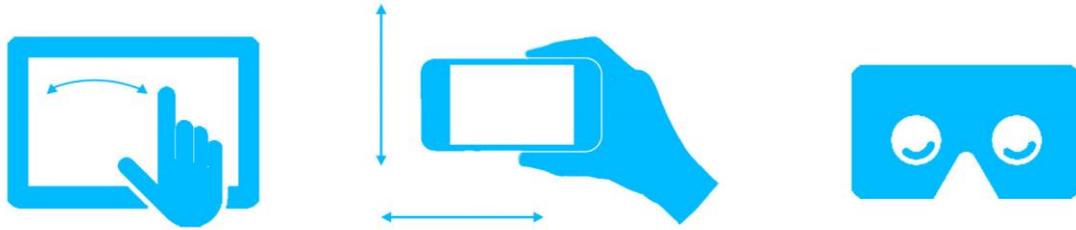


Figure 18. How to watch 360 video in YouTube.

The first option is to move the scene with your finger. The second is to move the phone and the video is going to move too. The last is to use Google Cardboard, however, last two option do not function with all types of mobile phones.

In conclusion, the aim was reached. These videos have given the start for the new huge project in virtual reality.

3.2. VR APP FOR MOBILE PLATFORM

To begin with, the first idea was to create a VR app for Android platform. The reason was that this kind of application is easy to show. You just need a mobile phone and Gear VR headset, there is no need in laptop or other extra devices. Thus, it supposed to be the easiest way to show the application.

3.2.1. 3D Modelling

The purpose of the application was to have a virtual environment, in this case it was a house, to show the function of one of the kits of home automation system, which produces the company. It was necessary to have at least 4 spaces: living room, kitchen, laundry and baby's room.

First, a 3D model of a house was created in Autodesk 3Ds Max and later was exported as FBX file to Unity 3D. I have some experience in modeling for VR and I made a list of tips, which I followed to export the model:

- Group all elements of an object
- Group zones (like bedroom, bathroom etc.)
- Plane objects do not work good in Unity => better to use cubes
- Plane plus shell modifier also do not work good (All walls and floors better to do as cubes)
- With mental ray and Vray renders modifier “hair and fur” does not work in Unity
- Textures and bitmaps should be done through Materials -> Standard, otherwise textures wouldn't export correctly to Unity

Some of the 3D models were created by me and some of them I downloaded from free resources like BIM archiproducts. As I mentioned before, it was important to put textures in 3Ds Max with UV mapping, so that the models after exporting have UV mapping in Unity. Though, it was essential to put textures in Unity one more time due to the different render engines in these programs.

The first problem that I faced was a number of polygons in the scene. The VR experience was really slow and with noisy images. The issue was that the mobile phones do not support heavy applications. Therefore, I needed to make objects more simple, delete faces of the objects which could not be seen by user, use more bump maps for the surfaces. Moreover, the mobile platform does not support real time shadows and reflections, nether point lights only direct light (sun). There are some scene screenshots in Figure 18.

The scene includes some simple interactions and animations. For instance, when you put the washing machine it starts to flood. Furthermore, the user can turn on the oven, switch on TV and see how the alarm system works, when you touch the windows.



Figure 18. Kitchen, Living room, Laundry and Baby's room.

3.2.2. Testing and changes

There were two important things to fix for the presentation. The first, it was vital to have a rotating chair with wheels to have better VR experience. The second was screen sharing option. For a staff member it is necessary to see, where the customer “goes”. Thus, google Chromecast was a solution.



Figure 19. VR app testing

The feedback, which was given by users is that they wanted more interaction with objects in the scene and more image quality. Some of them also had difficulties understanding the controller. In my opinion, the problem is that the touchpad of the controller is too sensible.

The solution for controller was to add an interaction with headset and eyes to choose object, thus, the other person could have a controller to navigate the client.

As I have mentioned before in the part designing for VR, after testing I realized that the tips from David Francis are very useful. The test has showed that 3 of 5 women and only 1 of 6 men felt motion sickness, this proves the fact that 70% of women experience nausea in VR. Another tip was that user need time to settle in. I have understood that it is essential to have an introduction to the scene, otherwise people feel lost. Subsequently, the menu part was created. It includes some instructions and interaction (Fig 20). From the beginning the background of the menu was light grey and white due to the company image. Despite the fact

This kind of position of instruction (Fig. 21) make people from the beginning move the head. Thus, if a person tries virtual reality for the first time, it is better to understand how VR works.

In conclusion, in this point the development of the application for Gear VR has stopped. Heavy 3D scenes in real time does not function good for mobile application platform. In our case it was essential to do everything in real time due to the type of the application. Subsequently, it was impossible to get more realism and better quality of the scene. Thus, next project for PC platform was launched.

3.3. NEW APP FOR COMPUTER PLATFORM

For our new VR application, Oculus Rift headset was chosen. The last version of Oculus platform has some new features which makes the experience more entertainment. The controllers include tracking area for the arms, thus, inside the scene the user can see his virtual arms, which responds to his real arms. Another novelty is Oculus Avatar (Fig. 22). The user can have his own avatar inside the virtual world, which tracks the movement of the head and arms.



Figure 22. Oculus Avatars (<https://www.youtube.com/watch?v=X6XOwtscnY>)

3.3.1. Differences and benefits

The menu did not have many changes; it includes same informative option. Inside the scene the person is in the middle of a dark room and there are bright instructions. The pedestal where the person standing has a “X”. Not only is it a logo of the company, it is also a point to check if you are in the right position of the scene. The difference is that the computer platform menu is more interesting due to the mirror effect in which you can see your avatar, who is “you” (Fig. 23).



Figure 23. Mobile and computer versions of menu

The 3D model of the house I needed to do from the beginning. The scheme was the same, first basic structure of the house in 3Ds Max and then exporting models to Unity. This time the model was more complicated with more details and objects. The plan of the house has not been changed too much. The idea was the same, to show four spaces: living room, kitchen, laundry and baby’s room. This time I had more freedom in designing because I did not need to think that much about number of polygons. However, it was still important.

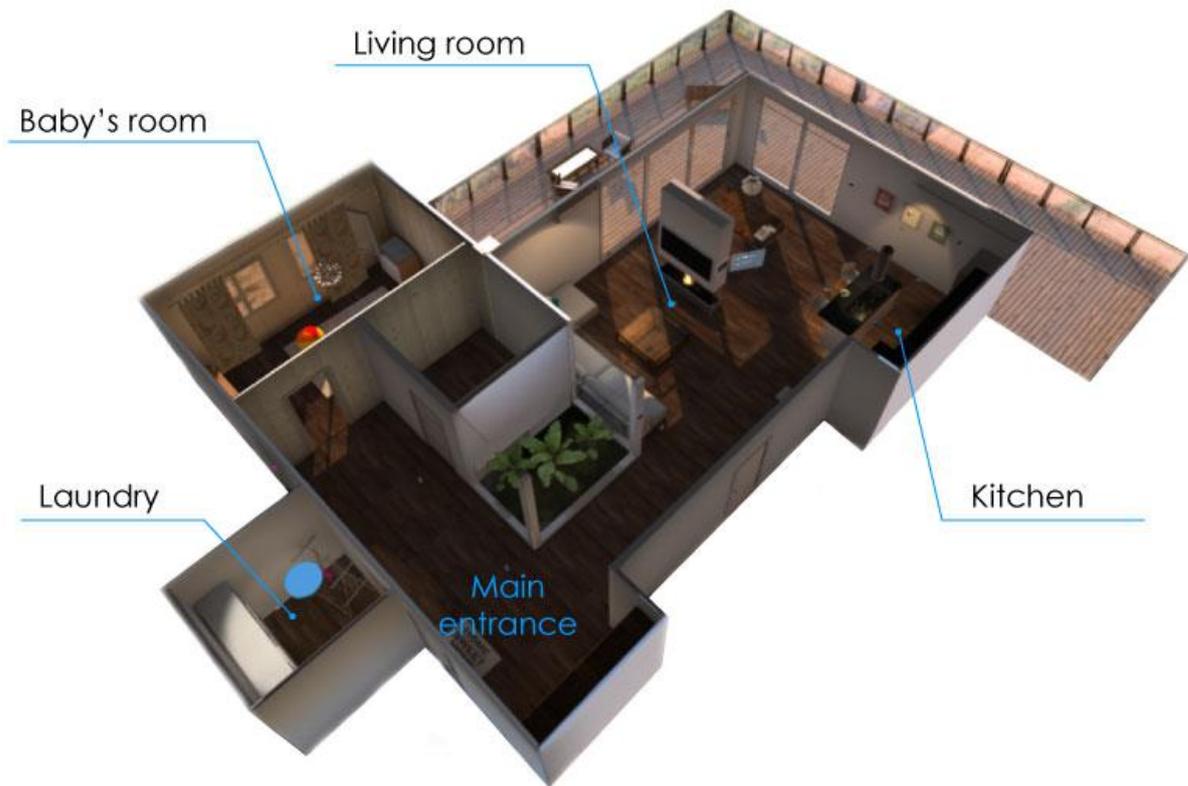


Figure 24. House plan

As can be seen on the plan (Fig. 24), the scene starts in the main entrance. The customer has two options of a tour, half and the whole tour. The most important devices and things to show are located in the zone of living room and kitchen. Thus, if the customer feels motion sickness it is not compulsory to make the whole tour. Just with visiting the living room and kitchen, it would be enough to get the idea.

To navigate the customer inside the house there are informative popup windows (Fig. 25), which appears when the user is close to the interactive object. Some of the popup windows have just information and others says what it is necessary to do to see the function of a device.

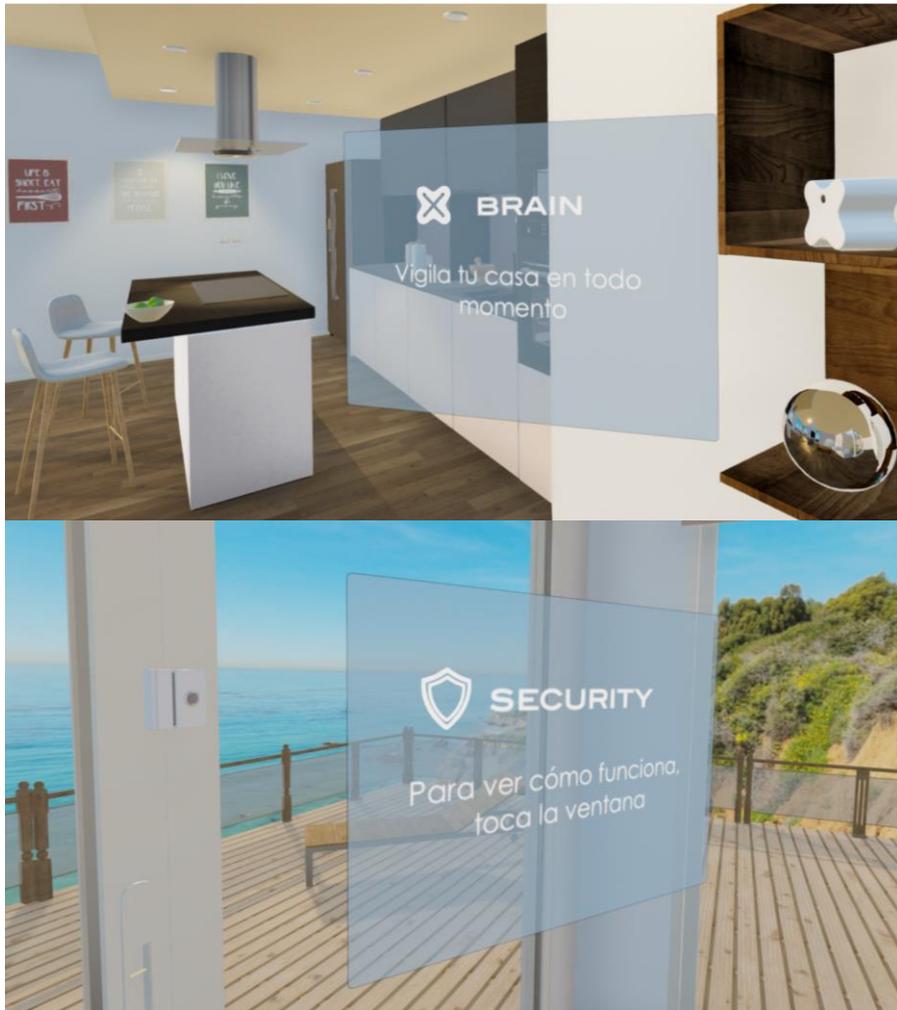


Figure 25. Informative popup windows

Other new feature in this application is that the user can pick up the objects in the scene with the virtual arms (Fig. 26). This option has two meanings. It makes the scene more entertainment because player can take some objects and play with them. Another is that the user can see the devices of the company, turn them around, change their location and see how they will look in the different places.



Figure 26. Playing with objects

One more thing, which I would like to pay attention to, is that there is an application inside the application (Fig. 27). The customer can test the real application which exists to control the home automation devices. It is like in real life, there is a tablet with app and you can choose the section that you want with your virtual finger. In the part of security, there is a possibility to choose the cameras that are installed in the house. Moreover, there are functions such as put up and down blinds, switch on and off the lights.



Figure 27. Application

The animations inside new scene are pretty the same as before such as alarm and flooding washing machine. However, the new effects look much more realistic than before. (Fig. 28)



Figure 28. Mobile and computer version of animation.

There are some tricks that help to make the scene look more realistic in Unity:

- A huge amount of reflections; materials with high level of smoothness
- Extra point lights with soft type of shades
- Post processing asset for the camera with ambient occlusion

3.3.2. Testing

The feedback from people who tried both applications was obvious, they enjoyed more the experience with Oculus Rift (Fig. 29). During the test, users had much more expressions on their faces than before. The only disadvantage is the cable that goes from goggles to the computer.





Figure 29. Testing new application

However, some changes were made after testing. Few people were trying to switch on the light not only from the app but also from switches. As a result, the interaction between switches, app, lights and the player was added. Other changes were technical. According to Oculus, in the controllers the hand trigger (Fig. 30) is a default button for picking up the objects. I found this option very confusing for the people who were testing the application. Despite the fact that there were instructions from the beginning, all the time they were trying to take objects with index trigger. Subsequently, the button was changed to index trigger. Moreover, sprint acceleration was canceled for final version.

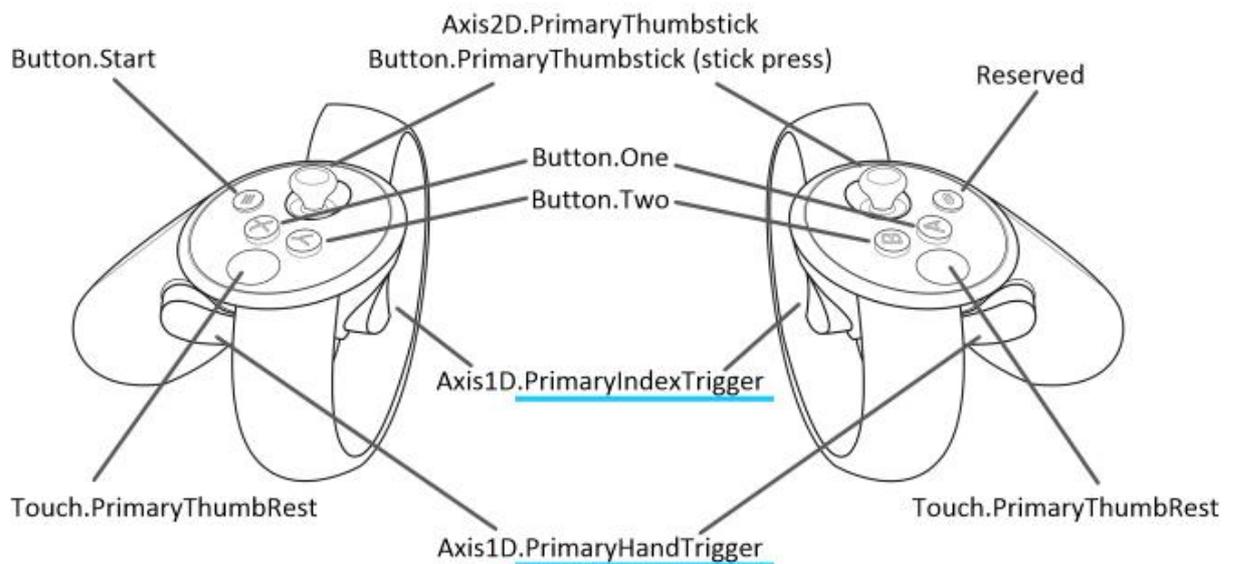


Figure 30. Controllers

(<https://developer.oculus.com/documentation/unity/latest/concepts/unity-ovrinput/>)

To sum up, the advantages of the computer application and Oculus Rift are:

- quality of the scene
- less motion sickness
- tracking arms system
- more possibilities of interaction: catching objects and touch screen inside the application
- less coding, some basic codes are coming with Oculus package.
- Avatar provided by Oculus

3.4. LIGHTWEIGHT RENDER PIPELINE

In May Unity 3D has released a new version of 2018. It was decided to export the project to this version due to the Lightweight render pipeline. Unity developers have announced that this render should be better for virtual reality scenes; more realistic and faster performance in headset. There is a comparison of characteristics of new and previous render version in Table 3.

	Unity Built-In Pipeline	Lightweight Pipeline
Platform Coverage	All	All
Rendering Paths	Multi-pass Forward Multi-pass Deferred	Single-pass Forward
Lighting Attenuation	Separate precomputed attenuation textures for Point and Spot Vertex light attenuation does not reach 0 intensity at range boundary.	Attenuation computed in the shader smoothly fading to light range. Inner and outer angle for spot lights.
Color Space	Linear with sRGB light intensity sRGB	Linear preferred, Gamma supported Linear light intensities
Realtime Lights	Directional, Spot and Point Amount of pixel lights controlled by Quality Settings Forward path limited to 8 pixel lights. Supports up to 4 vertex point lights.	Directional, Spot and Point Amount of pixel lights controlled by Pipeline Asset Limited to 8 pixel lights. Supports up to 4 vertex point lights.
Light Modes	Baked Mixed Baked Indirect Shadow Mask Distance Shadowmask Subtractive Realtime	Baked Mixed Baked Indirect Realtime
Global Illumination	Directional, Spot, Point and Rectangular Area Lights Baked Lightmap (Non-Directional and Directional) Light Probes	Directional, Spot, Point and Rectangular Area Lights Baked Lightmap (Non-Directional and Directional)

	<p>Realtime Dynamic Lightmap Realtime Lightprobes</p>	<p>Light Probes Realtime GI Not Supported.</p>
<p>Shader Library</p>	<p>Dozens of non physically based shaders specializations Unified Standard PBS Shaders: Metallic workflow Specular workflow Roughness workflow</p>	<p>Unified Standard non physically based Shader (covers most legacy and mobile lit shaders) Unified Standard Shader (Metallic or Specular workflow)</p>
<p>Reflection Probes</p>	<p>Sorted per-object, blend between at most 2 probes</p>	<p>Sorted per-object, no blending</p>
<p>Shadows Features</p>	<p>PSSM Stable and Close Fit Filtering: PCF No depth clip. Pancaking done in vertex.</p>	<p>PSSM Stable Fit Filtering: PCF No depth clip. Pancaking done in vertex.</p>
<p>Shadow Modes</p>	<p>Light Space Screen Space</p>	<p>Screen Space</p>
<p>Shadow Casting Lights</p>	<p>Directional, Spot, Point Multiple shadow light casters, one per-pass.</p>	<p>Directional and Spot Single shadow light caster supported as main light.</p>
<p>Anti-Aliasing</p>	<p>MSAA, TAA</p>	<p>MSAA</p>
<p>Post-Processing</p>	<p>Legacy Post-Processing stack new Post-Processing Stack</p>	<p>Subset of the new Post-Processing Stack FX No support for: TAA, Motion Blur, SSR</p>

Table 3. Comparison of old and new pipelines

(<https://blogs.unity3d.com/es/2018/02/21/the-lightweight-render-pipeline-optimizing-real-time-performance/>)

According to the characteristics, new pipeline has better features such as rendering paths, shader library and some colours settings. However, I have faced with plenty amount of bugs in this pipeline. The main problem was that it was vital to use real time rendering or mix lighting mode in the scene due to moving objects such as blinds. Although in the comparison table it is written that both of light modes are supported by Lightweight render, point lights did not have shadows in these modes. Other disadvantages were that this pipeline did not support Oculus avatar shader and post processing in VR mode.

The option that was left to try was baked lightning. Finally, the result was very impressive. The lights and shadows looked more realistic, furthermore, the option of ambient occlusion have been included in baking mode. Thus, the next step was to make a plan how to avoid moving objects and shadows. For instance, the colour of blinds was changed to more transparent one. In this way when they go down and up it is not that notable that there are no shadows, because naturally transparent objects have less shadows. As for avatar shader, Adrian (Software engineer) made a new code, so that it was possible to add a custom shader to the avatar model. Before the colour was provided by Oculus and there were no possibilities to change it manually.

There were some more baked lightning difficulties which did not exist in real time mode. Although in some areas shadows looked very realistic, in other places the geometry of the shadows was extremely strange (Fig. 31).



Figure 31. Badly baked shadows.

In my opinion, it was the problem of incorrect transformation of wall's vertices from 3Ds Max to Unity. The easiest way to resolve the problem was to build a new wall in Unity not in a 3D modelling program.

In baking mode, it is essential to put settings correctly. Despite the fact that in Unity documentation for developers there are explications of every light map setting, it was very difficult to find a proper value. It depends a lot on the scale of the scene. Thus, I have spent a huge amount of time trying various baking settings. In the Figure 32, these are the final settings which were used for baking. The final baking of the scene took more or less 10 hours.

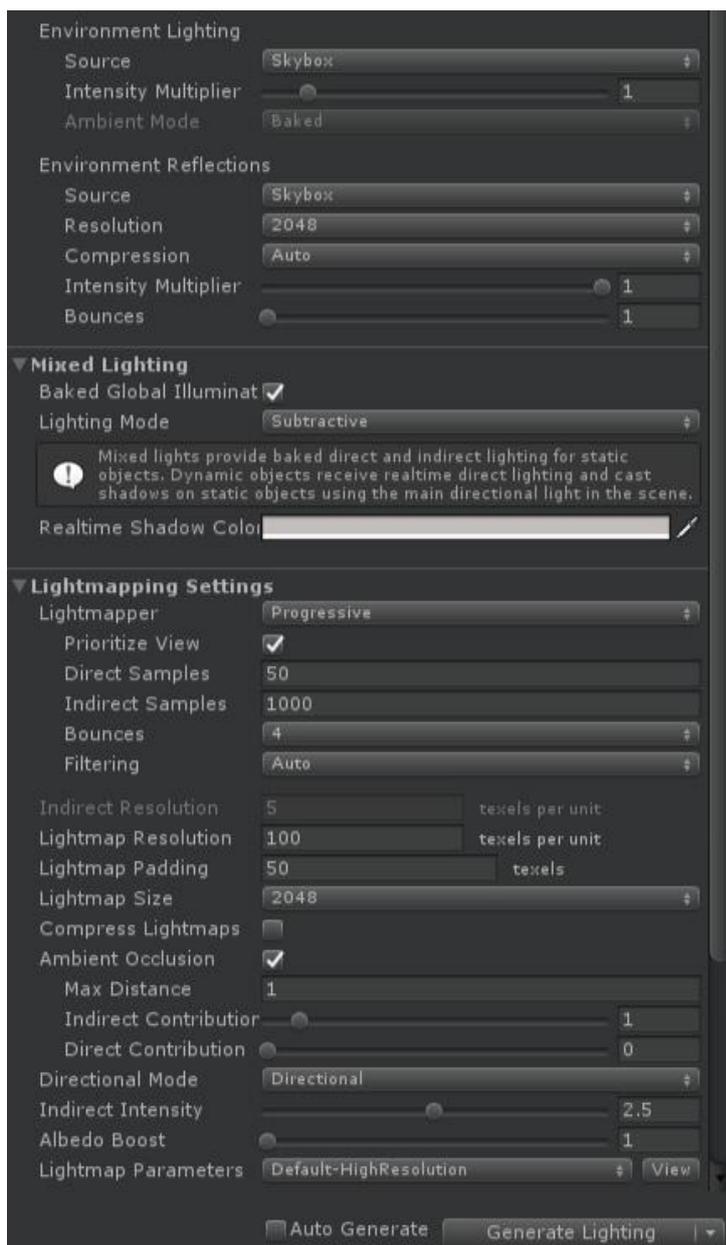


Figure 32. Final baking settings

In conclusion, Lightweight render pipeline has many advantages for virtual reality, however, there are still some errors which need to be solved by Unity. Despite this disadvantages, I still prefer to use new Unity version for the project due to more realistic scene (Fig. 33).



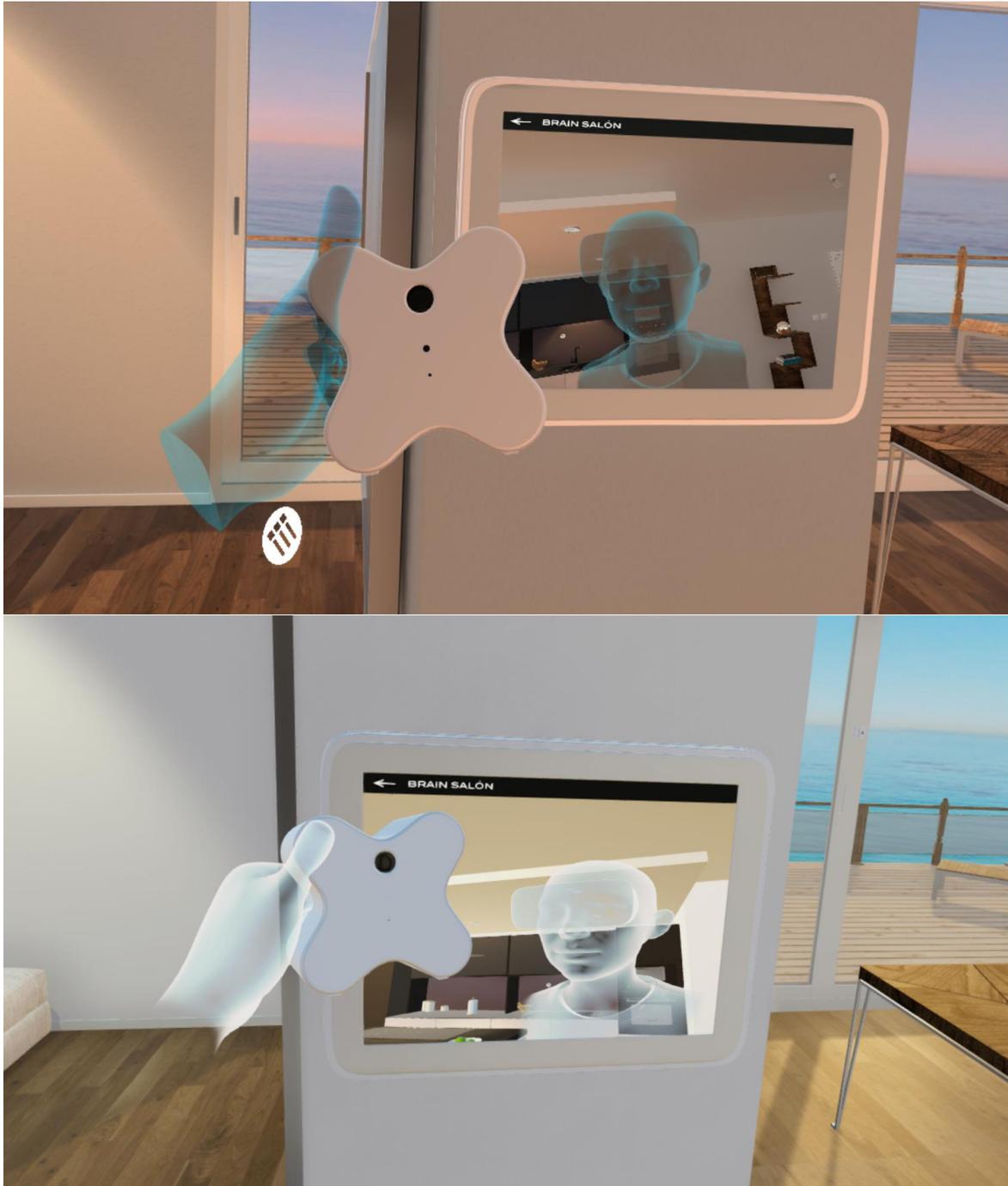


Figure 33. Visual comparison of Lightweight render pipeline and Unity Built-In Pipeline

Nowadays it is only possible to try this virtual reality experience in the office of Baintex and soon in a new shop in the center of Valencia, Spain. There are some screenshots of the final project (Fig. 34).





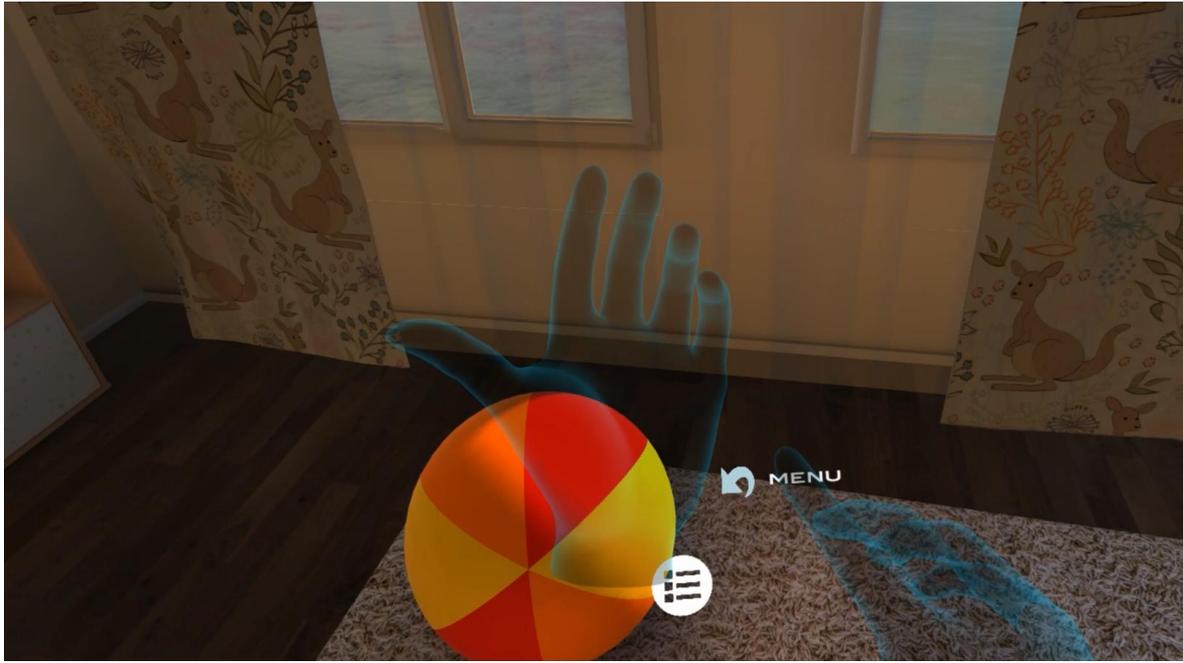


Figure 34. Final application screenshots

4. CONCLUSION

To sum up, I am very glad with the final result of the work. My aim was to reach more realistic scene than I have in the project that I have done for my bachelor thesis. Moreover, I earned a great quantity of new skills during this work. I got a new experience such as designing for virtual reality application for mobile platform. Furthermore, I had an amazing team worker, which helped me a lot with the coding part of the whole project. In total we have spent more or less 4 months working on this research.

Besides, this project was presented inside the whole company. The virtual reality experience had success. This was also one of the most important things during this work. Nowadays I am waiting to launch this VR experience in the shop of the company. Besides, we are expecting to have more visitors in the shop just due to virtual reality.

In conclusion, I am keen on working in the field of virtual world. There are novelties all the time, for instance, new professional headsets have been announced already for next year. Moreover, game engines every year are becoming more advanced and adjusted to augmented and virtual reality. There are more and more fields which discover that virtual reality helps a lot in their type of work. Thus, this is only the beginning of virtual reality, the most impressive things have not been discovered yet.

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