



Viewing the future... or maybe not

Virtual Reality and neuroscience

Abstract

This research project tries to show if it is possible to create a full immersive virtual reality system, linking the brain to a computer software where the virtual world is processed. To confirm that idea in the project, it is investigated about which are the current virtual reality systems, what they offer, and which is their limitation.

Also, it is analyzed how does the brain work and how the impulses and responses of an action are processed. For achieving that, it is important to know the different parts involved in the process of cognition and stimulation of the brain and which not.

Every part analyzed in the project is directly related with the final idea of the full immersive virtual reality system theory, which is currently impossible to transpose it into a practical frame. By other way, a full comprehension of the current virtual reality systems that is showed in the practical part, is essential for the correct planning of the future device.

Resum

Aquest treball de recerca pretén mostrar si és possible crear un sistema de realitat virtual totalment immersiu, connectant el cervell amb un programa informàtic on és processat el món virtual. Per a confirmar aquesta idea del projecte, s'investiga sobre els actuals sistemes de realitat virtual, què ofereixen i quin és la seva limitació.

També és analitzat el funcionament del cervell i com els impulsos i les respostes d'una acció són processades. Per aconseguir-ho, és important conèixer les parts que estan involucrades en el procés de cognició i estimulació del cervell i quines no.

Cada part analitzada al projecte està directament relacionada amb la idea teòrica final del sistema de realitat virtual totalment immersiu, que actualment és impossible de traspasar a un marc pràctic. Per altra banda, una comprensió completa dels sistemes actuals, que és demostrat a la part pràctica, és essencial per a la correcta planificació del futur aparell.

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1. Proleg

It has been a lot of time since I really got into VR world and games world. Actually, I got interest in this topic when I saw a film called Matrix. It was just amazing to think that people could live in a virtual world, where their mind was connected into an enormous computer that processed all the virtual world. But this project has not the same goals as the Matrix film does. It wants to make this fiction, a reality but a reality for people. In other words, it wants to create a device that will help the society in many ways as possible.

The idea of the full immersive virtual reality presented in this to help people that is in paralysis, people that had lost any of their body parts, people that is unresponsive. But the project is even more ambitious, it is not limited to the medical field. My idea is to expand the full immersion virtual reality into as many fields as possible. For example, architecture and design, why people should see the house of their dreams in a paper or a tridimensional image, when they can see it directly in a virtual world? This is one of the infinite and exciting applications that this project could be used. The limitations of it would be the people's imagination.

Also entertainment is important, games companies, nowadays are ones of the most advanced and interested in the progression of technology. The idea of using full immersive virtual reality for games, was worldwide extended by Reki Kawahara, with his light novel series called Sword Art Online, where a character gets trapped inside a virtual world. This fact, led to inspire big companies such as IBM to investigate how this amazing idea would be possible.

During the research project, I will be investigating about the current virtual reality devices and their functionality, I will also try and test these devices and see which would be the most useful for the project idea. Also, I will be investigating about the human brain, what is exactly, how does it work, and how can people analyze and take control of what is happening in our mind.

The ideal practice part would be with neuroscience equipment, testing the ideas that in the project are mentioned. The only problem is that the really high tech labs are private, and the opportunity to try their technology is limited to the best university

and master students, so in my case, I had to improvise a homemade visor, to understand how it exactly works.

About neuroscience, I had the opportunity to talk with a scientist that works at the Institut Guttmann, Jose M. Tormos, who gave me some advices about how I should focus the project, and which was the correct way to investigate what I wanted to.

I also have to say that I was inspired by Elon Musk and his newest project called Neuralink, briefly, Elon wants to connect the brain with a computer and make it even better, faster and more efficient that is now. In other words, he wants to implant to people's brain, a device that enhances the brain capabilities.

This project is not as science-fictional as many people may think, is even closer than most can expect. And the full immersive virtual reality is a concept that maybe is closer than expected too.

2. Theoretical frame VR part

We certainly had the dreams before, but the computing just wasn't good enough

- Tom Furness

2.1. Brief introduction of virtual reality and VR project

Nowadays is normal the concept of virtual reality the idea of virtual worlds has been increasing the last few years and the society is being used to the concept of mixing the virtual world with the real world. The fast development is caused of the creation of new microprocessors technology that lead to faster and more powerful systems in the market.

As new devices are released constantly, the prices of the systems fall rapidly as new ones have appeared, so many people can afford this technology and can work with them, and so new stuff can be developed easily. The average users can afford one device capable of emulating virtual reality, this is one of the most important points of evolution, and a big number of users can create new stuff by their own way of using the technology. The big idea of giving the power to the users is that appear unlimited possibilities of development as the imagination is the power of the creators. Only current technology limitations can stop the users. This fact leads to a faster development and common feedback, which finishes with an increasing of popularity of the device. More benefits for the developer.

Although the device prices are important for the development, the users' feelings and thoughts about the final product will conditionate if it is a successful gadget or is not.

So, graphics are one of the most important parts in simulating virtual reality as the vision is the most important factor in our sensorial system (Heilig, 1992). If our brain is tricked by realistic fictional graphics, the feeling of being in another imaginary world will increase enormously. If the users feel they are in another world, it is a successful device and consequently it will be popular and more stuff will be developed for it. Creating by this way a chain of evolution. Besides, current powerful technology can process high quality graphics that lead to realistic computer processed worlds that sometimes can be quite similar to the reality.

So, the idea of this project is to verify if it is possible to create a virtual world which would be as realistic as the real world is. For achieving that, many facts are involved. It is important to know exactly which are the current VR capabilities, and which is the edge between the project idea and the technology reality.

Also, is necessary a fully knowledge of the human brain and cognition, as the project idea links the brain to the virtual reality devices, by that way, simulating true feelings to the user, such as the real world.

According to the main purpose that is verify if the idea is possible or not, the project is divided in two important parts, the first one is based on research and the objectives are:

- To know when the first idea of virtual reality appeared and which was the purpose of it.
- To analyze the current VR systems.
- To analyze the brain process of cognition.

The second part is a more practical research which involved:

- To test the different VR systems.
- To create a homemade VR system.
- To compare the results and concluding if it is possible or not.

2.2. Virtual Reality History

2.2.1. First idea

But the idea of virtual reality came up many years ago. The strictly meaning of virtual reality is creating the illusion that someone is present in a place where he is not. According to this meaning, the first attempt of virtual reality is the 360 degrees murals from the nineteenth century. But paintings sometimes are not included in the definition of “virtual”, as the society connects this term as a recent word, not usable by defining a painting from nineteenth century.

2.2.1.1. The beginning

The real beginning of virtual reality is dated in 1938, when Charles Wheatstone researched that the brain processes two-dimensional images into a unique tridimensional object. By this way, he deduced that giving the brain two stereoscopic images it will give the user the sense of depth and immersion, as the real vision work as the same way. The idea of using stereoscopic images inspired many devices are currently on the market such as Google Cardboard and many other low-cost stuffs that later will be described more accurately (Wheatstone, 1838).

2.2.2. Sensorama

In years 1960-1962, Morton Heiling developed Sensorama. It was a multi-sensory simulation system. Heiling used a prerecorded film, but was not only sight and stereo sound what made the system famous. It also included smell generators and a vibrating chair. Sensorama pretended to be the first fully immersive system but the only problem it had was that it was not interactive. The user could not decide what would happen.

After creating Sensorama, Heiling developed the Telesphere Mask, curiously it was patented before Sensorama, exactly in 1961. It was the first head-mounted display, with a design that is quite similar to the newest devices. (Heiling, 1960)

2.2.3. The Ultimate Display

“We live in a physical world whose properties we have come to know well through long familiarity. We sense an involvement with this physical world which gives us the ability to predict its properties well. For example, we can predict where objects will fall, how well-known shapes look from other angles, and how much force is required to push objects against friction. We lack corresponding familiarity with the forces on charged particles, forces in non-uniform fields, the effects of nonprojective geometric transformations, and high-inertia, low friction motion. A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland.” (Sutherland, 1965)

This is how Ivan Sutherland described how the human perception works. Ivan is one of the most important designers of the origins of computer graphics. He is the creator of the computer graphical user interface Sketchpad and he wrote an essay titled The Ultimate Display, where he described a futuristic display that allows users to immerse themselves into computer-generated environment.

“The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming, such a display could literally be the Wonderland into which Alice walked.” (Sutherland, 1965)

His concept of the ultimate display, include three essential points:

- A virtual world viewed through a Head Mounted Display (HMD) and which allows to hear 3D surround sound and tactile feedback.
- Computer hardware to create the world and work in real time.
- The ability of interact with the objects generated in the world.

2.2.4. Sword of Damocles

Sword of Damocles created in 1968, is the name of the first project that can be called as an HDM virtual reality device with computer-generated graphics.

Ivan Sutherland and his student Bob Sproull created this device that was not connected to a camera but in a computer. The invention supported stereo view that was updated correctly according to the user's position.

The Sword of Damocles was a large and heavy to wear comfortably so it was hooked on the ceiling.

2.2.5. Artificial reality

Myron Krueger described as a computer artist, he developed different experiences that he called "Artificial Reality" this was also the name of the book, published in 1983 where he explained the experiments he did.

Artificial Reality consisted on different researches, the projects were named GLOWFLOW¹, METAPLAY², and PSYCHIC SPACE³. These different projects led to his final invention called VIDEOPLACE.

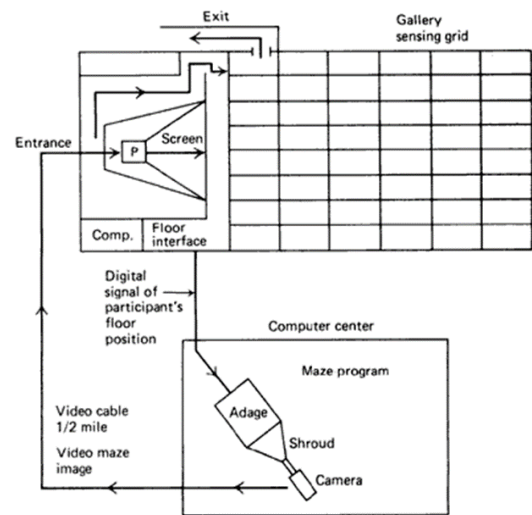


Figure 1 PSYCHIC SPACE from Myron Krueger

VIDEOPLACE was "a conceptual environment" it introduced the ideas virtual reality, full-body participation in interactive art, and the concept of a shared telecommunication space. This invention permitted people to communicate each other thanks to processing techniques that create a computer-generated environment. (Krueger, 1991)

2.2.6. Virtual reality evolution

After some experiments, led by big companies such as the NASA with devices like VIVED (Burdea & Coiffet), the evolution of virtual reality augmented positively.

¹ GLOWFLOW was a computer-controlled light-sound environment. It was a computer art project conceived by Dan Sandin, Jerry Erdman, and Richard Venezsky; and exhibited at the Memorial Union Gallery of the University of Wisconsin in April 1969.

² METAPLAY was exhibited in the Memorial Union Gallery of the University of Wisconsin for a month in 1970. In this work Krueger emphasized the interaction between the participants and the environment. "The computer was used to facilitate a unique real-time relationship between the artist and the participant.

³ Figure 1, annex

Many new devices appeared and virtual reality became more usual than expected. An example is Virtuality Group, this group launched a range of arcades games and machines. The devices consisted of a set of VR goggles, these were connected to gaming machines and the users could play and feel a real-time response⁴.

2.2.7. Gaming companies take the control

The development of Virtual Reality soon was controlled by the most important gaming companies from the moment, SEGA was one of them, even Nintendo joined the VR development.

- SEGA VR

The device created by SEGA, announced in 1993 but never released because it was demonstrated that it could cause ocular damages.

The VR system consisted on an add-on for the popular Sega Mega Drive, the console that was in the top leaders of gaming market. The design consisted on a virtual reality headset (HDM)⁵ with LCD screens in the visors and stereo headphones. It included sensors that track and react to the head's movements. It was designed to be light and not tiring or painful after using it during long periods of time.

Although this device was cancelled and never was released to normal users, it invested significantly changes in the evolution of VR. (SEGA, 1993)

- Nintendo Virtual Boy.

Nintendo was the first competitor of SEGA and the company also created their own VR device, it was named Virtual Boy.

The Nintendo Virtual Boy is a 32-bit console. It was released in 1995. The display was used like a HDM, placing their head against the eyepiece to see a red monochrome display. The games used a parallax effect⁶ to create the illusion of depth.

⁴ Response times of 1 second or less are fast enough for users to feel they are interacting freely with the information. – Robert Miller

⁵ Head Mounted Display

⁶ The same System was used in SEGA VR, see figure 19 -from the magazine SEGA VISIONS.

Unfortunately, after four years of development Nintendo Virtual Boy sales were not good as expected and soon the production stopped. But the same as in SEGA devices happens, the devices were unsuccessful but the knowledge of the experiment was used for improving future devices.

2.2.8. Virtual reality 21st century

Last years the evolution of Virtual reality increased rapidly. More new and powerful companies are interested in being involved in this kind of projects. New computer technology, more powerful microprocessors and the latest graphic cards lead to more realistic images, in consequence more people really feel that they are “in” the scenario created.

Ultra HD 4K⁷ panels, improved sensors and advanced techniques of deepness processing can provide the clearness to a user that lead him to think that what he is watching to, is real and is there where his head is pointing to.

The feeling that current VR users have is not the same as in the first years of VR history had. The feeling of “being there” is sometimes even terrifying, for that reason, the most played demos are rollercoasters or frightening games.

The only problem that current virtual reality has to face to is that the user thinks and feels that is in a pre-created world, but he is not there actually. So, in a clear example, a user is using one of the top VR current systems in his room, he may think that is in a pre-created world, designed by some game developers, but if he decides to walk, he will hit the wall of his room. This is the limit of the newest virtual reality devices. The user may think is in another world but he is not.

The future of virtual reality is overpassing this issue, that is called Full Immersive Virtual Reality, where the users would move using all their body and no space limitations would exist.

⁷ 3840x2160 pixel screen

2.3. Virtual reality and augmented reality

These two topics are frequently confused each other. Is true that both use the idea of “being in a place where you actually are not” but the way they make the user feel that emotion is totally different.

In one side, there’s the virtual reality (VR) that is an artificial, computer-generated and technically designed simulation of real life environment to make the user feel that is inside the other world.

Normally the newest VR systems consist of a headset and sometimes headphones. The main idea of VR is that you can’t see and hear the real world, you only can feel the computer-generated one.

By the other side, the augmented reality (AR) is a recently improved technology that mixes the reality and computer-generated elements. The most interesting thing of AR is that is being designed for interact with the stuff generated by computer.

So, the idea of AR is not to replace the real world for another fictional, but to combine both idea to make an even better real world with fictional and interactable elements. This technology is increasing in popularity as it’s useful in many aspects not only in gaming, such as is VR, it can be used in the design sector for showing previews, etc.

The main idea is that they are in the way they work, the opposite, Paul Milgram described how both concept affect the real world with a simple diagram.

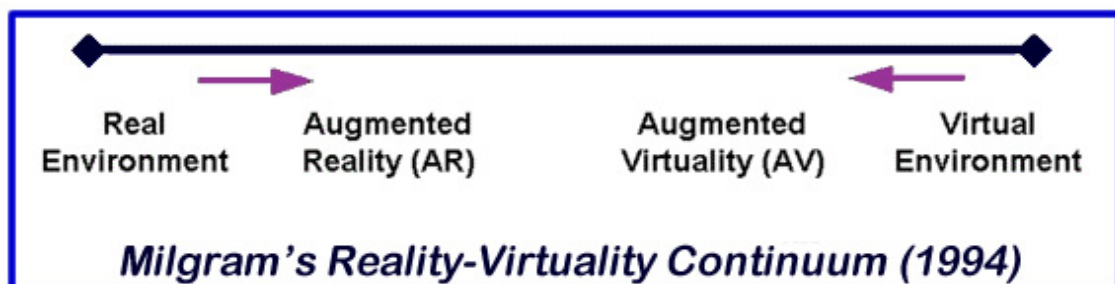


Figure 2 Milgram's Reality-Virtuality Continuum from *Mixed Reality Experiences Series: Augmented Reality*.

2.4. Analysis of the current virtual reality devices

Greenwald described the different virtual reality devices perfectly in his article at PC Mag (2017)

2.4.1. Sony PlayStation VR

The PlayStation VR is the system designed by Sony to enter in the race of virtual reality.

It's an add-on to the current PlayStation systems, PS4 and PS4 Pro. The full set includes PlayStation Camera⁸, PlayStation Move⁹ and the headset.

The headset can be divided in two parts, the visor that holds most of the electronics, and a single plastic band that runs around the back of the head. In the front are two light sensors that the PlayStation Camera detects and uses to track the position. It has a wire connection to the main console that makes the most important processing part. Such as most of other VR systems the PS VR bundle includes earphones but the headset at all has not any type of headphones.

To use the headset is not as difficult it was in past years, the user only has to put the headset on, just place the visor over the eyes and pull the headband back, stretching the elastic until the crosspiece fits against the back of the head. Turning the wheel tightens and locks the headband, keeping the headset in place while the user is using it.

The PS VR uses a 1920x1080 OLED panel split into 960x1080 images for each eye. This means the PS VR's picture is just slightly grainier, but aside from some minor blurred small text, it is a quite acceptable quality.

The controls of the Sony system do not allow the user to move freely as the correct running depends on the PlayStation Camera. The user cannot turn completely around. PS VR relies on visual tracking with colored lights rather than infrared tracking, it seems to be more vulnerable to disruptions from ambient light and reflections.

⁸ Is an add-on for the Sony console that consists in a camera that can detect the users' movements and position taking reference to the shape of the body and the sensor in the controller.

⁹ Is another external accessory for PlayStation system that consist of two new controllers that have precise sensors and the devices detects and tracks the position of them.

2.4.2. HTC Vive

The HTC Vive is the virtual reality device created by the mobile company HTC and Valve¹⁰.

The device is completely independent and can be connected and used in any PC that has the minimum requirements of graphic processing memory. The bundle includes a headset, motion controllers, and even external sensors for setting up a virtual room to play in.

The headset is a large visor with 32 motion-tracking sensors and a single camera located in the middle of the visor.

The Vive uses a single 2160x1200 LCD, paired with two lenses that separate the display into 1080x1200 images for each eye.

A set of three wide elastic straps secure the headset to your head with hook-and-loop fasteners. A triple cable runs over the top strap and down the back of your head to connect to the Vive's link box, which then connects to your PC. The same as in PS VR system, Vive includes earphones that can be used while using it.

The main difference between Vive and the most of current virtual reality devices is that the HTC one allows the user to move freely inside a small area. This area is limited by two base stations that detect the space of the room and generate a virtual space in the area pre-selected.

With the head motion-track sensors and the controller sensors, the base stations receive an exact position of the user at real time that can allow the user to feel that it is moving inside another world, and not the real. The user can optionally define boundaries of that space for the Chaperone¹¹ feature. It projects a set of virtual walls on the edge of your play area, letting you know when you're about to step out of bounds and bump into anything.

The most important feature of Vive is that is completely compatible with Steam VR, and that allows the user to get access a huge number of demos and games.

¹⁰ Is an American video game developer. The company is known for many famous titles such as Half Life, Counter Strike, etc. and its software distribution platform Steam, the most popular in the PC gamers users.

¹¹ Feature that limits the virtual space where the user can move freely.

2.4.3. Oculus Rift

Oculus Rift was officially launched in 2016 after few years of development. In fact, this device was the first new generation VR systems to appear, but only few models were released for testing during previous years of the release.

The use of the device is quite similar as HTC Vive, is totally independent and it can be used in any computer that can handle the technical specs that are required. For consumers, there's a bundle that includes the visor and the controllers and has a lower price than other devices in the market.

The headset has a simple design, as other headsets, completely flat front panel with rounded edges. It is attached with three-strap harness for securing the device on your head.

A difference from Vive is that Oculus uses a single external sensor, a black cylinder that sits on a metal desktop stand. The sensor can tilt up and down, and must be placed where it can maintain a clear view of the headset when in use.

The device uses a 2160x1200 OLED¹² panel producing a 1080x1200 picture for each eye separated by the lenses in the headset (just like the Vive). Vive and Oculus are quite similar but the main difference is the control.

You can use the Oculus visor without any control device, but with the Oculus Touch controllers the use is like the Vive, natural-feeling control scheme with responsive physical components like analog sticks and face buttons in addition to motion tracking.

The Rift headset is a display, so smoothness and graphical fidelity will depend on the power of your computer and sophistication of the software. In terms of hardware, the Rift produces a compelling virtual experience for the eyes.

For this device are many titles available, there's the Oculus Store that is exclusively supported by this device and there are many titles compatibles with the Steam VR.

¹² An OLED panel is a light-emitting diode (LED) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current.

2.4.4. Google Daydream View and Samsung Gear VR

Google Daydream View or a similar device called Google Cardboard with a lower price are VR systems designed by the software company Google, actually is being in development but the low price and the easy use it has, makes these Google devices a good option to get in Virtual Reality world.

By the other side, the user also has Samsung Gear VR, the direct competitor with the Google devices, it is more expensive than the Google one and the user needs some of the newest Samsung smartphones to use it. But the way that the devices work is quite the same.

Both devices are basically a phone holder. Neither of them can be plugged into a computer and have any screen panel. So, both devices are a structure that has an area designed to situate the phone. In the phone will be executed the applications that are compatible with VR, basically the screen is divided in two sides and the image is barely modified to simulate the distance between the eyes. Also, the devices have two lenses, one for each eye, as the phone is located in a small distance from the eyes is impossible to focus correctly so the lenses correct the distance and make the image clearly visible for the eye.

The resolution of both devices and smoothness of the image is directly related to the resolution of the smartphone used, so is quite recommendable to use big screen smartphone, 5" or higher, and with a resolution of FullHD (1920x1080) which is the common in most devices, but higher resolutions such as 2K (2048x1080) give a clearer image.

2.4.4.1. Introducing Google Cardboard

This is the cheapest option a user can choose to experience virtual reality. Is not the most comfortable and not the most realistic, but not everyone has the money that is needed to buy Oculus Rift or the Vive.

Google Cardboard is a simple structure made by cardboard as its names indicates, because of the material and the simple structure the price is the lowest you can find

in these devices. The phone-holder visor also includes two lenses to focus the image that is reproduced in the smartphone.

The most important feature for the user is that this device can be built at home. As the materials are easy to buy and cheap many users decide to build themselves this visor.

Google provides free user's guide to build it, also, gives the manufacturing blueprint drawings which the user can modify to adapt the visor to their specific smartphone and the provides links to different websites to buy the different materials that will be used in the construction of it, such as the convex lenses or the neodymium magnets. Making the visor by yourself also permits the user to customize it as he wants adding details, colors or other ways of holding it.

This idea, also gives the user free use of the blueprint drawings so sometimes people who has good imagination can create new models that can be used by future Google Cardboard designs so giving free access only contributes to a constant development and evolution of this device. Consequently, if this visor has a huge development, other devices that are the competence will also start developing by this way an advance in the field of virtual reality will occur.

Google Cardboard succeed in the world Virtual Reality visors as the final experience is the nearly the same as other visors and some users enjoy building themselves the device.



Figure 3 Google Cardboard from Google.

2.4.5. Microsoft HoloLens

Microsoft HoloLens, a device designed by the Bill Gates' software and hardware company. The main difference with HoloLens and the other Virtual Reality devices is that they are not a virtual reality device, HoloLens are classified as an Augmented Reality device.

The way that this device works is perfectly described by Will Greenwald:

“You can see completely through it and look at anything around you. Instead, it projects holograms over your surroundings, combining the real environment with computer-generated elements like floating app windows and three-dimensional models.” (Greenwald, 2016)

By now this device is under development but you can buy one developer model, the only problem for many users and that's one of the reason why is not as popular as the other devices is the price. It costs \$3000 which is a huge amount of money, especially if that price is compared with the cost of the other visors.

The design is not complex, it consists of a big black headband and a transparent black visor.

The idea of HoloLens is to be a portable computer as you can move with and it could be difficult if it is connected to a PC.

The most interesting part of the device is the way HoloLens work and the idea of combining the reality with computer-generated elements. The project is based on hologram projections. The multiple cameras and sensors on the visor constantly scan the area around you, mapping walls and other obstacles and tracking your location relative to them.

Also, there's a simple controller that allows you to click at what you are looking but the main use of it is for replacing some apps that can be executed or resizing them.

The concept of augmented reality is different from Virtual Reality, the finality of them is different but, is also an interesting technology that is developing fast and can change the way the people life in a near future.

2.5. Introducing full immersion virtual reality

Most of the devices analyzed only consist of a visor that show a stereoscopic 3D image, which the user has the feeling that what he sees is what really happening in front of him. Head motion track and images distortion provide that feeling. But the root of the virtual reality is to experiment and be in a world different from the real, in a computer-generated world.

This feeling is not complete only with a visor, for fooling the brain and making him to think that is in a computer-generated world is necessary to also experience with the other sense.

Here is when the full immersion reality concept appears, giving all the senses stimulus to make the brain think that what you see is not an image generated but a real object. The main problem is that the nowadays technology can't make the stimulus enough realistic to make the brain think that this is real.

Some Virtual Reality devices try to solve some of this stimulus, for example the movement. One of the most important stimulus to solve, if the user can move freely in the computer-generated environment, the feeling of "being inside" is augmented.

This problem is partially solved by movement sensors, for example with the Vive, but there's a limitation and is the space, is true that you can move freely but only in a limited area, this also limits the experience of immersion of the user. Some other devices, use special machines to create this feeling of movement, such as vibration or moving platforms, but the problem is barely the same, the user can experiment a truly full immersion experience.

One of the most innovative and more near to what could be a full immersion experience is called the project, Sword Art Online: The Beginning. (IBM, 2016) (IBM)

This is a project developed by the multinational IBM in Japan, inspired by a series called with the same name that the main character was trapped in a virtual world.

This project, allows the user to move your arms, hands and fingers with an accurate precision, also allows to move freely inside the area created, and interact with the object that appear in the visor.

Is one of the most innovative projects in this field as the people who test it, received enough stimulus to think that they were inside the virtual world and not in a high-tech hardware program. These innovative systems are based on physical stimulus for the senses but the idea of some scientists got another way.

Is not necessary to create stimulus to the sense if these stimuluses can be introduced directly to the brain as neurological impulses. In that point is where the concept of Neuroscience in Virtual Reality appears.

The idea to connect the neuroscience and the virtual reality seems to be science fiction, but other investigation programs such as Neuralink¹³, directed by Elon Musk, don't make this idea so crazy.

The Virtual Reality connected to neuroscience wouldn't have only an exclusive entertainment use, it will be used too inside medical treatments. Nowadays some virtual reality devices are used for medical support, but is mainly used for personal entertainment such as games or virtual desktops and applications.

The project will be based on a fictional situation that can be perfectly true. So, the project will be User-centered design, as Jose M Tormos, the coordinator of the Investigation center of the Institut Universitari de Neurorehabilitació Guttmann.

The situation for the project will be a man who had an accident and their neuronal system has been damaged. He can't move his legs, a common injury in some important car accidents.

The idea of the neuro virtual-reality is that the man will have the opportunity to walk again and feel that he is walking in a real world, but he is in a computer-generated environment.

To make a human feel truly that he is doing an action, he has to receive stimulus from all senses, so the concept of this neuro virtual-reality is to create false impulses and send it to the brain, in a way that the person will feel that he is doing the action actually when he is not, because his brain is receiving the impulses for that action.

¹³ Implanting of tiny electrodes into the brain that could be used to give direct computing capabilities. See: <http://waitbutwhy.com/2017/04/neuralink.html>

An accurate study of it is the final goal to achieve this science-fiction project. Also, this is the main problem of the neuro virtual-reality concept. The brain is the most unknown part of the humans and directly related the nerves and the nervous system.

But before going deeper in how this idea could work, is important to know which parts of the brain are the most crucial for this project.

3. Theoretical frame neurology part

3.1. What is the brain?

The brain is the more complex and unknown part of the human body, neuroengineer Tim Hanson calls “one of the most information-dense, structured, and self-structuring matter known.” The brain can also be described as MIT professor Polina Anikeeva calls “soft pudding you could scoop with a spoon” (Anikeeva, 2015).

Brain surgeon Ben Rapoport described it more scientifically, as “somewhere between pudding and jello.”

Even many important scientists often make jokes about the brain and its complexity, it can be defined as the command center for the human nervous system. It receives input from the sensory organs and sends output to the muscles. (Lewis, 2016)

The brain can be separated in three parts:

3.1.1. Hindbrain

The hindbrain coordinates functions that are fundamental to survival, including respiratory rhythm, motor activity, sleep, and wakefulness.(The Editors of Encyclopædia Britannica)

It is composed by:

- Medulla Oblongata

The lowest part of the brain and the lowest portion of the brainstem.¹⁴

- The pons

A mass of transverse nerve fibers that connect the medulla with the cerebellum. It is also the point of origin or termination for four of the cranial nerves that transfer sensory information and motor impulses to and from the facial region and the brain.

¹⁴ Area at the base of the brain that lies between the deep structures of the cerebral hemispheres and the cervical spinal cord. This part of the brain controls vital body functions such as swallowing, breathing and vasomotor control.

- The cerebellum

Section of the brain that coordinates sensory input with muscular responses. As the cerebellum coordinates the responses and the movement is one of the parts that is important in the project of neuro virtual-reality.

3.1.2. Midbrain and forebrain

The midbrain has acts in the motor movement, especially in the movement of the eye and the auditory processing, while the forebrain its main function is to process information related to cognitive, sensory and voluntary motor activities (The Editors of Encyclopædia Britannica, 2016), (The Editors of Encyclopædia Britannica, 2015).

They are mainly composed by:

- Brainstem: this structure is also composed by two previous parts mentioned in the hindbrain, the pons and the medulla oblongata. All nerves except the ones associated with the olfaction and vision, are in the brainstem. As this part has barely most of the neural system terminations is important for the project and also is a delicate part of the brain as can produce severe paralysis.
(Joynt, 2015)
- Limbic system: this is an interesting part of the brain, as its main function is “what animals do”, more scientifically, what is necessary to survive. It coordinates the primal impulses, such as eat, drink, hide, etc.

For the neuro-virtual reality concept, the computer-generated images are planned to be extremely realistic, such as to make the brain think that is not a graphical image and is real. So is important to take care about the limbic system, it is formed by three essential parts.

- The amygdala: this part is important to take care, it deals with anxiety, sadness and responses to fear. For the neuro-virtual reality idea, is crucial to monitor this part of the brain, as some people could be stressed in a virtual world, some scenarios could create the user a

real feeling of fear and if it is not perfectly controlled, it can produce serious mental illness.

- The hippocampus: this part's function is basically a memory storage. But is quite immediate, after some time and giving the brain other activities, it will make difficult to remember.
- The hypothalamus: This section controls the functions of the autonomic nervous system¹⁵ and the endocrine system¹⁶.
- The thalamus: this essential part of the limbic system. This part is one of the most important parts and at the same time, the challenging in the project of the neuro-virtual reality. This part receives information from the sensory organs and sends it to the cortex. When people are in the sleep, this part is disabled, so that's why sometimes is hard to wake up a person when is in deep sleep.

The idea why this part is crucial for the project is that, the device for the idea has to make the function to inhibit this function. The theoretical device will create its own stimulus according to what the person is doing in the virtual generated world, and will send it directly to the cortex.

Is important, to avoid to transmit the pain, (Purves D, 2001) virtual generated worlds won't have the option to simulate pain, as the device will lose all the purpose it has, if the device simulates pain it can be used as a weapon or a torture way, and that's not the medical or entertainment finality it has to have.

So, for the optimal work of the device, the thalamus has to be disabled while using the VR system.

¹⁵ The part of the nervous system that controls the internal organs without any recognition of the organism.

¹⁶ Any of the systems to produce hormones, substances that regulate the functioning of the organism.

The easy way to get the thalamus inhibited is to induce deep sleep to the user. But the idea is to let the other cerebral functions awake such as the cortex, to elaborate responses to the stimulus created by the device.

3.1.2.1. *Conscious but unresponsive*

The idea for the Virtual Reality project is to inhibit the thalamus but at the same time remain the cortex awake and the person conscious, which means that he would be able to think but not to move.

This concept is really important for the project, as the virtual system will transmit stimulus to the brain and simultaneously the brain is going to elaborate its own response so is important to block that response to muscles avoiding possible injuries with the environment where the user is staying. But at the same time is needed to be the cortex totally conscious to receive and elaborate stimulus and make the user feel the “virtual reality”.

For that idea, there's a neurotransmitter that its function is exactly what the project needs, they are called gamma-aminobutyric acid (GABA).

These neurotransmitters "switch off" the specialized cells in the brain that allow muscles to be active. GABA appears during the REM sleep¹⁷ and has the function to inhibit the muscles while sleeping, people have vivid conscious experiences in dreams but are unresponsive because inhibition by the brainstem induces muscle paralysis. So, unresponsiveness can occur without unconsciousness. (Hobson JA, 2001)

As the human brain is so fragile there are no experiments that were made with people but in the University of Toronto neuroscientists Patricia L. Brooks and John H. Peever, PhD, found that the neurotransmitters gamma-aminobutyric acid (GABA) and glycine caused REM sleep paralysis in rats by enabling the specialized cells in the brain that allow muscles to be active.

¹⁷ Rapid eye movement sleep. Is a phase during the sleep that people moves the eyes randomly, with low muscle tone throughout the body, and often dream vividly. During the REM sleep, mixed frequency brain wave activity becomes closer to that seen in wakefulness.

In that experience the scientist made different tests and discovered that what they thought initial, neurotransmitter receptors called ionotropic GABA_A/glycine receptors in the motor neurons caused REM sleep paralysis, was not true at all as the paralysis still occurred when they blocked these receptors.

So, they decided to block both the ionotropic receptors and metabotropic GABA_B receptors. The rat registered high levels of muscle activity. Concluding about that experience is that to induce unresponsiveness is necessary to activate both GABA_A and GABA_B achieving paralysis. (University of Toronto, 2012)

Even this receptors may be the clue of the unresponsiveness there's not information enough to affirm that theoretical hypothesis as most anesthetic agents appear to cause unconsciousness by targeting, directly or indirectly, a posterior lateral corticothalamic complex centered around the inferior parietal lobe, and perhaps a medial cortical core. (Michael T. Alkire, 2008) And what in this project is wanted to avoid is exactly the loss of consciousness, so more experiences are needed to find the exact neurotransmitter that is needed to stimulate.

3.1.3. The cortex

The cortex is mainly the part of the brain that does everything. It processes all the information that receives and creates responses, in other words, decides how to act and what to do in every moment.

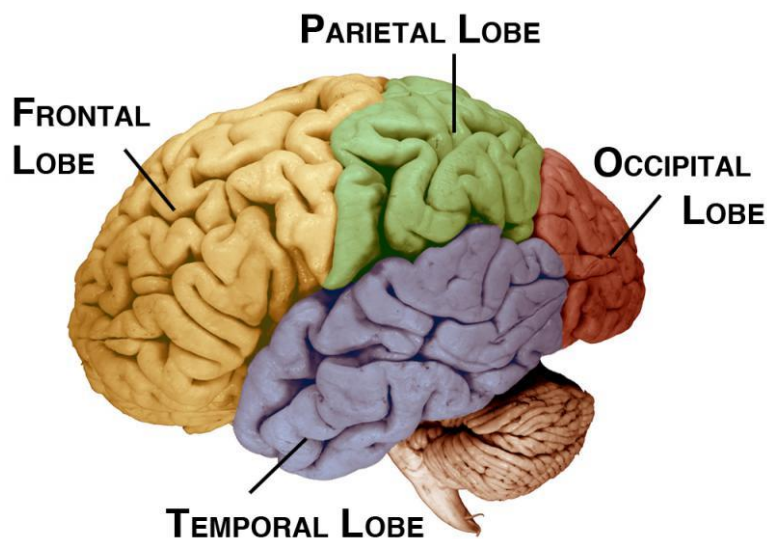


Figure 4 Cortical brain parts from MRI lab

It is divided in four lobes:

Each lobe has different functions, so for the Virtual Reality project, every lobe will be analyzed and operated especially (MS Team, 2015).

Is important to realize that even the brain can be divided in four different lobes, most of the times all lobes work at time and together, they are no independent

one another but they make different functions, that's why the brain is the most complex part of the human body.

- Frontal lobe

The frontal lobes can be divided in two different parts: the prefrontal cortex and the motor cortex.

The prefrontal cortex: has de function of planning complex cognitive behaviors and the personality every person has.

It has de function of solving problems, reasoning... Basically is what sometimes is called the part of the brain that "thinks".

The motor cortex: by the other side, divided in premotor and primary motor cortex, they contain nerves that control voluntary muscle movements. So, in other words, they control and elaborate responses to the stimulus that the nerves receive. The nerves in the primary motor connect to the spinal cord, which enables the muscles movements. The premotor cortex helps to perform the correct movements in response to the stimulus, such as determining the direction of a movement (Bailey, 2017).

- Parietal lobe

The parietal lobes have a crucial part of the mental process, they receive and process sensory information from all the body.

The somatosensory cortex is found in the parietal lobes and is essential in the touch sense. The neurons that are received in the parietal lobe come from the thalamus, so the function of this cortex is to process the information of the nerves. (Bailey, 2017)

- Occipital lobe

The occipital lobe are the main centers of visual processing. The eyes transmit the information by nerve impulses to the visual cortex. The function of the occipital lobe is to process that information and identify colors, shapes...

Most of the times, the information received is combined with the parietal and temporal lobes to do a specific action (Bailey, 2017).

- Temporal lobe

This part of the brain has important functions in the auditory system and the language producing, as well as memory.

The limbic system is located in the temporal lobe, including the olfactory cortex, which is a separated cortex from the other ones, the nerves of this cortex don't connect with the thalamus, they make neural direct connections with the brain.

Even it has various functions, the main task of the temporal lobes are processing the sound (Bailey, 2017).

3.2. Neurons and impulses

3.2.1. Neurons

Neurons are the core unit of communication in internal system of humans and animals. (NIH - National Cancer Institute)

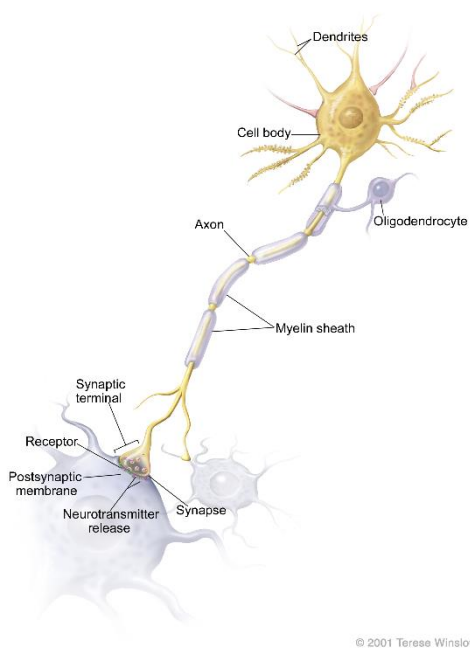


Figure 5 Neuron from NIH

Humans have an enormous number of neurons about 100 billion. They use electrical impulses and chemical signals to transmit information between different areas of the brain.

A neuron basically consists of a cell body or soma that contains the nucleus¹⁸ and special extensions, the axons and dendrites.

- Axons:

Is the structure that transmits messages from the cell.

- Dendrites:

These structures receive the message from the cell.

¹⁸ The structure in a cell that contains the chromosomes. The nucleus has a membrane around it, and is where RNA is made from the DNA in the chromosomes.

3.2.1.1. Communication of neurons

The way that the different neurons communicate each other or between a neuron and a cell is called synapse. The cell or neuron that sends the signal is called presynaptic and the neuron that receives the signal is called postsynaptic (KHAN Academy).

Nowadays is known that synaptic transmission can be chemical and electrical. If the neurons can be stimulated and synapse can be induced by electrical impulses, the brain would receive the stimulus induced. But first is necessary to understand the synopsis concept.

- Chemical synapse

This type of transmission involves a chemical messenger, the neurotransmitter. This units, carry the information form the presynaptic neuron or cell to the postsynaptic one.

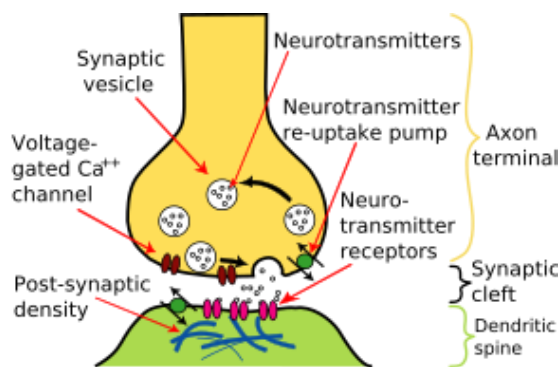


Figure 6 Chemical synapse from KHAN Academy

The neurotransmitters go from the axon terminals of a neuron to the different dendrite branches, allowing in that way a connection between multiple neurons at time. Neurotransmitters are inside the synaptic vesicles that are found on the axons. Is important to clarify that

between the presynaptic and the postsynaptic neurons there is a gap of space called the synaptic cleft.

When an action potential, or nerve impulse, arrives at the axon terminal, it activates voltage-gated calcium channels in the cell membrane. The Ca²⁺ allows synaptic vesicles to release the neurotransmitters. When that occurs, the postsynaptic neuron depolarizes or hyperpolarizes closing or opening the ion channels by that way, receiving the neurotransmitters. With this information it can be affirmed that the cell that releases neurotransmitters can regulate the number of neurotransmitters it releases in response to the arrival

of a potential. So, the neurons can dynamically change their behavior based on what they receive.

- Electrical synapse

At electrical synapse the cells are in direct contact each other. This connection takes the form of a channel called a gap junction. The ions can flow directly inside these channels. As they have an easiest way to move, electrical synapse is faster than chemical.

Most of times the synapse is a combination of both types even the chemical is the most common. The electrical synapse as is faster is sometimes useful in the synchronization of groups of cells but they don't have the capacity of signal modulation that chemical ones have.

But even the different synapses action potentials move between 1 to 100 meters-seconds⁻¹, that occurs because there is another type of nervous cell, the Schwann cell, this cell covers the axons with myelin sheath and makes the velocity of transmission higher.

All of these cells are structured in a network that connects every part of the body with the brain and the information can be send and received.

The brain be divided in two different "materials" one that is called the grey matter

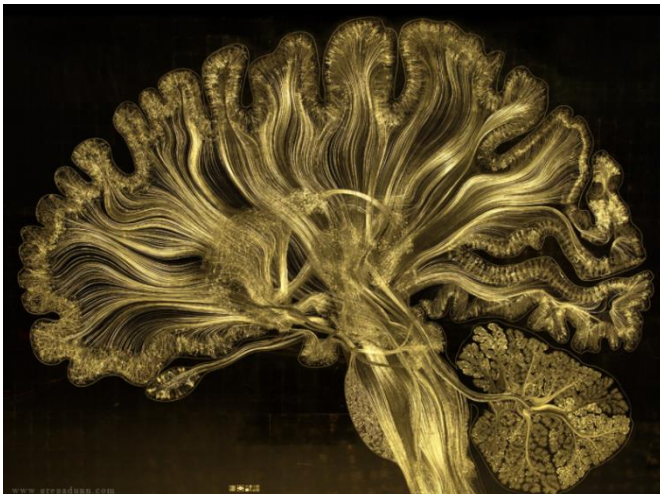


Figure 7 Graphical representation of the brain by by Dr. Greg A. Dunn and Dr. Brian Edwards

and the other one is the white matter. The gray matter is composed by the soma and the dendrites of the neurons, while the white matter is formed by the axons covered by myelin sheath.

The nervous system is divided into two parts: the central nervous system, which includes the brain and the spinal cord, and the peripheral nervous system,

pertaining the different ramifications of the main parts of the central system. Inside the system are found different type of neurons, each one with a different function.

- Interneurons

The ones that communicate with the other neurons

- Motor neuron

Neurons that communicate with a muscle cell.

- Sensory neuron

Neurons that communicate with a receptor cell.

The concept of nerve is a bundle of axons wrapped together and that communicate information at the same time and have the same function at time.

3.3. The project main issues

- 1- How to get the information of the brain?
- 2- How to send the information into the brain?

Briefly described, the solution of both of questions are, for the first one, it is possible to record what neurons transmit and which of them are activated and when. For the second answer, it can be summarized as stimulating neurons. All these actions occur naturally but the real problem appears when someone wants to stimulate neurons artificially to induce a feeling.

The brain is not only composed by nerves and neurons, also other cells called glial cells¹⁹, which are found in the same number as the neurons, and blood vessels that cover every part of the brain giving oxygen and other nutrients that the cells need to work correctly. So, when in the laboratories is wanted to induce and electrical impulse to stimulate a nerve, is a really difficult process.

¹⁹ Cells that come in many different varieties and perform many different functions, like mopping up chemicals released into synapses, wrapping axons in myelin, and serving as the brain's immune system.

By now, there is a project called Human Connectome Project²⁰, where the main purpose is to investigate and create a real, functional and complete map of the human brain.

3.3.1. How the cerebral activity can be measured?

Paul Merolla described the brain activity and measurement in an interview with Tim Urban as:

“The visual cortex has very nice anatomical function and structure. When you look at it, you literally see a map of the world. So, when something in your visual field is in a certain region of space, you’ll see a little patch in the cortex that represents that region of space, and it’ll light up. And as that thing moves over, there’s a topographic mapping where the neighboring cells will represent that. It’s almost like having Cartesian coordinates of the real world that will map to polar coordinates in the visual cortex. And you can literally trace from your retina, through your thalamus, to your visual cortex, and you’ll see an actual mapping from this point in space to this point in the visual cortex.” (Urban, 2017)

So far so good. But then he went on:

“So that mapping is really useful if you want to interact with certain parts of the visual cortex, but there’s many regions of vision, and as you get deeper into the visual cortex, it becomes a little bit more nebulous, and this topographic representation starts to break down. ... There’s all these levels of things going on in the brain, and visual perception is a great example of that. We look at the world, and there’s just this physical 3D world out there—like you look at a cup, and you just see a cup—but what your eyes are seeing is really just a bunch of pixels. And when you look in the visual cortex, you see that there are roughly 20-40 different maps. V1 is the first area, where it’s tracking little edges and colors and things like that. And there’s other areas looking at more complicated objects, and there’s all these different visual representations on the surface of your brain, that you can see. And

²⁰ The Human Connectome Project aims to provide an unparalleled compilation of neural data, an interface to graphically navigate this data and the opportunity to achieve never before realized conclusions about the living human brain. See the references to get the webpage link.

somehow all of that information is being bound together in this information stream that's being coded in a way that makes you believe you're just seeing a simple object" (Urban, 2017).

Neurons and nerves generate electrical impulses that can be analyzed and registered with different processes. During the synapse the axons and the dendrites alternate a release of low voltage charges, so a map of which neurons are active in determinate situations can be virtually mapped.

3.3.1.1. EEG

Electroencephalography is a physical method that allows to record the electrical activity of the brain (iMotions, 2016).

To achieve that, the head is covered with a structure, normally a plastic cap designed especially for that use of electrodes that detect the electrical activity. Its use is simpler than can be expected. Is a noninvasive technique.

The interface measures the electricity that the neurons generate, this data is written in a graphic and measured in voltages, so it is easy to see if the brain analyzed is active or not.

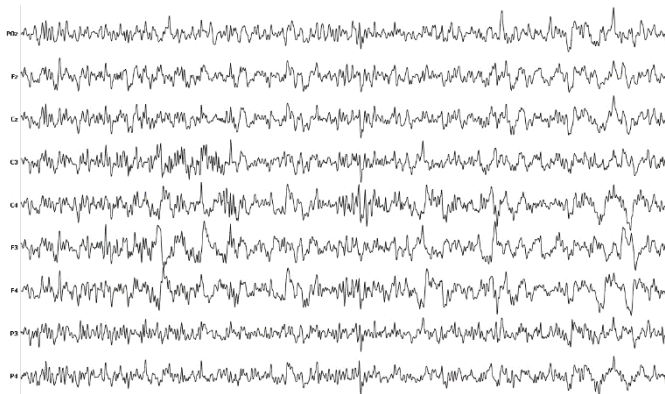


Figure 8 EEG graphic from iMotions

Also, this method offers the option to analyze the areas separately, so it is written which part is active and which is not.

Depending on the electrical activity the frequency patterns have different wave shape.²¹

- Delta (1-4 Hz): Deep sleep and in non-REM phases
- Theta (4-8 Hz): This register appears when the brain is working with a cognitive process such as counting,
- Alpha (8-12 Hz): This occurs when the brain is relaxed. Also happens when the brain is coordinates multi-attention and concentration.

²¹ See the annex to view the approximate shapes.

- Beta (12-25 Hz): The more the movement increased the more the frequency does, but it also happens when people see other's movement as a "mirror neuron system" effect.
- Gamma (<25 Hz): these frequencies are the most discussed, some scientists argue that they appear when the subject is attentive focused, while others affirm that is relate to rapid eyes movement.

There is another similar way to measure the electrical impulses that is called ECoG, which is mainly the same as EEG but it is required a surgery, the electrodes are on the surface of the brain.

3.3.1.2. *fMRI*

Functional magnetic resonance imaging, is another technique to measure the activity of the brain (Devlin).

A difference from the EEG is that fMRI measures the changes in blood oxygenation and flow in the brain. This occurs when neurons make responses, when an area is activated it consumes more oxygen, consequently the blood flows faster. As it analyzes all the brain, the system can create a map of which areas are active and which is its intensity depending on the activity is doing the brain.

Like the EEG is a noninvasive method of analysis so it is easier to test in many different patients.

fMRI uses a magnetic resonance imaging, as the scanner is mainly a powerful-electro magnet, it measures the variation, orientation and movement of the H from the water is in the blood.

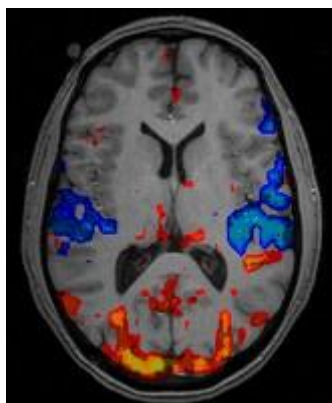


Figure 9 fMRI image from Psychcentral

The images that the scanner gives are more visual than other type of detectors as the scientific can obtain a map of the areas where the blood flowed faster. These parts are colorized and sometimes it can also be shown in the graph where blood flow has increased (red/orange/ yellow) and where it has decreased (blue).

As it is a full brain scan, it also gives a 3D image about the brain and not only a visual 2D diagram.

3.3.1.3. MEG

Magnetoencephalography is a noninvasive technique of analysis of the brain that shows which are the active parts of the brain in a situation. At the cellular level, individual neurons in the brain have electrochemical properties that result in the flow of electrically charged ions through a cell. (University of Washington).

The electromagnetic fields are generated by the flow of these ions, so when multiple neurons are excited together, the magnetic field value increases in a measurable value.

The MEG requires scanners with superconducting sensors that work with liquid helium that is in a temperature near to 0 K²² which can detect and amplify magnetic fields generated by neurons a few centimeters away from the sensors.

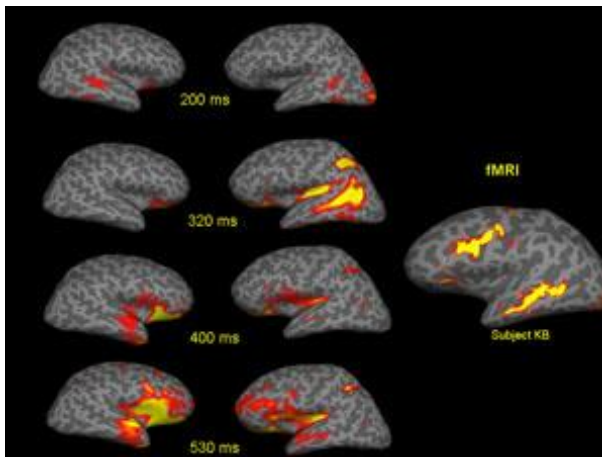


Figure 10 MEG from NYU COGNITIVE NEUROPHYSIOLOGY LABORATORY

MEG has advantages over both fMRI and EEG. Only MEG provides timing as well as spatial information about brain activity. fMRI signals reflect brain activity indirectly, by measuring the oxygenation of blood flowing near active neurons. MEG signals are obtained directly from neuronal electrical activity.

MEG provides temporal characteristics about brain activation with sub-millisecond precision, whereas fMRI measurement provides poor temporal information. MEG provides also more accurate spatial localization of neural activities than EEG. There are wide options of analysis but are not as efficient or not precise as the most used ones. An example of them is the Near-infrared spectroscopy (NIRS) which is not invasive. Near-infrared spectroscopy is based on molecular overtone and combination vibrations²³. It gives a spectrum of data that is not as visual as the fMRI, the EEG and the MEG.

²² 0 K=-273,15°C

²³ NIRS uses infrared light to detect fluctuations in cerebral metabolism.

4. General working of the project idea

After analyzing how the brain works and how is possible to measure the cerebral activity, the final step to achieve the idea is to induce stimulus to the brain by electrical impulses. By that way, the neurons will be excited and will transmit the information to the brain as if an external factor had activated the same feeling.

Taking this information as a reference, for the Virtual Reality project all parts of the cortex are important, as every part has its own function that is needed to simulate a fake reality. The device should analyze the cortex's nerves impulses to a specific stimulus and detect a pattern. Each different stimulus activates different parts of the brain, and the impulse patterns are different from every stimulus. The idea is to detect that pattern, and the device creates a response that the brain can detect as real. This diagram shows exactly what the theoretical process would be.

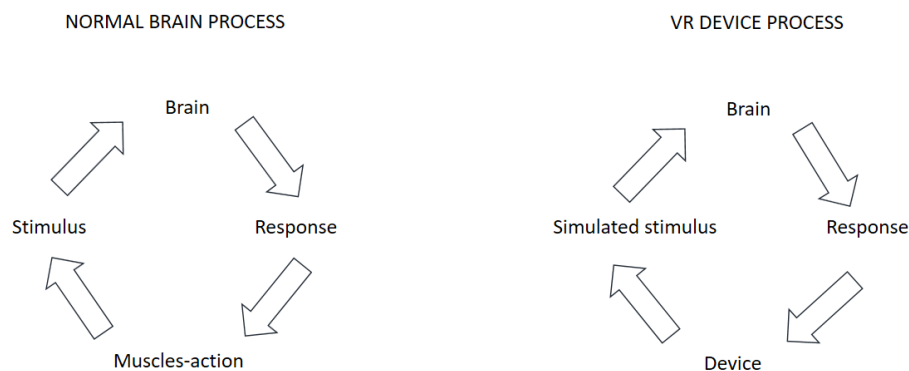


Figure 11 Project idea diagram created by myself

4.1. Using the motor cortex as a remote control

For the virtual reality project are both important, the part which the brain is analyzed and processed, and that information is transmitted to the program, and the part that stimulates the brain in response to what happens to the body.

Nowadays, the investigation of the electrical patterns of the brain has evolved enough to create systems that can be controlled only by the user's mind. They offer some limitations but is a real advance of technology. If patterns of neuronal activity can be detected and saved, the computer will recognize what the user is thinking or

pretending to do comparing the in real-time detections with the ones that had saved before.

There are many examples of mind control systems, most of them are used by people that suffer paralysis illnesses as the motion control of their body is lost.

Braingate is one of these examples, this is a research team that is focused on developing brain-computer interface (BCI) technologies to restore the communication, mobility, and independence of people with neurologic disease, injury, or limb loss. Using an array of micro-electrodes implanted into the brain, the research has shown that the neural signals associated with the intent to move a limb can be “decoded” by a computer in real-time and used to operate external devices (Braingate). By that way, the user can control the mouse of a computer or to move inside a specific software. The only issue that Braingate has found is that it uses an invasive method to analyze the neurons activity.

Other laboratories decided to go further and not only limit the uses of neurology science in the field of medicine. Is the case of Neurable, the enterprise founded by Ramses Alcaid, which also decided to enter in the fields of entertainment.

This team developed a Brain-Computer Interface based on the EEG analysis and connected with a virtual reality visor²⁴.

As the team described in his owns website (Neurable) Brain-computer interfaces function by gathering data on biophysiological activity in the brain, which is then analyzed by software to extract and classify data features. The difference between Neurable and other teams is that is not used an invasive method of analysis as the detector is based in EEG, Neurable’s BCI platform uses machine learning to classify EEG control signals in real time.

These possibilities of analysis and precision have conduced some scientists to think that maybe one day, people will be able to type with the mind. And for the virtual reality project, is expected the communication from the user to the machine and receive a response.

²⁴ More precisely the HTC Vive

4.2. Stimulating the brain with electrical impulses

As the motor cortex can be analyzed and detect the patterns, that patterns can also be induced by electrical impulses, but this is more complex task as the idea is to excite only some specific neurons to give the user the feeling that is wanted and not any stranger sensation that can cause pain or even serious illnesses.

There are different ways to stimulate the brain.

The electricity can be given directly by electrodes implanted in the brain, or noninvasively through electrodes placed on the scalp. The electricity can also be induced by using magnetic fields applied to the head. Electroconvulsive therapy is the best studied brain stimulation therapy. Other stimulation therapies are newer, and in some cases still experimental methods. (National Institute of Mental Health)

That's why creating artificial impulses is not as developed as the analysis, but even these problems, in the medicine field, there are many studies that have concluded good results.

The most advanced results in human brains are based on cochlear implants and retinal implants.

Cochlear implants are electronic medical devices that replace the function of the damaged inner ear. Unlike hearing aids, which make sounds louder, cochlear implants do the work of damaged parts of the inner ear (cochlea) to provide sound signals to the brain.

In other words, a cochlear implant is basically a device that processes the sound and converts it into electrical impulses and sends them to the implant. The implant's electrodes stimulate the cochlea's hearing nerve, which then sends the impulses to the brain where they are interpreted as sound. (Cochlear)

A similar thing happens to the retinal implants. Generally, the implant is an epiretinal prosthesis surgically implanted in and on the eye, that includes an antenna, an electronics case, and an electrode array. For seeing, there are glasses that are

connected to a central unit. It is important that the optical nerve is not damaged as the device stimulates it with electrical impulses (Second Sight).

Both devices, show that the evolution of neuroscience is amazing, but the laboratories haven't stopped working and the most innovative experiment that is also really related to the project of full immersion virtual reality is the mind control.

The experiments of mind control haven't been on human's brain, but in rats.

One of the biggest research in this topic was the Magnetothermal genetic deep brain stimulation of motor behaviors in awake, freely moving mice²⁵.

In that project the scientists focused on a technique called "magneto-thermal stimulation." This method it requires the implantation of specially built DNA strands and nanoparticles which attach to specific neurons. Those magnets, receive a signal and activate the neurons, by that way, the brain can be controlled.

In the experiment cited, the scientists could control the movement of the rat, freeze it, turn around or run.

4.3. Humans?

After all, humans mind is far away to be completely understood. But the current advances and the constant progress can make these realities even more soon as the most citizens expect.

Neurology products, originally had the finality in the medical field but past years, more and more other fields have been interested in neuroscience. Especially if it is combined with the Virtual Reality.

The entertainment companies have been searching for the ideal game, and the best game. The more time passes, the more realistic are the graphics, so in fact, what is pretended is to simulate an alternative life, where there are no laws, superpowers, or whatever the director wants. This idea is exponentially increased with the introduction of virtual reality and with the participation of neuroscience, the expectation is on his records. The future of the humans will not maybe be the world we live, but many other virtual worlds where everything is possible.

²⁵ See references (Pralle, 2017)

5. Creating a virtual reality visor

After seeing what is the theory about this device, now is time to turn up to the reality and see what is really going on inside the Virtual Reality world. For that, it was necessary to test and see the different capabilities and functions for each device.

It's impossible to talk directly to the big manufacturers and designers to see what are the real capabilities of every device, as if they were published, others could copy the same technology and sold it with a lower price.

As they are enterprises, and like other companies, they want to earn money, they try to maintain in secret all the features and the exact functionality of their own device.

That is not a good start for the research as if it's not known which are the current limits of this technology is quite difficult to elaborate a pilot project about the device.

In that point is necessary to add the factor of money, each device cost an average from 400 to 600 € excluding Google Cardboard which is much cheaper and Microsoft HoloLens which are extremely expensive.

5.1. BGW with VR experience

As the budget for the investigation part was not large, the only solution was to go to the Barcelona Games World. This was an enormous exposition where different game developers and software and hardware companies were exposing their latest products and showing to the public to try them.



Figure 12 VRX Sim at BGW 2017

There were also the most important VR systems that the people could test and experiment.

For the investigation, it could only be tested Play Station VR, Oculus Rift, HTC Vive, Google Cardboard and an innovative full immersive virtual reality system created by a Japanese company which was called VRX Sim.

All the devices tested had the basics functions analyzed in the theory part. They had the stereoscopic vision effect which actually was pretty realistic, the tracking movements was really accurate and the experience in general was great. But it was not similar to the project's final idea.

The only device that was the nearest similar to the final idea of the device, was the VRX Sim.

That prototype included a visor, which was similar to the other competitors' headset, two wireless controllers and the most innovative system. A platform which allowed the user to walk, bend, jump, move the entire body freely. The user didn't move the place he was standing as the platform was moving with his steps. That experience was the most realistic VR seen by now by the general public. Maybe some companies and laboratories have other innovative prototypes but they are confidential and are not part of this investigation.



Figure 13 PSVR CoolPaint VR demo at BGW

There were different demos to test the viewer with, each one with a different function.

The device that had the wide range of demos was the PlayStation VR, which was good as I could see the true potential of the viewer.

Each demo wanted to highlight a crucial point of the VR. One, which main purpose was a shooter, it simulates the user to feel what handling a real gun was. As the controller had the same shape as a gun it was a really immersive situation.

Another demo, showed skyscapes and frenetic movements, this wanted to show the immersion and the feeling of dynamics that the visors offer.

The other one that actually captured my attention, was an app name CoolPainter, it was an app which you could paint with a brush the space in a virtual world.

This idea is similar to the one that created HTC Vive with the collaboration of Unreal Engine which they created a platform to create and model 3D maps and structures directly inside a virtual reality environment.

5.2. Analyzing the situation

After seeing what each device can offer, the idea was to work on a specific device as the resources to create the entire project from scratch by now are not available and the knowledge and the difficulties of doing it in a save frame are by now impossible to achieve.

Instead of trying to build something out of the limits. Is important to start the project from a solid base. Is necessary to recognize and know how current VR works and how to develop it correctly as in a future combined with neuroscience can be the final's project goal achieved.

For that, the device used was the Google Cardboard. Mainly for each price and also because of the lower price, the constant developing from amateur designers and programmers who test their new ideas in this affordable VR device.

The idea is to build the visor at home and then make some experiences with existing apps and creating a VR application to know the programming part used in the future project.

The programming part will be essential in the future, as combining the neuroscience electrical impulses and the machine responses is its main function.

For the understanding of the VR systems, the programming is not as essential as will be in the full project as the current developing software have done scripts that can be easily used in the creation of the VR application. The difficult part is to transform them and adapt them to accomplish the same function linked to the brain.

Finally, the last problem was the main brain, the most complex part of the people's body and at the same time the most fragile. The project needs, a full understanding of the brain that by now is not investigated yet. Sending electrical impulses to the brain, as the theory says, if it is not correctly done, can make people suffer serious and irreversible disruptions and illnesses, even sometimes cause the death.

So the collaboration of real and professional neuroscientists was essential. Institut Guttman²⁶ was contacted to participate in the project, but even they answered happily to help, they were not disposed to make the investigation needed in this project by the moment, as it was not a relevant and immediate necessary project, but they were opened to study it and starting an investigation as soon as they found it relevant.

As the reasons showed, the practice part only consisted in the elaboration of a visor, the test and learning of its functionality and a brief starting in creation of VR applications.

5.3. Creating the visor, home-made Google Cardboard

Google Cardboard offers the option of buying a new and premanufactured visor. But also, it offers the choice of build the visor by yourself. For that, the company includes the maps and the guides of the visors, which are two different models, and the materials that are needed to build them.

The version used in the experience was the v1.2 as the newest offered functions that were in general useless for the test and it had a more difficult manufacturing process, so as the first version perfectly fit the needs for the project.

The device consisted of different parts, or pieces, the main structure is most laborious part in the holder, as it has to be designed manually taking in references the Google blueprints models.

²⁶ Emails attached in the annex.

5.3.1. Structure

To build the device, there were no exact measures as it's a phone holder VR system, so you can build a generic size or you can customize it specifically for a particular phone.

The device consisted of different parts, or pieces, the main structure is most laborious part in the holder, as it has to be designed manually taking in references the Google blueprints models.

In this case, I decided to use a custom design as it would adapt more efficiently with the phone. So, I used my current smartphone, One Plus 3T and I got the specs²⁷ that were 152,7 x 74,7 x 7,35 mm and I designed the suitable size taking the blueprint as a reference.



Figure 14 Google Cardboard Structure

After the first design, was important to check if the measures were correctly suitable for the phone, so I had to do different designs after finally I found the more efficient and correct.

²⁷ <https://oneplus.net/es/3t/overview>

When the design was done, it was time to assembly the different parts. That task was facilitated by Google as in its original designs was drown the parts that were needed to put together and how was the way to do it.

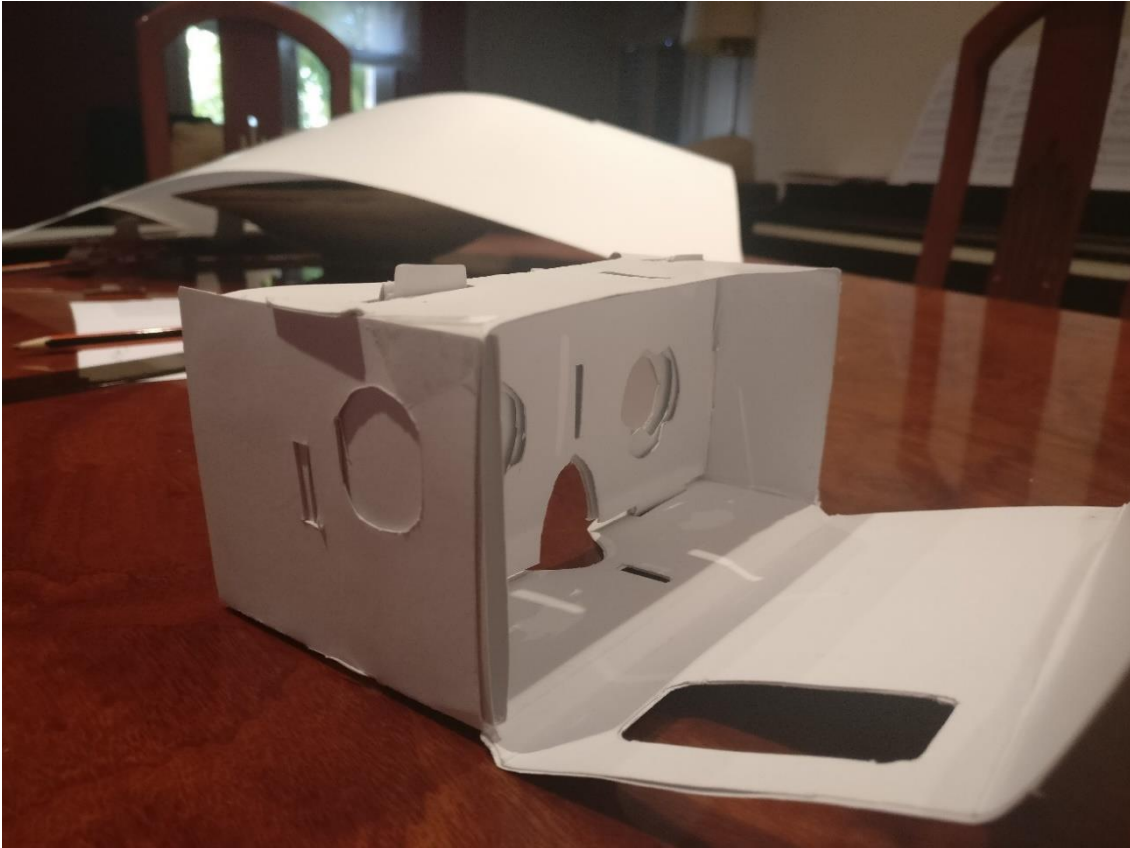


Figure 15 Assembly of the Google Cardboard created

This was the main structure, but it is totally useless without the lenses, one of the essential parts of the visor.

5.3.2. Lenses

The lenses help the user to focus their vision to the smartphone that is placed at short focal distances (2-3 cm).

The exact specs of the lenses, recommended by Google are these:

Parameters	Value	Unit	Notes
Designed FOV	80	°	Circular total field of view
Nyquist frequency	8.7	lp/mm	Based on Nexus 5 screen resolution (1920 x 1080 px), pixel pitch 57.6 μm
Display cover glass thickness	1.4	mm	$n_d = 1.5, v = 55$
Design wavelength	550	nm	+/- 25 nm (equal weighting)
Pupil diameter	15	mm	Also known as the "eyebox"
Eye relief	18	mm	From the designed eye pupil to lens surface vertex
Nominal virtual image distance	-667	mm	None
Lens diameter	34	mm	None
Lens edge thickness	1.5	mm	At 34 mm diameter
Lens material	PMMA	n/a	$n_d = 1.492, v = 57.4$
Tab to screen distance	39.07	mm	From the tab surface (facing display) to the front surface of display coverglass

Figure 16 Lenses specs in the Google Cardboard instructions

Even the Google specs, the lenses used were biconvex 25mm diameter and 45mm focal length. They are not the perfect suited lenses, but they accomplished its function to correct the focal distortion.



Figure 17 Difference between lenses from Google

The model on the left is the one that should be used for the perfect function of the visor, but with the specs needed for the Cardboard, these lenses are really strange in Spain, and the shipment from United States or another

country is expensive or sometimes there is no shipment service, so they only ones I could use were the lenses on the right. They are not such clear, but they also give the immersion feeling.

The final part when the lenses were displaced, was to secure the closing and adding some details like an anti-slipping band for the smartphone and some other visual details.



Figure 18 Final result of Google Cardboard

6. Conclusion

After analyzing all the virtual systems and the brain process of the information, it can be affirmed that is not possible to build by now, a full immersive virtual reality device where the user is unresponsive and at the same time conscious, and he receives the impulses generated and elaborates a response, all that concepts supposing the user is feeling a true sensation of reality.

There are huge lacks of knowledge of the brain that are not enough investigated. The human brain is one of the most fragile and complex part of the body, consequently is also one of the most unknown parts. This implies that the tests and advances inside the neurology field are really dangerous.

This project showed that is important also to talk about the ethical consequences. In the moment that the body is unresponsive, the user loses all control about what is happening around him in the real world, even he is conscious, he would not receive the external stimulus, only the system ones, so he would become and exponential victim of any type of crimes such as abuses, etc.

By the other side, if people receives the virtual reality stimulus and they feel like if it was real, there is the danger of being stimulated with feelings that no one wants. Is important to say that as every other computer system, is not a perfect machine, and bugs, fails or even other human hacking can lead to the user experiment feelings that it does not want. This information would lead to a new research that involves ethical thoughts about virtual reality and morality actions.

All about the virtual world seems amazing until people gives bad uses to it. But this is not an exception, and that is not a reason to stop thinking and progressing in this amazing and field.

This project won't cure people, but is an alternative while the real cure is investigated. People with paralysis, people that do not have some parts of the body..., they would feel again the sensation of being and moving freely, in a world, a virtual world, but for them a real sensitive and unique world.

Furthermore, if the technology evolves enough, the idea is to connect many people in the virtual reality at time, such as a current online game, together in the same virtual world.

That is the main idea of the full immersive virtual reality, it will make people happier giving them memories that in other way should be impossible to have.

But by now, the only way to achieve this project is continue investigating the brain, the technology and maybe one day, closer than expected, the first virtual reality device linked to the brain will appear.

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8. Annex

Figures

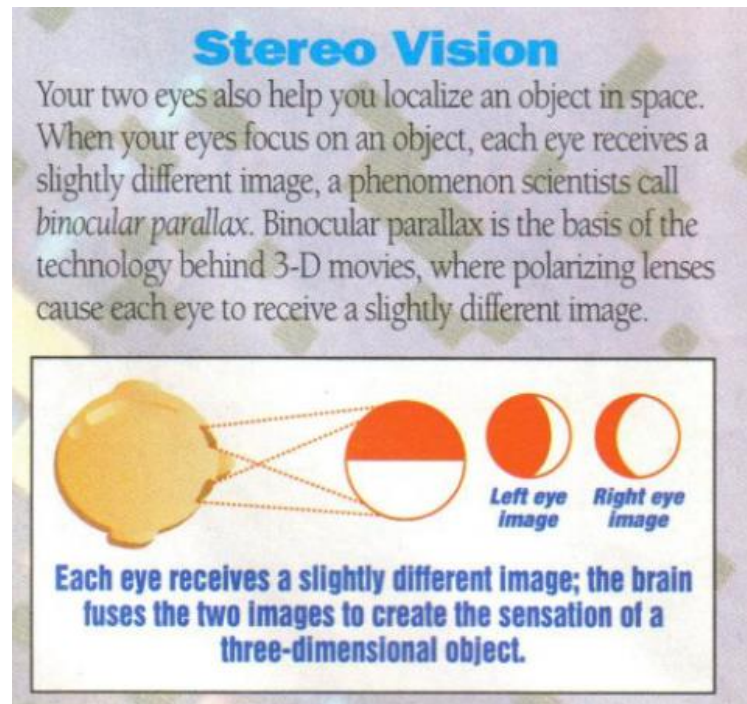


Figure 19 SEGA stereo visión

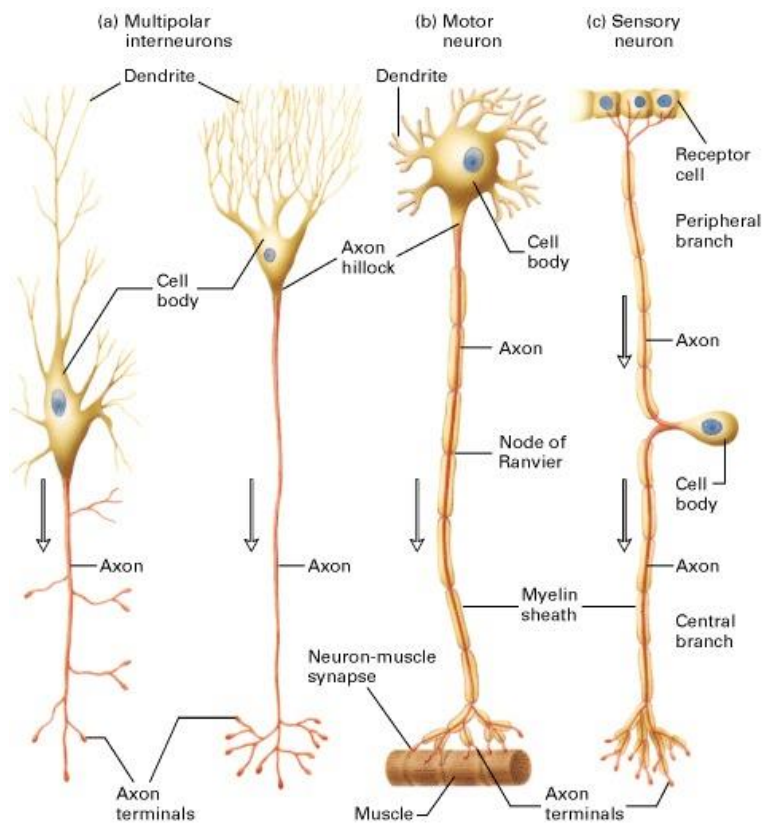


Figure 20 Types of different neurons

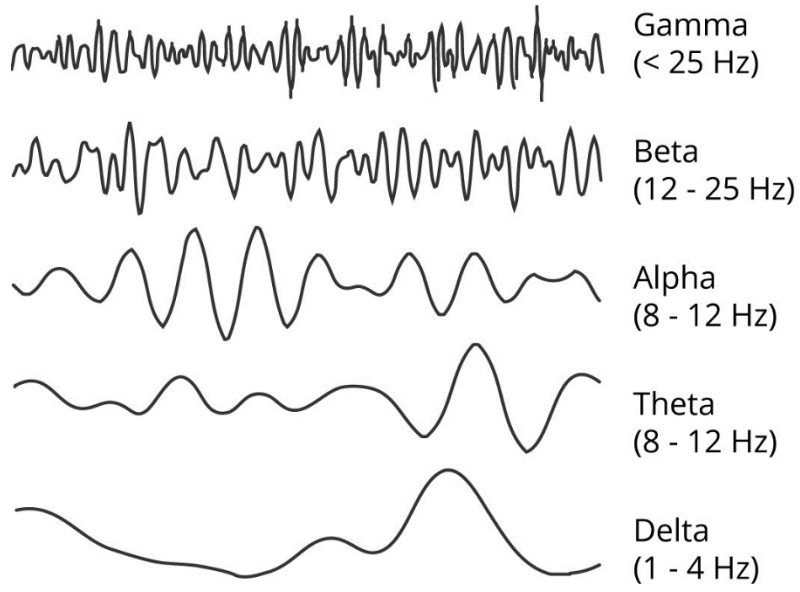


Figure 21 EEG wave shapes



Figure 22 PSVR demo from BGW



Figure 23 PSVR Gran Turismo demo on the BGW



Figure 24 Manufacturing of the VR Google Cardboard

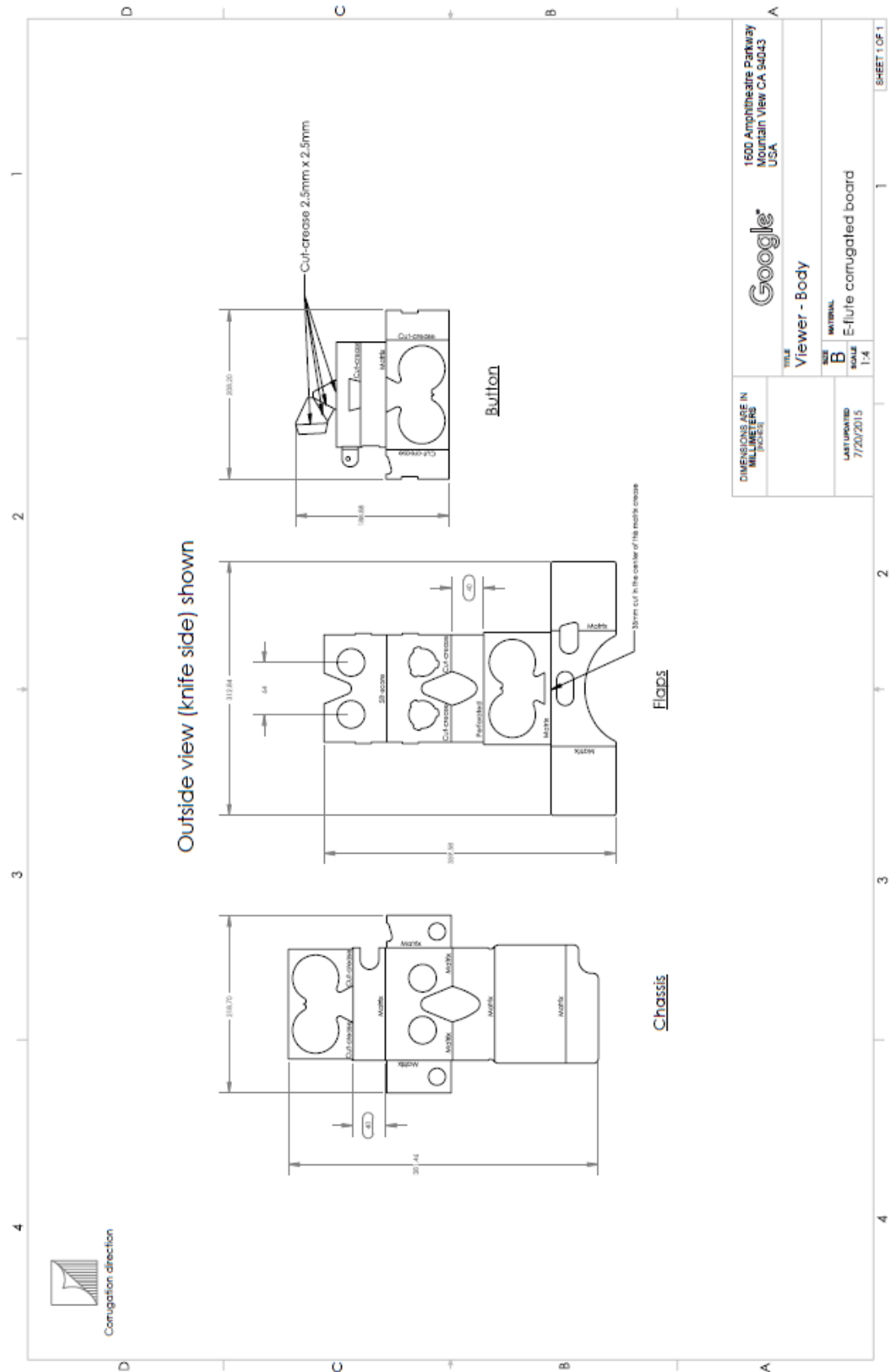


Figure 25 Google Cardboard Blueprint V2

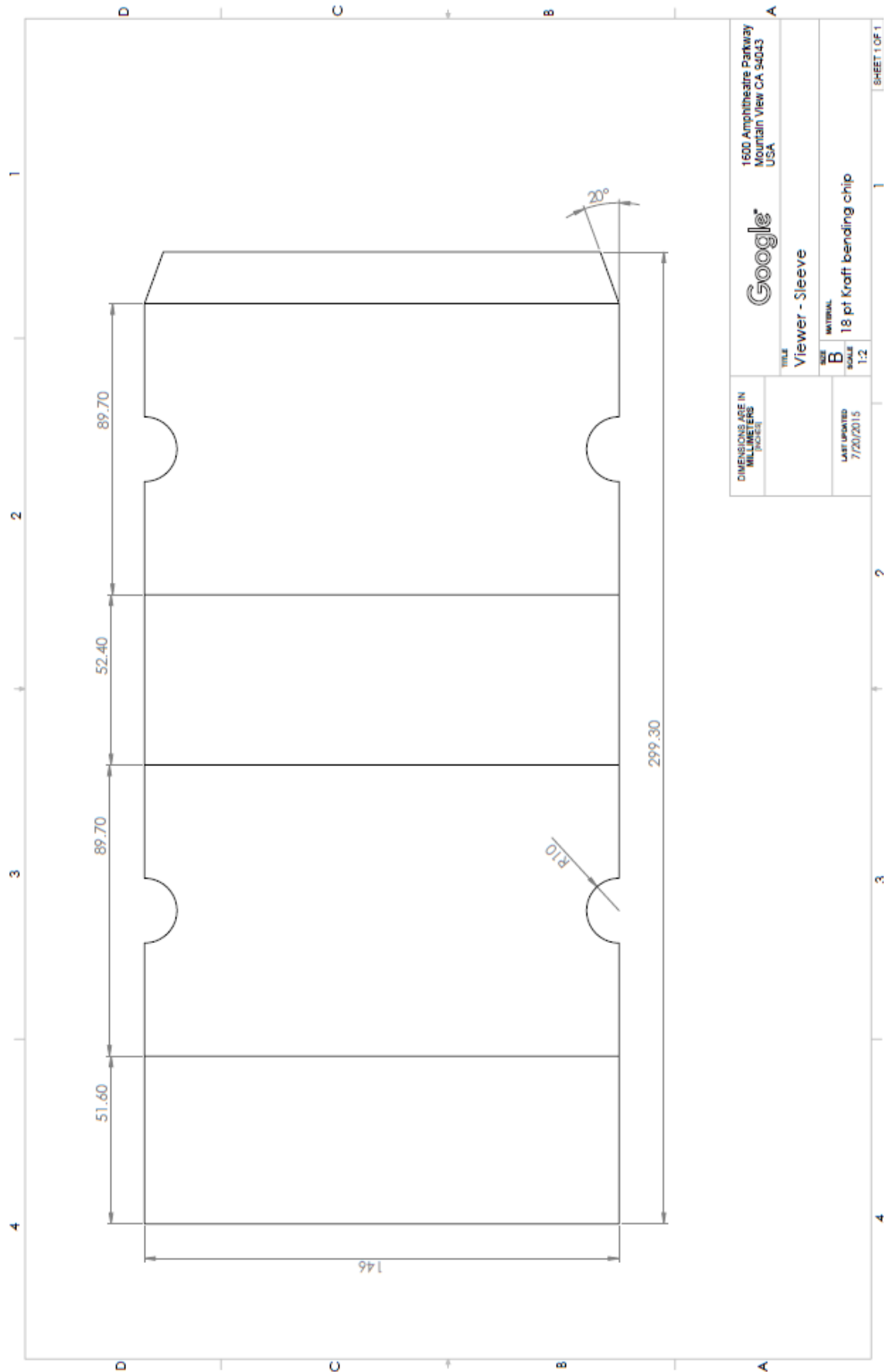


Figure 26 Google Cardboard Blueprint V2

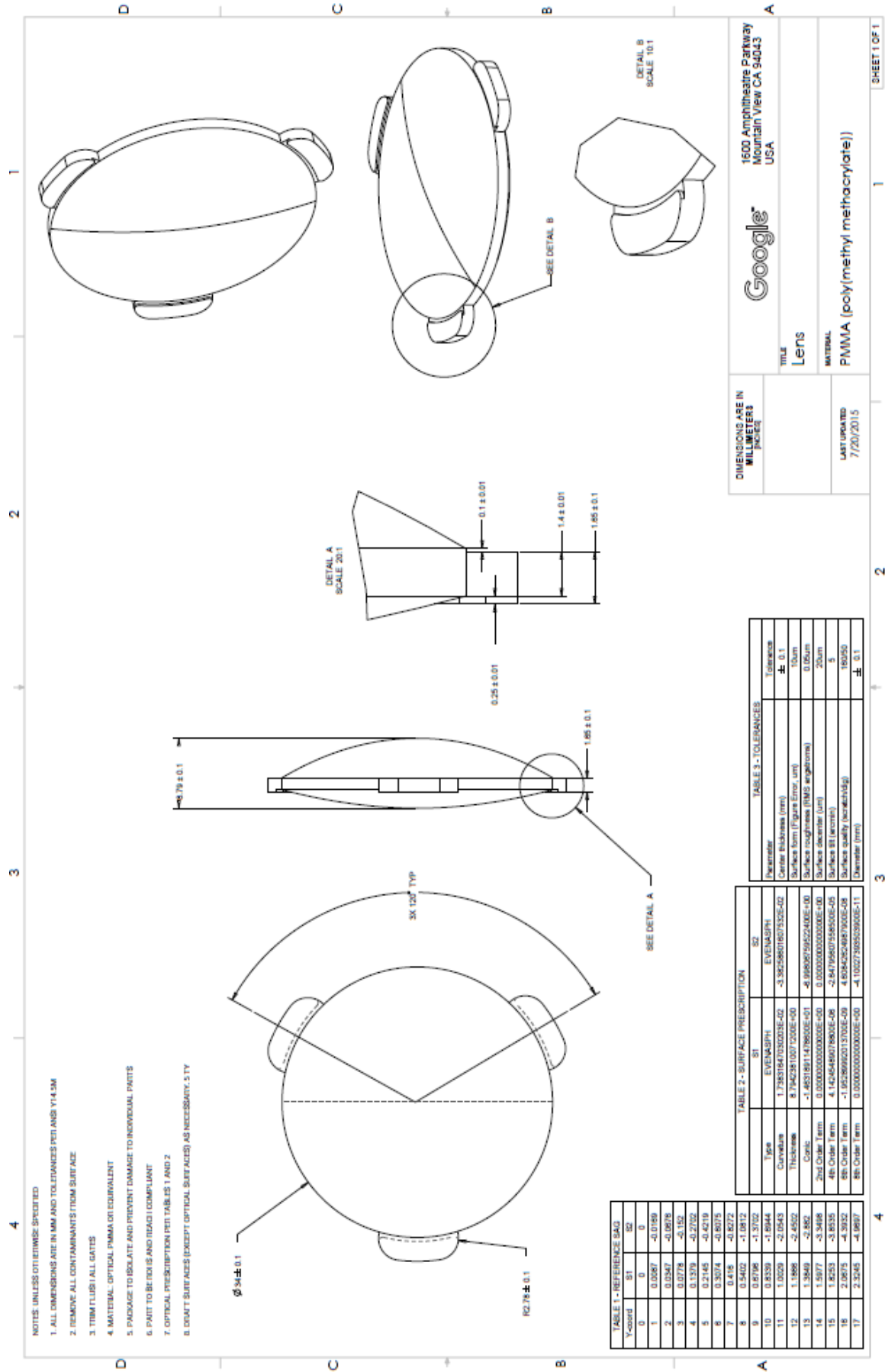


Figure 27 Google Cardboard Blueprint V2

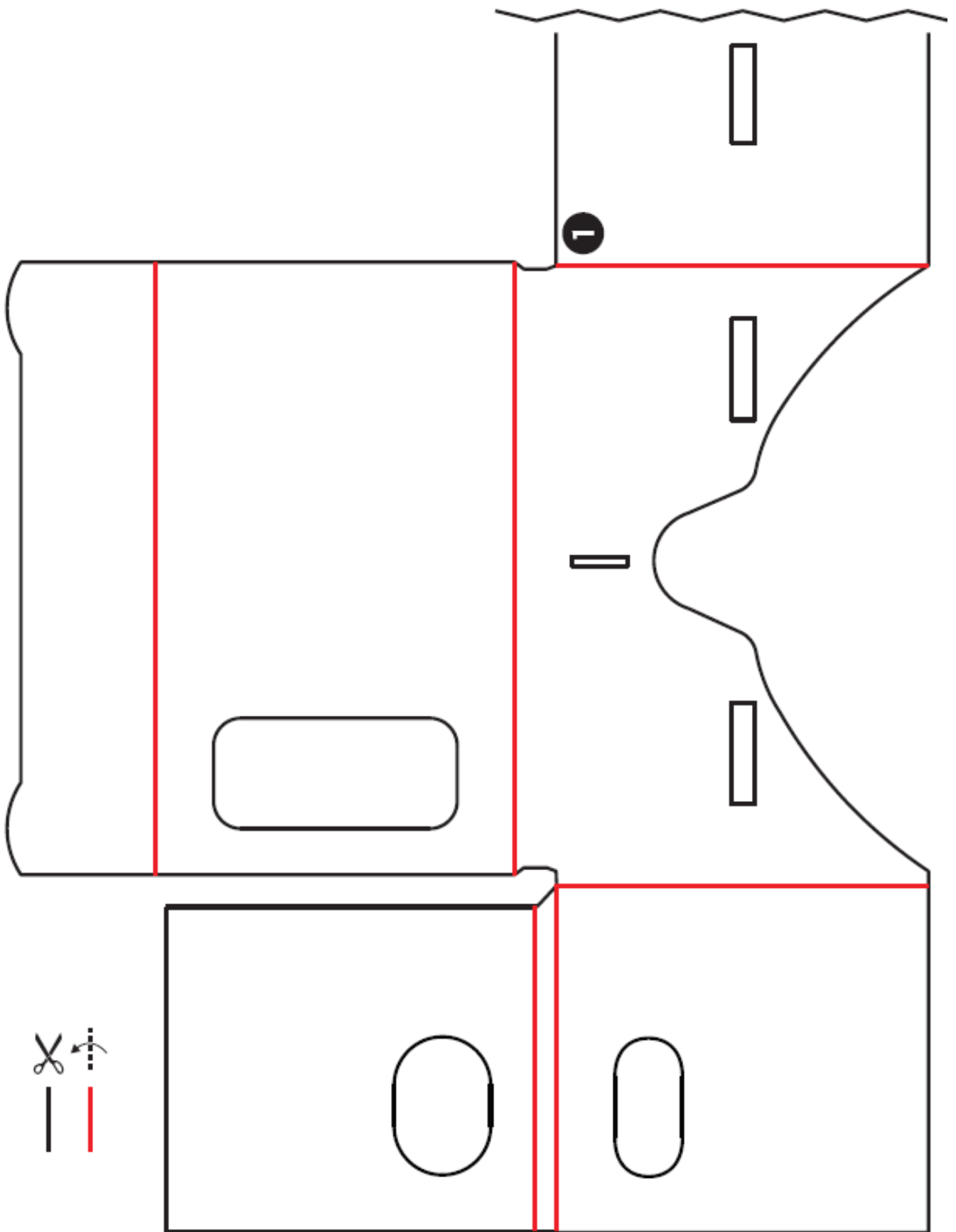


Figure 29 Google Cardboard Blueprint V1.2

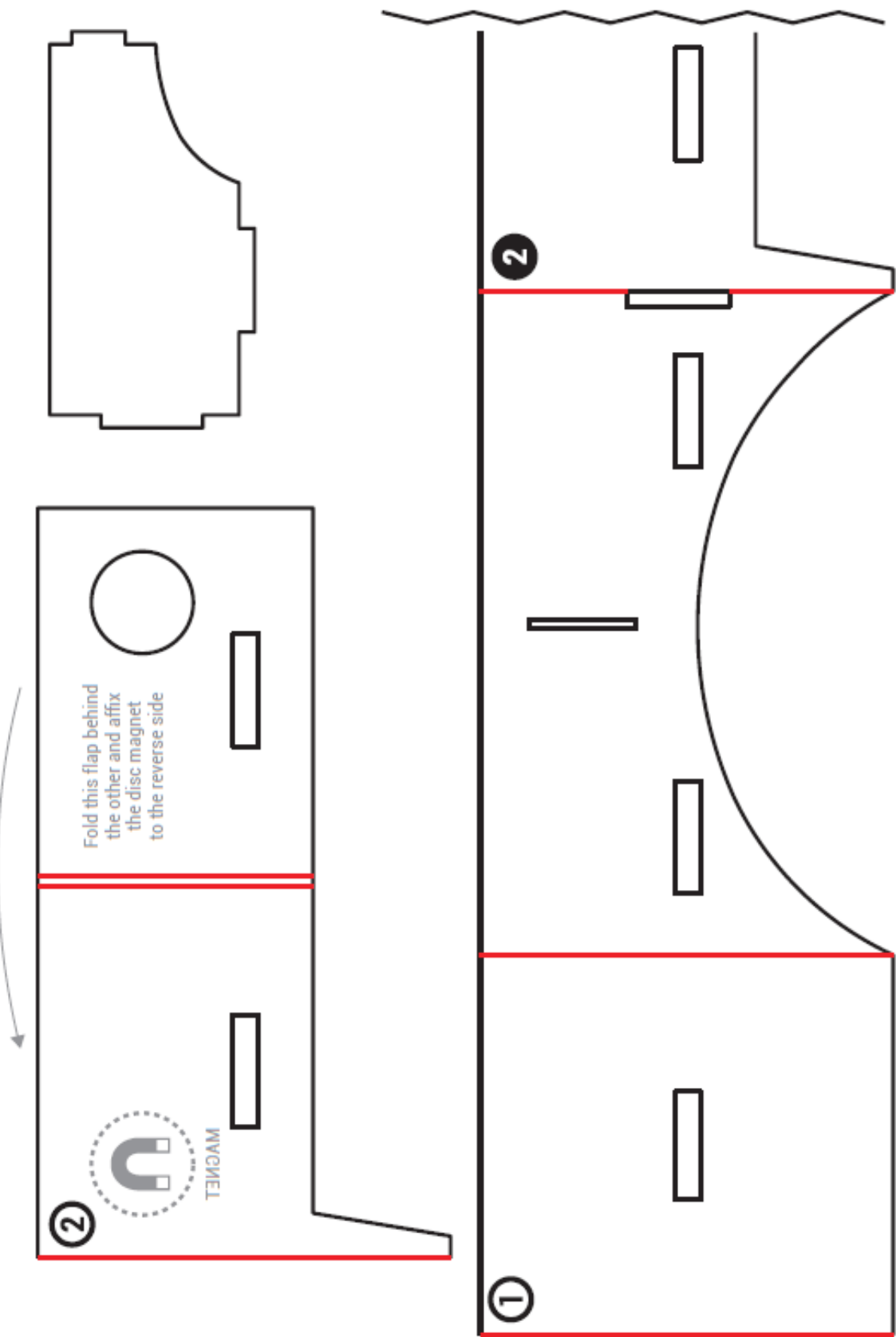


Figure 30 Google Cardboard Blueprint V1.2

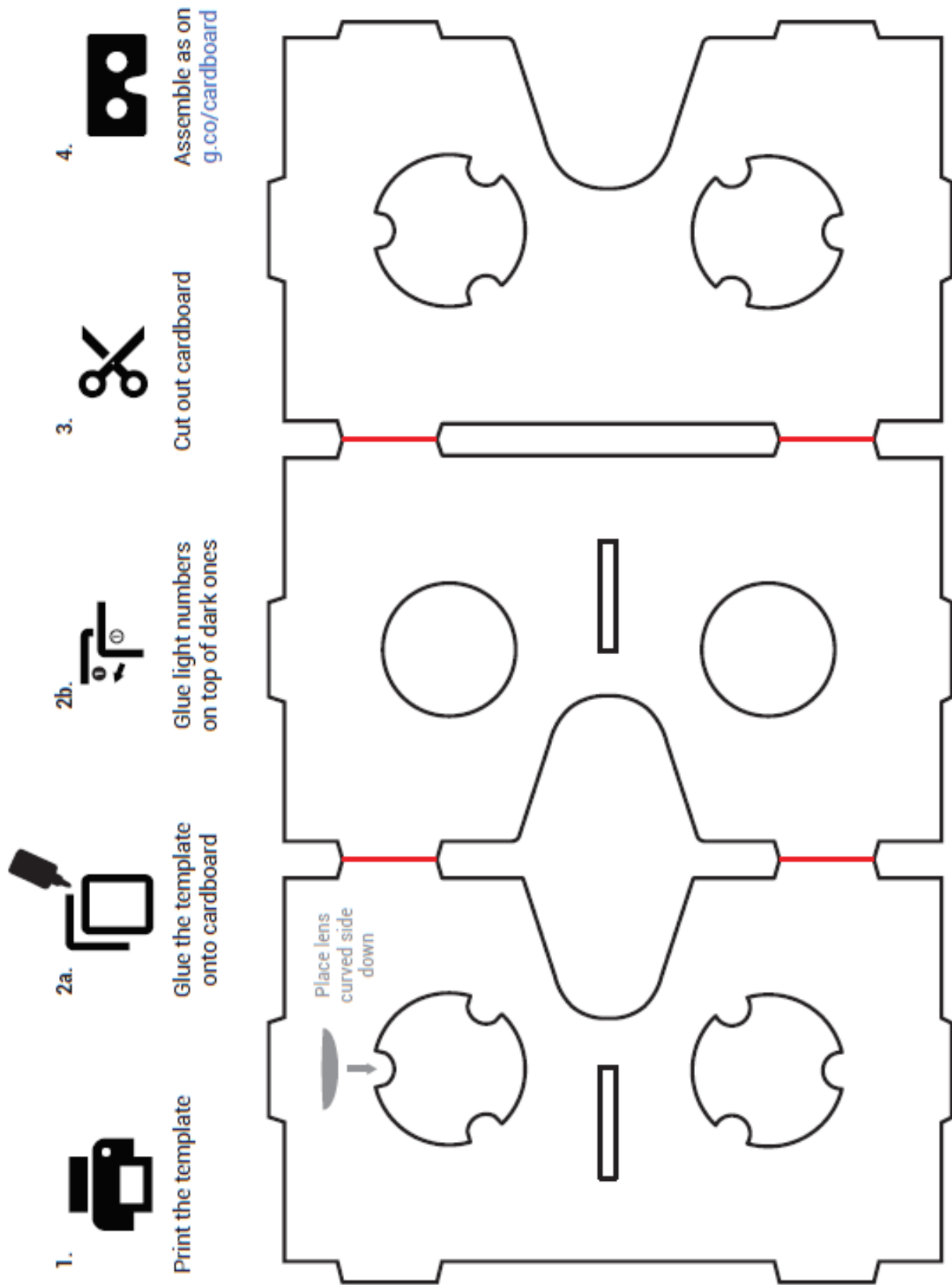


Figure 31 Google Cardboard Blueprint V1.2

Guttmann Emails

7th July 2017, 10:25 wrote:

Bones,

Sóc estudiant de batxillerat del Col·legi Episcopal de Lleida. Actualment estic desenvolupant el treball de recerca de final de batxillerat. El treball tracta sobre un futur projecte que englobaria l'àmbit de la neurociència. Aquest projecte que segurament no serà posat a la pràctica fins d'aquí bastants anys, estaria encarat sobretot a malalts terminals o a persones amb discapacitats de moviment.

En aquest correu demano la possibilitat de poder entrevistar o mantenir contacte via correu amb alguns dels professionals que treballen a l'Institut per a poder realitzar una bona investigació.

En qualsevol cas, moltes gràcies per tot.

7th July 2017, 10:51, Josep M. Tormos Muñoz <jmtormos@guttmann.com> wrote:

Ens hauries de donar una mica més d'informació sobre al teva idea, per donar-te resposta. Ara, és excessivament vaga.

Xema

--

Jose M Tormos

Coord. Investigació

Institut Universitari de Neurorehabilitació Guttmann

7th July 2017, 11:28, wrote:

Hola,

Cap problema, encara estic redactant el treball per tant no us puc passar cap document, però sí que puc explicar-vos amb més detall la idea. Entenc que per idea us referiu al projecte del treball.

Bé, bàsicament el meu treball consisteix amb investigar les possibilitats de fer una immersió total dins un món virtual. M'explico, jo havia pensat que un projecte així podria ser útil per a persones amb discapacitats de mobilitat, per exemple, una persona que no pot moure les cames, es podria connectar al sistema i el seu cervell rebria impulsos i imatges d'unes cames virtuals, el pacient podria sentir el mateix que si estigués caminant, però en realitat no ho estaria fent.

Sóc conscient que és un projecte que gairebé sembla ciència ficció, però per aquest motiu estic investigant com es podria fer, almenys la part teòrica, i d'aquesta forma en un futur, poder-lo realitzar.

10th July 2017, 13:42, Josep M. Tormos Muñoz <jmtormos@guttmann.com> wrote:

El que comentes sembla un desafiament tecnològic força interessant.

Una cosa que si caldria que tinguis en compte, i que nosaltres intentem promoure, és que els reptes científics acompanyin les necessitats reals de les persones, perquè no son pocs els casos que després de superar nombrosos esculls i trobar fantàstiques solucions d'enginyeria, aquestes no han pogut ser convertides en elements de valor per la societat, perquè no responien a necessitats reals o prioritàries de les persones amb una discapacitat.

Et recomanaria que revissis els conceptes de recerca “top down” i “bottom up” abans de definir sobre quin tema t'agradaria treballar.

Salutacions

Xema

--

Jose M Tormos

Coord. Investigació

Institut Universitari de Neurorehabilitació Guttmann

10th July 2017, 14:52,:

Bones,

He revisat el tema que m'havieu comentat i no he acabat d'entendre que inteneu dir-me.

És a dir, la idea del treball crec que la tinc més o menys clara, ja que és un tema que m'apassiona i a més crec que pot ser realment útil. Llavors no acabo d'entendre a què us referiu amb l'anterior correu. Respecte a lo de "top down" crec que es podria relacionar amb el fet que es faria primer una explicació general i després ja s'aniria detallant.

Gràcies per tot,

10th July 2017, 17:43, Josep M. Tormos Muñoz <jmtormos@guttmann.com> wrote:

Disculpa si he estat excessivament criptic en el meu missatge.

El que et volia dir es que no sé si aquesta és una necessitat que tenen les persones amb una discapacitat neurològica... no et dic que no sigui una bona idea... sino que no tinc clar que sigui quelcom que una persona amb mobilitat reduïda demanaria o quina funcionalitat podria aportar-li.

Et volia fer una reflexió sobre el perill que pot tenir focalitzar-se sols en el repte tecnològic sens analitzar primer les necessitats.

Si ho fas i et surt que, efectivament, és quelcom que estan buscant les persones amb aquest problema, doncs tindria molt bona repercusió. En cas contrari podria ser un esforç menys productiu.

JM Tormos

--

Jose M Tormos

Coord. Investigació

Institut Universitari de Neurorehabilitació Guttmann

12th July 2017, 10:14, wrote:

Bones,

Primer disculpar-me per no contestar abans, però ahir vaig haver d'anar a Barcelona i em va ser impossible.

Referent al correu, entenc el que em dius sobre que si no és una necessitat no és molt bona opció seguir investigant. Però, per això ja ho havia estat pensant, en les necessitats d'aquestes persones, he tingut familiars molt propers que han acabat amb discapacitats (en el cas del meu germà mentals, i en el cas de la meva tieta físiques, a causa de la ELA) durant aquest temps vaig estar observant en especial a la meva tieta i vaig veure una clara evolució en el seu pensament. Era una dona que es passava bona part del temps treballant com a professora, però la seva passió era el camp. Per culpa de la seva malaltia, hi va haver un punt en què ella ja no podia anar al camp, ella s'havia de quedar cada dia, dia rere dia a casa, aguantant-se el desig.

Aquesta és la finalitat del meu projecte, no és un projecte per a recuperar la mobilitat de les cames (en aquest cas), ja que realment el projecte en sí està encarat cap a persones que no es poden recuperar. Té una finalitat molt més simple i a la vegada molt menys científica, per això estic tenint problemes per obtenir consells i ajuda de professionals. La seva finalitat només és poder donar felicitat al pacient, que almenys pugui complir el desig que té, ni que no sigui de forma real, almenys que pugui tenir la sensació d'haver-lo complert.

Bé, sento haver-me fet pesat amb aquest correu, potser és una mica extens, però crec que aquesta és la finalitat, com deies en l'anterior correu, no és "una necessitat" però sí que crec que és un projecte que en cas de fer-se real pot fer feliç a moltes persones, i per a mi aquest és motiu suficient per a intentar-ho.

En qualsevol cas, gràcies per tot.

12th July 2017, 10:52, Josep M. Tormos Muñoz <jmtormos@guttmann.com> wrote:

No!

Està força bé i el plantejament que fas es totalment comprensible i, ara sí, permet entendre que hi ha una motivació derivada d'una observació.

A partir d'aquesta motivació, un aspecte recomanable és que segueixes una metodologia de disseny centrat a l'usuari.

Aquí pots trobar informació:

https://en.wikipedia.org/wiki/User-centered_design

Moltes gràcies pel teu interès

Xema

--

Jose M Tormos

Coord. Investigació

Institut Universitari de Neurorehabilitació Guttmann