Universidade do Minho
Escola de Arquitectura

Raúl Soler del Vas

Reality, education and design challenges in the field of architecture after the embracement of Virtual Reality

março de 2022

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Dissertação de Mestrado
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Trabalho efetuado sob a orientação de
Professor Doutor Bruno Acácio Ferreira Figueiredo
Arquiteto Luca Martinucci

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Declaração

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Assinatura

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To Carlos, Laura, Jose and Germán for their moral support in those long discord conversations.

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Abstract

Virtual Reality (VR) has always been seen as tool with lots of potential, but it has been limited by hardware, high prices, and a lack of consumer-oriented experiences. However, this is slowly changing, and as VR adoption increases, new challenges will arise in the field of architecture.

When it comes to VR and architecture, most research are focused on its visualization aspect. However, this dissertation wants to put on the table some less talked topics in architecture that have been. Having the capacity of creating and being immersed in synthetic spaces arise various questions: What is considered real space? How does the language of virtual space differ from physical space? Should architects be involved in the design of virtual spaces?

These questions and more shapes what is this work, a non conclusive overview that tries to open discussions and minds about what could mean the interaction between virtual reality and architecture for architects.

Keywords. Virtual, Reality, Perception, Embodiment, Design, Education.

Resumo

A tecnologia da Realidade Virtual (RV) sempre foi vista como uma ferramenta com muito potencial, mas tem sido limitada por hardware, preços elevados, e falta de experiências orientadas para o consumidor. No entanto, isto está a mudar lentamente, e à medida que a adopção da RV aumenta, novos desafios irão surgir no campo da arquitectura.

Quando se trata de RV e arquitectura, a maioria das investigações falam de seu aspecto como ferramenta de visualização. No entanto, esta dissertação quer colocar em cima da mesa alguns tópicos que têm sido menos falados na arquitectura. Ter a capacidade de criar e estar imerso em espaços sintéticos levanta várias questões: O que é considerado um espaço real? Como é que a linguagem do espaço virtual difere do espaço físico? Os arquitectos devem ser envolvidos na concepção de espaços virtuais?

Estas perguntas e mais moldam o que é este trabalho, uma visão geral não conclusiva que tenta abrir discussões e mentes sobre o que poderia significar a interacção entre realidade virtual e arquitectura para nos arquitectos.

Palavras-chave. Virtual, Realidade, Percepção, Encarnação, Design, Educação.

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Acronyms

VR. Virtual Reality
XR. Extended Reality
AR. Augmented Reality
MR. Mixed Reality
CAD. Computer-Aided Design
6DFO. Six degrees of freedom
HMD. Head Mounted Display
BIM. Building Information Modelling

Introduction

Virtual Reality (VR) has been always considered a technology with enormous potential, but tremendously niche due to hardware limitations, unaffordable prices, and lack of consumer-oriented experiences.

All of this is slowly changing, and since adoption of VR is increasing, all kind of new questions are arriving to various areas, like philosophy, anthropology, physiology...

Architecture is one of those. The intrinsic characteristic of VR as a device that can bring you to other places to explore them, to interact with them, and even to inhabit them, should be of great interest to the architect's community.

When it comes to VR and architecture, most of research works are focused on his use as a visualization tool to experience unbuilt space. This dissertation work on the other hand, wants to put on the table some less talked topic in architecture's discipline. Questions like: What we consider real space? How virtual space's own language could be? Should architects being involved in the design of virtual spaces?...

In sum, questions that make architect's rethink about their identity and knowledge about design space because of the arriving of VR.

Context

Virtual reality (VR) is part of the term extended reality (XR). XR is the umbrella category that covers all the various forms of computer-altered reality. Those forms are:

- Augmented reality (AR): is an overlay of computer-generated content on the physical world. This content can be interacted in a limited way and is running in real-time. AR is augmentation, while VR is immersion. The first head mounted device (HMD) ever created, "The Sword of Damocles" by Ivan Sutherland could be consider AR, since it superpose virtual geometry over his physical space (Sutherland 1968). Some current examples are most of the apps developed by the company Niantic (developers of Pokémon GO) or the real-time translation through a smartphone camera that makes Google Translate. The development of this technology regarding AR glasses still in a very premature state, since lots of technical bottlenecks still present.

- Mixed reality (MR): as it is pointing out in the paper What is Mixed reality? (Speicher, Hall and Nebeling 2019) is an evolving concept which still has not managed to establish a general consensus. Nevertheless, this paper offers 6 working definitions:

    - Continuum: On A Taxonomy of Mixed Reality Visual Displays (Milgram and Kishino 1994) On one end is found a purely real environment, and the other, with a purely virtual environment. They consider any environment which consists of a blending of real and virtual to be mixed reality.
    - MR as a synonym of AR.
    - MR as a combination of VR and AR.
    - MR as a stronger version of AR.
    - MR as a type of collaboration.
    - MR as an alignment of environments

-Virtual reality (VR): Virtual reality is a computer-generated simulation of a three-dimensional environment that can be experienced through virtual reality headsets or through devices that track a user's movement and

create a virtual environment accordingly. It is a system that can be used for a range of purposes, such as gaming, training, education, and design.

For years, those systems have been out of reach from the public for their lack of consumer friendly experiences and high technical knowledge to make them work. In addition they could not provide a solid experience, since they were highly limited by screen technology, processing power and weight. But now, with the improvements on miniaturisation and a lower cost, they are starting to come to the mainstream mass.

VR differs from other extended realities in that it completely immerses the subject in virtual space. Depending on the equipment, the user can even use their hand or their whole body to interact in the virtual space.

Objectives

From the beginning, this dissertation work has been driven by the motivation to try to bring to the surface many of the topics that are not usually talked about VR in the field of architecture. To be an excuse to initiate different debates between different points of view. Shaping in this way objectives such as:

- Investigate the possible changes about what is consider real.
- Discover the impact that VR could have in our perception about the physical space.
- Exploring how could be designing for virtual entities.
- To think about how VR can improve teaching about architecture.
- Test new ways of being designing architecture.
- To question the role of architects and check the validity they could have in this new scenario in which the need for designers of virtual spaces arises.

Having all of this into account, this work aims to achieve the objective of giving an overview of the different areas where the adoption of VR in the field of architecture will challenge us as architects.

Methodology and organization

The realization of this study involved phases of practical experimentation and bibliography research to provide theoretical support to achieve the previous objectives.

The aim of these hands-on experiences was to put oneself in the shoes of a VR developer, to understand the medium by getting involved in it and to learn about the real difficulties in its conception. These practical experiences range from getting to know the tools for designing virtual reality experiences (Figure 01) to investigating the different locomotion options when it comes to VR (Figure 02). Other experiences include designing non-Euclidean spaces, tracking objects or modelling a project inside VR.

At the same time, a theoretical examination of studies that had used VR as a medium for their research was carried out. To make the most of this knowledge, a system was put in place to process all the information relevant to this work. This process consisted of three parts:

- Capture: During the reading of the papers, one of these two pdf readers was used on an iPad: Liquid text or Apple Books. With these, all parts of interest were highlighted and commented on. These pieces of information were then passed on to the next process.

- Processing: For the highlighted files in Liquid text, they were automatically processed by Readwise (a web service), which provided as output a markdown file that would be useful for the connecting phase. In the case of Apple books, the highlights were exported to text and pasted into a blank markdown file. In both cases, the obtained markdown file showed the highlights along with their location inside the pdf/epub file.

- Connect: These markdown files were finally moved into Obsidian (Figure 03), a PC software that can create links between the content of different markdown files. This is how a small reference cloud was created where the information was not only stored, but also connected.

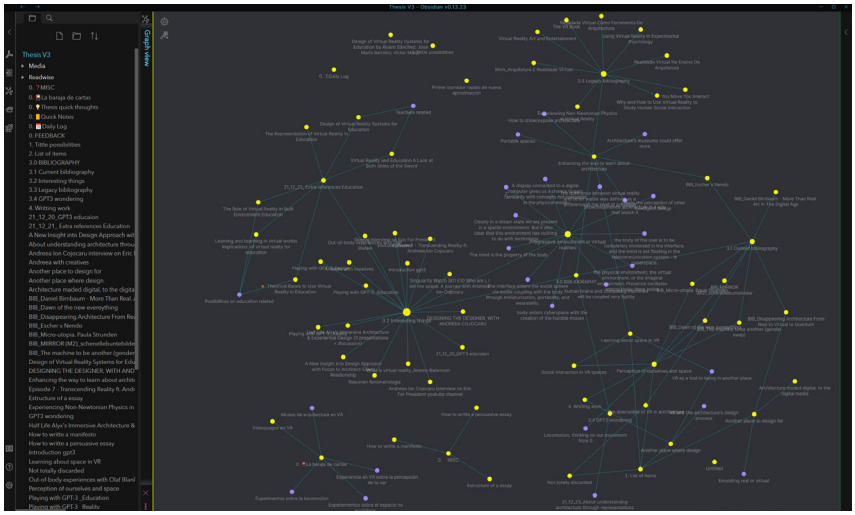


Figure01 Screenshot of a first experience designed in the context of this dissertation. It was the first contact with the game engine Unreal Engine 4

Figure02 Screenshot of an experiment where subjects without familiarity with VR tried 3 different ways of locomotion

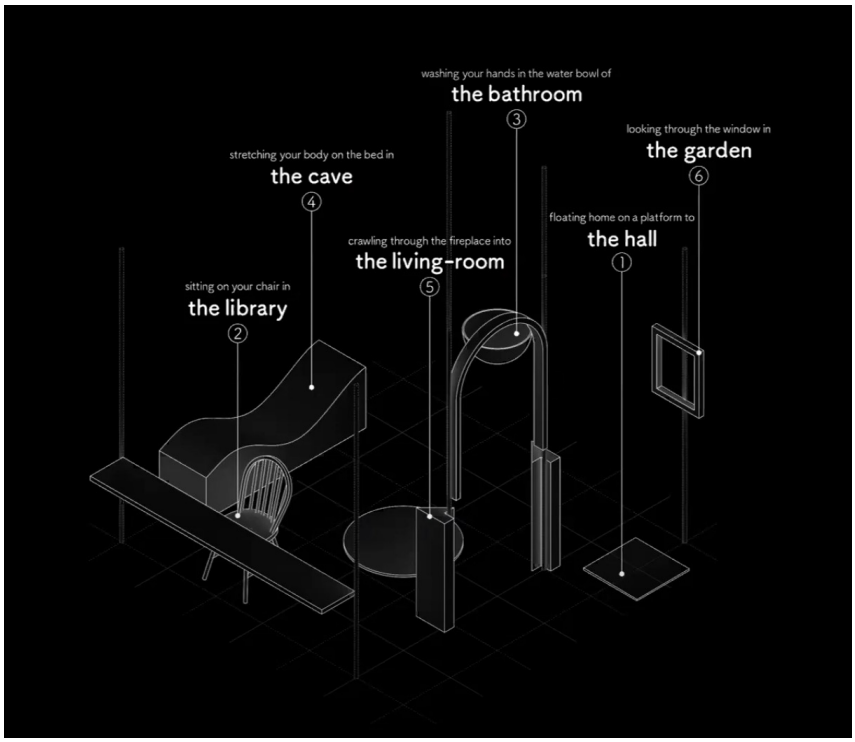
Figure03 Screenshot of one of the various Obsidian vaults behind this project

All these practical experiences and theoretical investigations were varied, but throughout the 11 months of research there were certain areas that predominated during certain periods.

Initially the focus was on exploring the unique possibilities of this medium when designing spaces. It was pretty influential the Paula Strunden's research work *Microtopia* (Figures 04-06) and the video game *Tea for God*.

Then, in the search for a purpose for working in virtual spaces, its potential as a teaching tool emerged as a point of interest. Much research and reflection took place.. Experiences like the *Museum other realities* were key.

Finally, during the last few months the research focused on the subject of reality, as it was felt that this could provide a solid basis for understanding everything that followed. Questions such as the nature of the subject in VR, the perception of what is real, or the way of living this kind of experience could affect us in general constantly came up when trying to unpack the rest of the areas. Therefore, it was decided to put it as an initial block of context to define the point of view of this research towards VR.



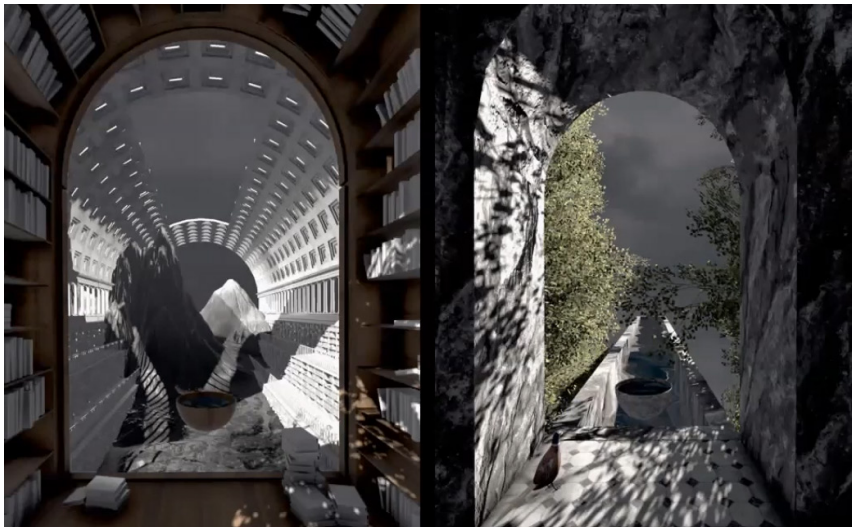


Figure04 Graphic showing the distribution of the different elements in the experience.

Figure05 A person is going into a hole that is in front of she in VR.

Figure06 A dynamic space that is possible to achieve in VR. Those figures were extracted from a recorded lecture called: Beyond Virtual-Reality, available in the youtube channel AA School of Architecture.

Reality

"Reality can never be fully known, and neither can virtual reality."(Lanier 2017)

Questioning reality has been a constant throughout our history as a species. Although it is a question we almost take for granted that we will never be able to answer, it is always something worth to thinking about.

As Lanier states, this chapter will not be able to give a complete explanation of what reality is, and doesn't pretend it neither. But in order to talk about the impact of VR, it is inevitable to start by questioning how exposure to this new reality will affect subject's perception.

From there, it will be developed some topics related with perception about ourselves, since who we are in VR is an important question to understand the underlying narrative that contains this dissertation.

Finally, it will be argued that this state of alternation between realities will not only not be negative, but will, for example, help us to acquire more knowledge about ourselves and about reality.

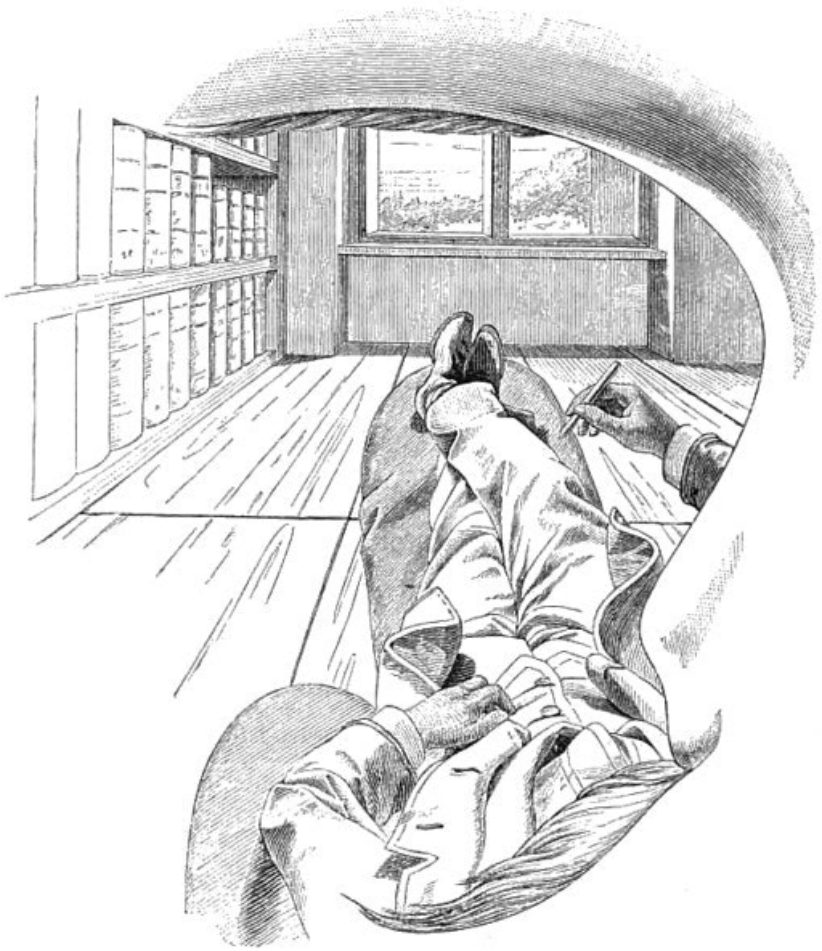


Figure07 *Self-Portrait*. Ernst Mach (1886)

REALITY

Physical and virtual spaces are equally real

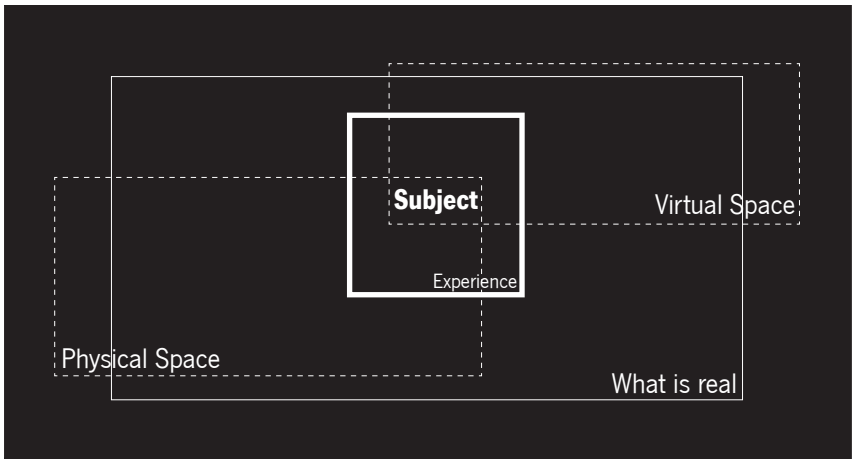


Figure08 Graphic showing the relations between the subject, physical and virtual space, and what is real.

What is reality in this context?

As it was mentioned on the introduction, what is reality is a question that cannot be addressed in its entirety, despite this, it is necessary to at least define to some extent what is considered real in the context of this work to build up on top the rest.

The present work resorts to some of phenomenology's basis to talk about reality from the perception of the subject. Phenomenology is a branch of philosophy that deals with the study of the conscious experience of things as they appear to the individual. Is distinguished from other branches of philosophy by the fact that it treats the subject's interpretation of reality as an empirical matter. A key idea of phenomenology is that a person's perception of reality is based on his or her own experiences, and that these experiences shape how world is understood. This means that the world we experience is not an objective one, but rather, is a subjective one.

What phenomenological approach implies for virtual reality is that since the validity of the experience is the only thing that matters, a virtual reality experience is considered as real as a physical one, and not only that, but this possibility of being exposed to new stimuli could lean us to reshape our general conception about reality, expanding our knowledge about it and interact with those new points of view through other embodiments forms (topics that will be developed further in the next chapters).

Accept other realities?

Accept other realities rather than the physical could seems inconceivable for some. But we already have access to different realities as Michael Foucault stated in his conference *Des espaces autres* (Foucault, 1967). This conference was the first appearance of the term heterotopia. Foucault defined heterotopia as a social space that is physically set apart from the rest of society, but at the same time is linked to all the other spaces.

In heterotopias we speak of simultaneous realities, of places that are different and present. Other places where we enter and our behavior changes. A cemetery, Muslim thermal baths...So certainty is easy to assume that we are already familiarized to a certain degree to accept other realities. The way to access to those heterotopias previously mentioned could generate the false assumption that, even heterotopias being other spaces/realities, they still attach to the physical, but there is a point in the work of Foucault where he talks about the virtual space too, referencing the mirror:

"In the mirror, I see myself there where I am not, in an unreal, virtual space that opens up behind the surface; I am over there, there where I am not, a sort of shadow that gives my own visibility to myself, that enables me to see myself there where I am absent(...). The mirror functions as a heterotopia in this respect: it makes this place that I occupy at the moment when I look at myself in the glass at once absolutely real, connected with all the space that surrounds it, and absolutely unreal, since in order to be perceived it has to pass through this virtual point which is over there."(Foucault, 1967)

What does it mean for VR?

Looking through the lenses of phenomenology, is easy to make a connection between the role of the mirror and a virtual reality headset. This heterotopia generated by the mirror is born from the subject. The mirror after all is a passive instrument, its composition is only a layer of glass with a silver bath inside. But even being just that, is able to open ourselves to another reality, confirm our existence, and make unreal our physical reality, all at the same time. Here is where this work wants to stablish a parallelism with a HMD. As an inanimate subject as is a headset, which is nothing more than a mixture of plastic parts and electronic components, exposes the subject to new realities as the mirror.

All of t this is bringing us to a scenario of hybrid experiences, since VR is a paradigmatic event that explicitly structurally transforms the very sense of reality (virtual realism), which could help us understand the implicit layers-mechanism of base reality, enabling the emergence of new forms of subjects-objects-concepts. (Ruberto 2019)

Impact on architecture?

This process of hybridization could lead architecture to different hypothesis. For example the book *Disappearing Architecture. From Real to Virtual to Quantum,* theorizes about an architecture that could conceive buildings as quantum objects:

"(...)objects able to be literally in two states at once - ON and OFF, 1 and 0, real and virtual. It is an architecture against architecture - at least of the traditional kind, which knows only either-or; either 1 or 0, either inside or outside, either enclosing or excluding. It is an invisible architecture that makes numerous parallel virtual worlds visible. It is an upside-down architecture. Architecture as a pure infrastructure. Architecture as an enabling platform - for all."

Beside that separation that this paragraph states between real and virtual (since in this dissertation virtual is considered real), this work agree with the possibility of the realization of this scenario. But by any means, this is not the only possible hypothesis. In fact, what this scenario of fractured/multiple/hybrid realities is going to build is a task that should start of being tackle by architects and other related disciplines.

Perceive physical and virtual as equally real is going to bring lots of questions about ourselves and about reality. Even it could make us, architects, question our role as experts in designing space, but that would be developed later on in the conclusion of this work.

For now, in the next statement we are going to explore another important piece when it comes to shape the foundations of this work, who we are in VR?

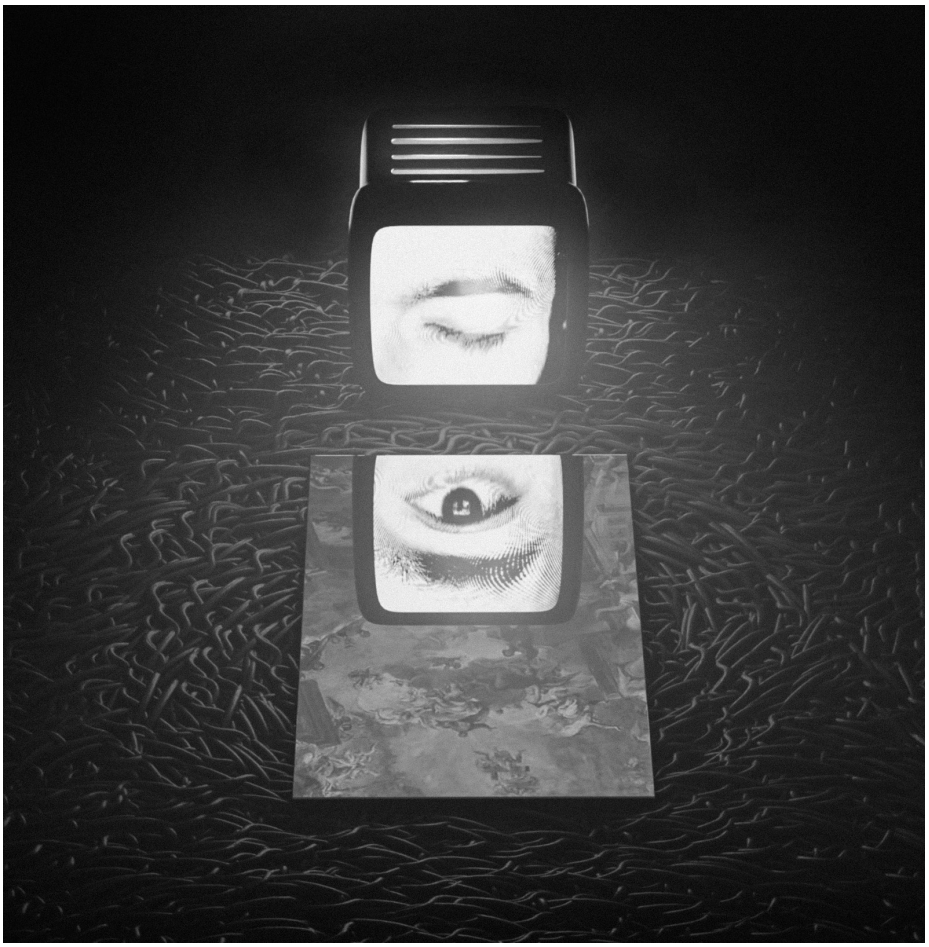


Figure09 *The other side of the mirror.* By dissertation's author.

REALITY

We will be able to switch between different embodiments easily

"VR lets you feel your consciousness in its pure form. There you are, the fixed point in a system where everything else can change" (Lanier 2017)

Is this even something new?

The feeling of transport us into the body of another is not something exclusive from the VR media. Literature, cinema, video games... all of them has certain creations that are seeking to put the reader/spectator/player... into the skin of another. So especially compared to video games, is not the first time that we can feel in control of other entities.

Nonetheless, since VR could probably be considered as our closest approach to a cognitive manipulation machine, it has the potential to go one step further, rewiring our metal connections and converting the sentence "I have felt inside another body" into "I have felt like another entity".

Accepting other "shells" that do not belong to us may seem a far-fetched question, but we have other disciplines that have been studying about this capacity, and showing positives results.

For example, in the field of neuroscience Vilayanur Ramachandran has conducted different researches in topics such as, behavioural neurology, neural plasticity and "phantom limbs" rehabilitation. In this last one, he found some interesting findings about the relief of pain by the simple use of a mirror. For instance, if a patient who has lost his/her arm feels pain in the wrist that should be there, by using a mirror to reflect his intact arm in the place where his absent arm, the patient is able to follow guided treatments under the illusion that the he/she is in control of his/her absent limb. Relieving in this way the phantom pain.

Another example would be the Rubber Hand Illusion experiment designed by Matthew Botvinick and Jonathan Cohen (Figure 12). In this one, participant's hand is occluded to his vision, meanwhile a rubber hand is on his field of view. Then, the experiment's conductor starts to touch simultaneously the occluded hand and the rubber hand with a brush, making the participant start to believe the rubber hand as his own.

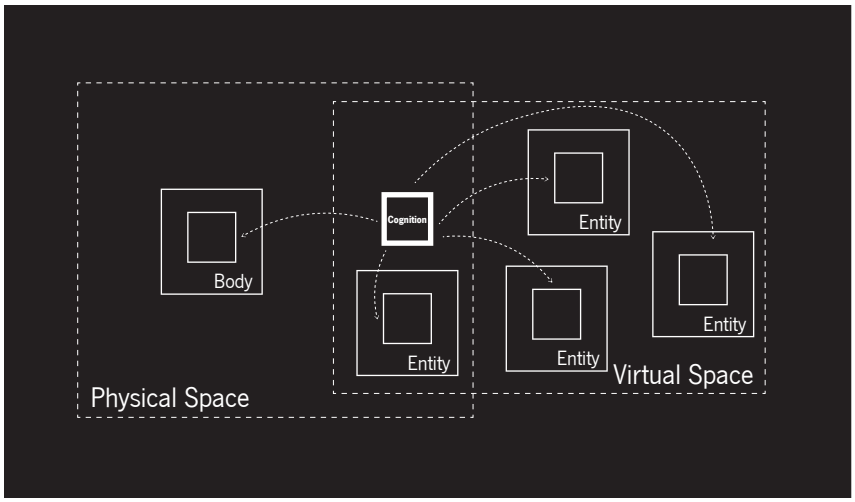
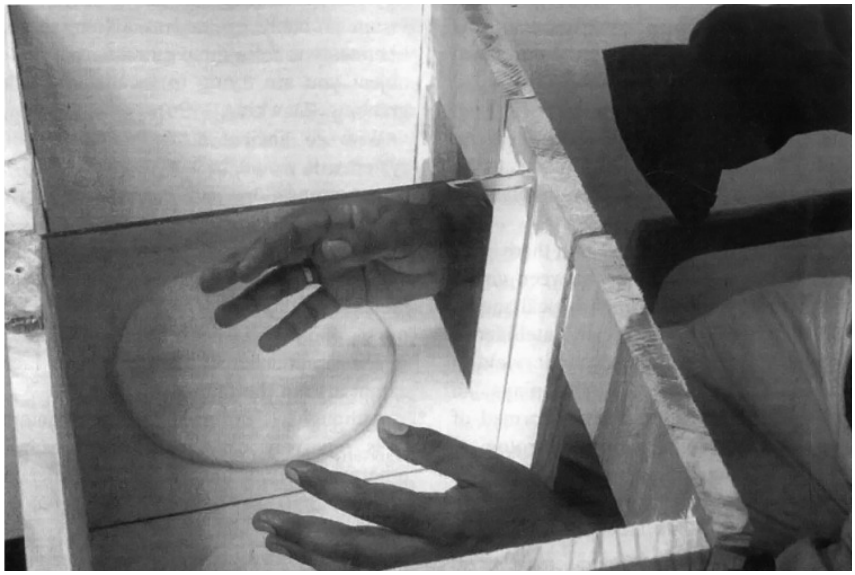
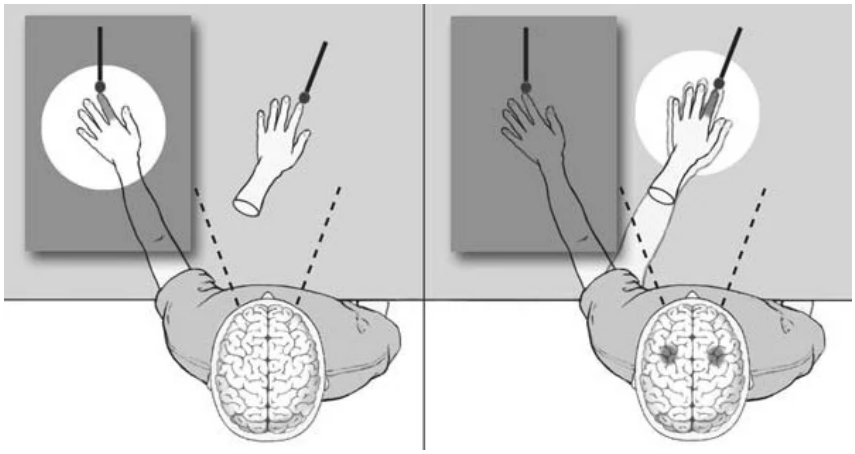


Figure10 Graphic showing cognition as something that could jumps from one identity to another.

Figure11 Picture showing the mirror therapy of doctor Vilayanur Ramachandran. Extracted from: europepmc.org

Figure12 Illustration from Thomas Metzinger's book *The Ego Tunnel: The Science of The Mind and The Myth of the Self* showing the rubber hand illusion.





Those 2 examples shows how our brain is already able to feel limbs that are not physically attached to our body as our own, so, how VR able us to make this translation of ownership?

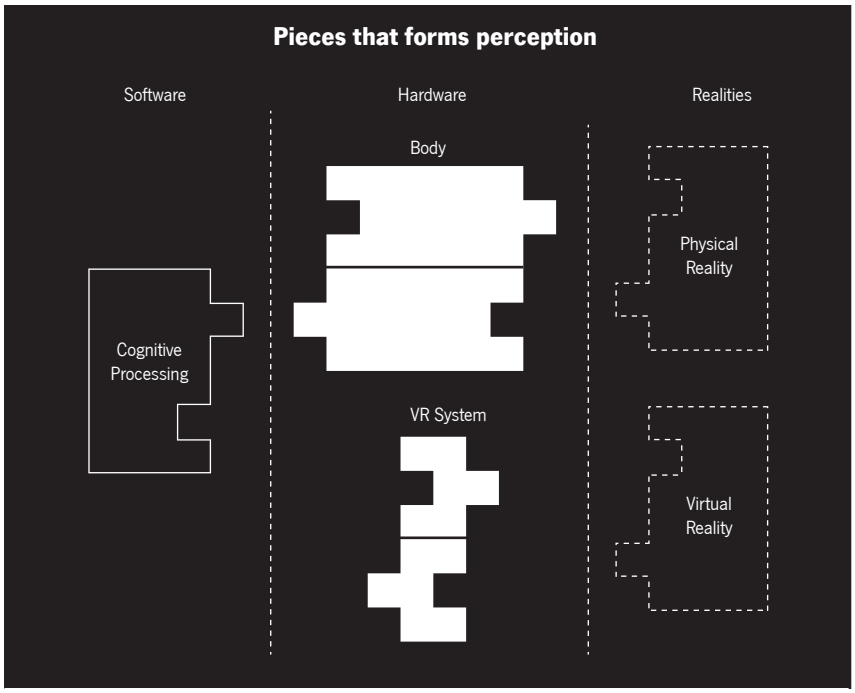
How to achieve embodiment in VR?

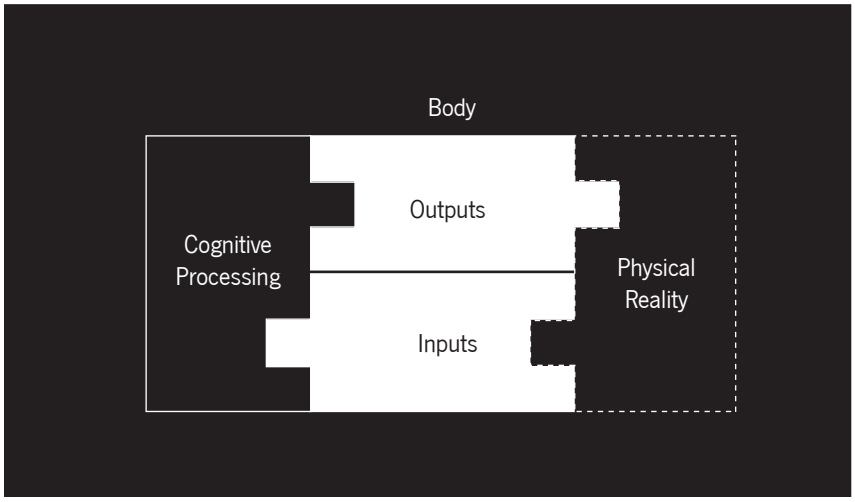
Narratives around embodiment in VR use to fall into assumptions like when users jumps into VR they enter into a fantasy land which is completely divorced from our physical body. Creating like a huge separation between these two things. Those assumptions are considered as a false dichotomy for the present dissertation. Our physical bodies are the thing that anchors us into the world, regardless of which world we are in. We need to acknowledge the limitations of our body from a cognitive point of view to create deeper translational experiences.

This work wants to propose a more moderate model where the body acts as the core of the interface that interacts with an specific world.

The body is understood as “hardware”. Is our physical interface between our cognition and the different realities. Always present, receives inputs from his sensory system and bring them to our cognitive processing part. This part is considered as “software”, and is the responsible to operate the inputs that receives and generate an output. Here is also where the task of decide where are ourselves resides. Taking into account phenomenology, a change in the type of input can generate changes in the way we understand things. So, in the absence of a VR system (Figure 14) we are receiving inputs from the physical reality and sending outputs that are interacting with this one. In this case, our entity under control coincides with our body.

But when a VR system is attached to our body (Figure 15), our senses inputs and our interactions outputs are manipulated by this one. Moving our cognition into thinking in virtual terms, and accepting in this way the embodiment of the other entity that is being offered by the computer. Depending the equipment, the body will be isolated from the physical reality to a greater or lower degree. In this way, VR is able to bypass the body to a certain range for make us partially forget about our body and the position of it relative to the physical space, but by any means, body will be always present.





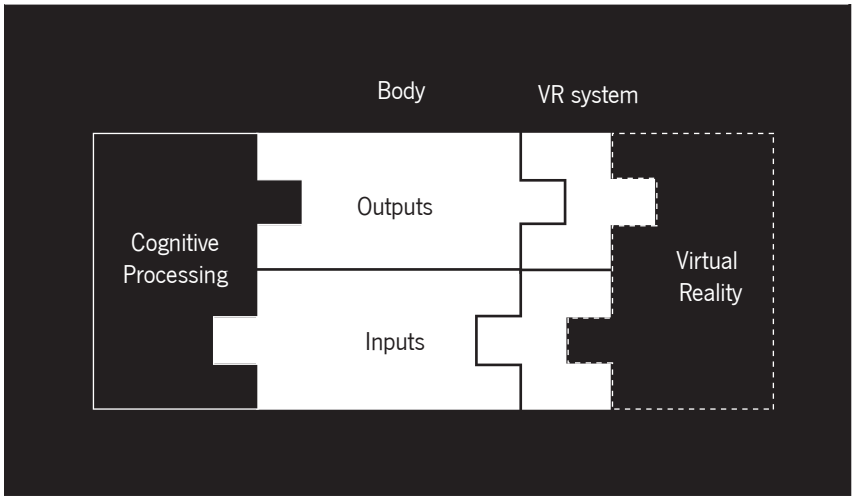


Figure13 Graphic exposing and categorizing the different pieces that shapes perception.

Figure14 Graphic exposing the pieces that are connected in the absence of a VR system.

Figure15 Graphic showing the how perception is formed when we are exposed to VR.

Case studies in VR?

Along the existence of VR, various studies have been conducted to research about the dislocation of ourselves.

Some examples that show this are experiences such as The machine to be another, created by BeAnotherLab team. Its goal is to explore the psychological consequences of experiencing oneself from a different body. Based on this system, they created the gender swap installation. On it two users of different genres place the headset on their heads, from that moment they are visualizing the point of view of the other person. By executing slowly moves synchronously (that they are proposing and following without words constantly through the experience), they start to feel in like owners of the other body. In addition, the experience's conductors appears sometimes during the process to stimulate participants in different ways simultaneously, creating in this way a stronger translation effect between them, in the same way the rubber hand experiment used the brush.

But in addition to those experiences that are seeking to make our brain feel into another body, there are others that are able to induce an out of body sense. This is the case with the experience *Outrespectre.* Designed by Frank Kolkman, and as part of a collaboration between Waag Society's Creative Care Lab, Makerversity Amsterdam and Museum Vrolik. This experience tried to deal with existential death anxiety by inducing an out-of-body feeling to the user, since this use to be a common sense that people report when nearly die. The system works by dislocating user's point of view and hearing with a pair of cameras and microphones that are inside a head shaped case. At the start the system moves away from the user, trying to mimic that sense of being expelled from your body. After that, the user is able to see himself in real-time from behind, in such an immersive way that wasn't possible before. After spending sometime hearing and seeing from another point of view, the artificial head comes back to the back of the user, trying to give the impression of return to the body.

Accepting entities by training ?

Until now, those examples have not required any adaptation period from the user. All of them were designed for being easily understood and accepted by the brain. But there are also examples that shows the plasticity of the brain to being embodied in less natural entities.

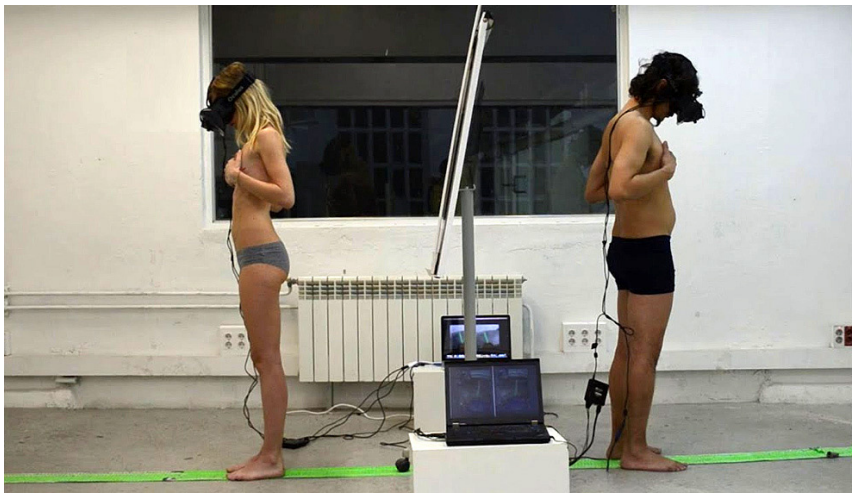


Figure16 Picture showing the machine to be another in use. Extracted from a video available on: beanotherlab.org

Figure17 Picture featuring one of the moments during the experience where conductors stimulates both subjects at the same time. Extracted from a video available on: beanotherlab.org

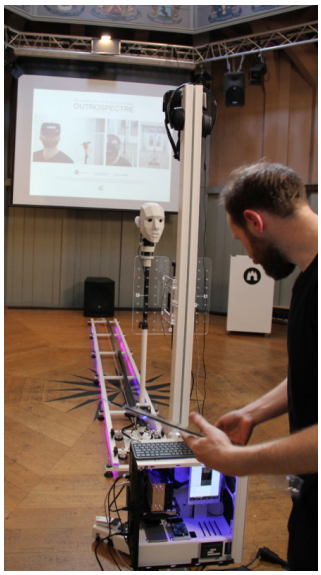


Figure18 Pictures showing the experience Outspectre. Extracted from: thenextweb.com

In order to test this, a short experiment was conducted for this research. The question was: Could a person laying down be able to feel inside an entity that is standing up?. For the setup, the headset Meta Quest 2 was used connected wirelessly to a pc by the app Virtual Desktop. Using the software WalkinVR (available on Steam) it was possible to offset the point of view 90 degrees and the angle of the controllers for being controlling any app on VR laying down as if the user was standing up. This without any doubts was perfect scenario for VR sickness, a sense of dizziness generated by the disconnection between what the body feels and what the user sees. In this case the individual having the experience had already been exposed to worst situations in VR like low framerates, so he was able to handle it. The app was a game called Boneworks, in which at the beginning it can be found an introductory area to the game, where the user starts to move and interact with some objects. At first was a totally confusing and uncomfortable experience. But during the 40 minutes that the user was just in this introductory area, it was evident a noticeable change between the first minutes and the last moments. At first even simple tasks as throw a cup was impossible, but in the end he even started to move very naturally. He didn't reach the point of forgetting that was laying down, but when he finished and took the headset off he experienced a bit of dizziness standing up. After some minutes he was totally fine. So answering the initial question, the answer would be yes, but definitely not immediately, since some time for adaptation is needed, as we are very familiarized to our way to interact with the world from our physical body interface. Trained doctors that are able to use the machine DaVinci (Figure 21) for surgery could show us how we can feel totally immersed into non-human embodiments.

In conclusion, this chapter wants to stablish some basis regarding what can be the subject in VR. As it has been showed, there is effectively infinite forms of embodiment, the limitations are what the computer is able to generate/simulate and what our cognitive system ends accepting as ourselves. This statement wants to raise awareness about having into account questions like Who are we designing for in VR?, Since designing a space has to have in mind the characteristics of the inhabitant. We are dealing now with a more plural and sophisticated definition of what a human is.

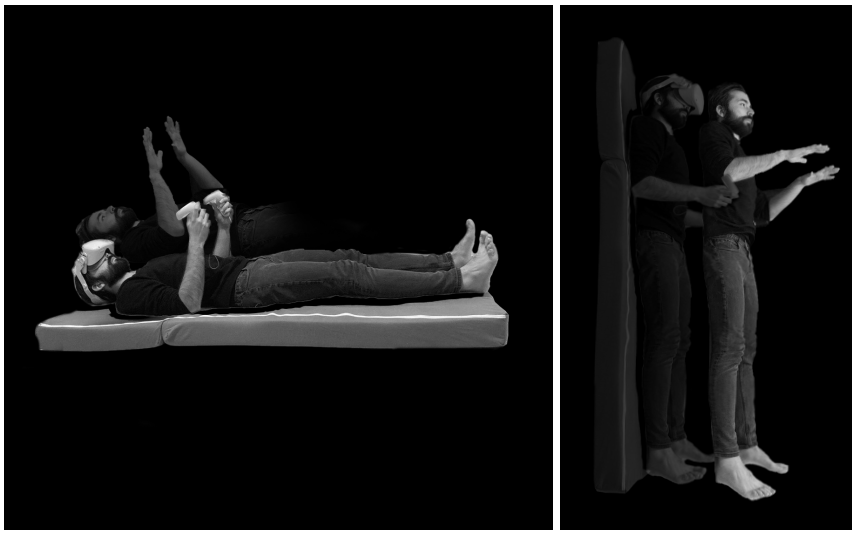


Figure19 Picture montage showing the transposition that the user was experimenting. On the left side how he was oriented in the physical reality, on the right side how was in virtual reality.

Figure20 Screenshot from the virtual reality game *Boneworks* being in the introductory area.

Figure21 Picture of the machine for surgery DaVinci. Extracted from: robocatz.com

REALITY

Interact through VR could help us expand our knowledge about reality and ourselves

"Seventh VR Definition: A coarser, simulated reality fosters appreciation of the depth of physical reality in comparison. As VR progresses in the future, human perception will be nurtured by it and will learn to find ever more depth in physical reality." (Lanier 2017)

When people talk about VR, they often fall into terms such as escapism, alternative and isolation. Terms with a certain negative connotation and that puts away VR from the physical. What this chapter wants to state is rather than being separating physical and virtual, we should start to think into interlinking terms, since from this junction we could expand our knowledge in both ways. Start thinking about VR as a new way to experience reality, not as a way to escape from it.

How tools could expand our knowledge?

Is known that VR can be a powerful tool that makes you feel transferred to another location , but it could also be a powerful tool to better understand physical reality. For example, in the early days of science, the apparition of the microscope gave us the possibility of visualize structures and types of life that have been always present, but we didn't have an instrument to perceive them . This discovery changed our understanding of the physical world and expanded our knowledge about it. VR, in the same way, can expand our knowledge about the physical world, but only if we treat it as a tool able to do that.

We are used to know how things react in the physical world, since we are already familiarized with it after being exposed to those events for a long time. We can predict how a ball will bounce, how a cube will change in shape depending on the point of view...But we lack familiarity with things that are not possible in our physical reality like forces that reacts in unnatural ways or geometry that is being generated in more than 3 dimensions. But a VR system could act as the glass that allows us to enter in those computational mathematical simulations.

Impossible experiences otherwise?

An example of this would be the software/game 4D Toys, created by Marc ten Bosch. This application born from an underlying research project of his creator that wanted to create a rigid body dynamics that was independent from the dimension of the space. As a result, he created an app for ios devices and for PC that allows to interact with 4D dimensional objects. Inarguably his best implementation is the one for PC VR, since allows user to interact with their hands on a 3D space that is showing a 3 dimensional section of a 4 dimensional space. Making possible to tinker with geometry impossible to generate on a physical space like a tesseract.

Figure22 Screenshot from the game *4DToys* introductory explanation.

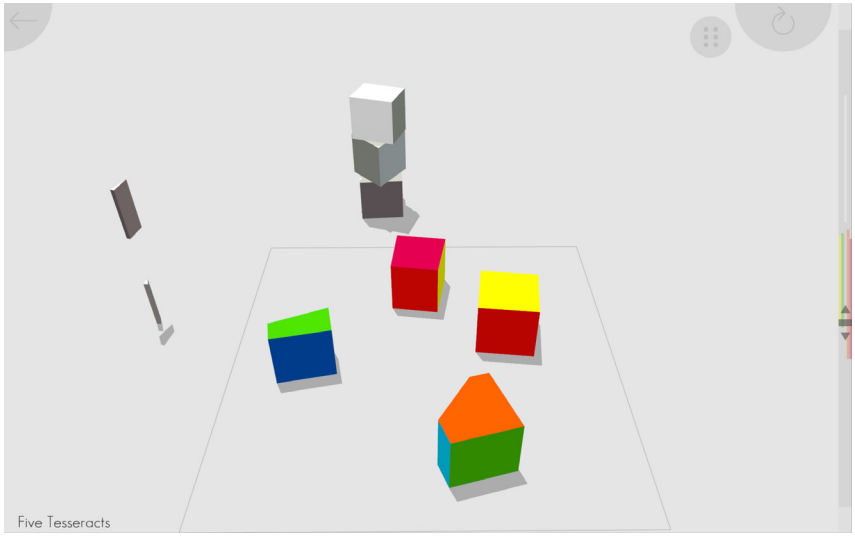


Figure23 Screenshot of 5 tesseracts in *4DToys*. As this is a 3D cut of a 4D space, there is one of the tesseracts that is not even visible because it is outside the 3D cut.

Another example that shows how a well designed VR experience can leave an strong impression in a subject is the project Aemula Naturae, by 18—25 Research Studio for Architectural Visualization. Aemula naturae is defined by his creators as an oneiric machine that builds spatial realities. Is conceived as an individual experience where 4 portals are opened up with totally unique realities in front of the eyes of just the explorer. From this point, the explorer has to make a decision, and choose one of the portals to step in. Once the individual enter in a reality, the other ones disappear, and such in life, there is no way to undo that decision that explorer took. The chosen reality is photographed and storage on the internet via the instagram account @aemula_naturae. The rest of realities will reside just in the mind of the individual that was able to take a glimpse of them. This experience shows how designing with the unique characteristics of VR in mind could lead to cause deep impact on subjects. Making that something that a user experience in VR does not leave/disappear when is taken out from VR.

Rediscovering ourselves after changing entities?

The sensation of still being affected after a period of time exposed to VR is surprisingly common. Although there is no big enough polls on this respect, a quick search on Google of terms such as “reality dissociation after being in VR” or “hand dissociation after VR” shows that lots of people have those experiences in their firsts weeks in contact with VR.

For lots of them, it will be just a funny/scary temporal trip, for others it might be the first step into questioning who are themselves. This dialogue between the virtual and the physical is what makes VR such a useful tool for researching what a human being is. Being able to contrast is what could help us to isolate and study the pieces that make ourselves, that defines our identity.

Questions like genre, sexual orientation, physical ethnic aspects... Are we going to bring those labels that were born in the physical to the virtual? Or are we going to reformulate or even vanish them when it comes to being inside VR?.

Just the act of being asking us those questions shows the potential for contrasting realities to enriching us.

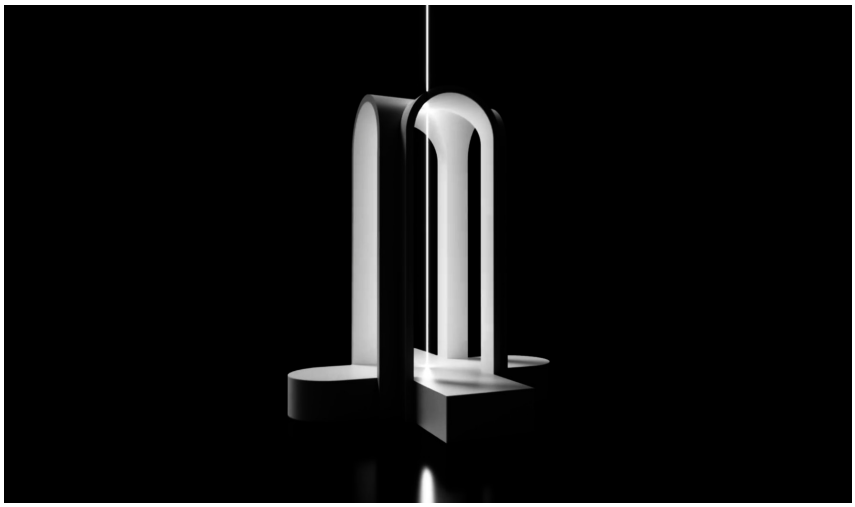


Figure24 Picture showing the portal in the experience *Aemula Naturae* . Extractred from: 1825.pt

Figure25 Screenshot from the instagram feed of the account @aemula_naturae showing a few of the thousand of worlds that were chosen by their explorers

Figure26 Picture showing the experience from the outside. Extracted from the instagram account @1825_studio.

More points of view about physical reality?

Going back to knowing about physical reality, although VR is not able to replicate the complexity of what is experience in physical reality (and presumably never would be), VR can be used as a media for being immersed in physical places that will be too dangerous for being in otherwise. By the use of photogrammetry, we are able to take an spacial snapshot of a place in an specific moment, and from this geometric info that have been virtualized, create consumer oriented experiences to bring those spaces to people. For instance, located in Pulpí (Andalusia) Spain, exist a geode about 8 metres long by 2 metres high (the second biggest one discovered until now) covered with enormous gypsum crystals. At first, it was not accessible to the public for conservation reasons and because it lacked any kind of infrastructure to embrace visitors. So, a recreation in VR was made while it was being conditioned. The range of visitor emotions ranged from perplexed to terrified(since some of them suffered claustrophobia).

But apart from being used for just visualisation, it can also be used to generate narratives that raise awareness of problems present in physical reality. Promoted by the initiative *VR for good* from Oculus, and directed by Celine Tricart, *The key* is a metaphorical journey until his revelation in the end. On his performance at the Tribeca Film Festival, the visitors entered in a misty room alone with a woman wearing a tunic with a large key on his hand. The user is already wearing a neckband speaker that is narrating the introduction, and while the mysterious woman helps you to put on the headset the subject realises how visuals ant sound are synced in order to ease the process of starting to be immersed. The narrator, called Anna, is telling you that she doesn't remember about her childhood, but keep having dreams about it, and that she is collecting those dreams in the place where you are. Also, she mentions that there is always a key present on those dreams that doesn't remember where it comes from, and she ask you to help her. In the beginning of the search, you are in colourful scenario and 3 floating balls with different personalities are introduced to you as your friends. Suddenly a storms comes, and you will be able to just keep two of them with your hands, losing one of them inevitably. From this point on, the dream scenarios will lose colour and your friends will be taken away from you one by one without being able to do anything about it, until you reach your lowest point being in a scenario underwater. (Figure 30). Here, a mermaid comes to you with an oxygen

Figure27 Screenshot from the VR experience of the geode of Pulpí. Extracted from the youtube channel: Joaquín Ruipérez

Figure28 Screenshot of the VR experience *The key.* This is the moment when one of your friends is taken out of you, since you just can keep two of them with your hands.

Figure29 Screenshot of the VR experience *The Key* showing one of the following scenes where most of the colours have already gone.

bubble, and suddenly, Anna says that remembers where the key comes from and what it opens. She recognises that was a truth she locked away, but was ready to talk about it. A key appear in the hand of the user, and puts it in the lock in front. Here is when the revelation happens.

The user is taken out from those previous dream scenarios and appear in the interior of a destroyed house. This is where Anna comes from, and this is what she can't come back, she is a refugee.

The meaning of the key concealed a reality for many refugees, since most of them continue to keep the key that opens the door to something that once was their home. Even if they will never go back.

The vision of the director was build the metaphors from the moments that refugees share with her. Refugees locking their memories as a survival mechanism, your belongings being taken from you...

When visitors took the headset off, the woman that was at the start in the room give them a physical key, being an object that from that point, will remind them this experience that they have lived.

In conclusion

We have seen in various fictional books how when artefacts/substances that allow us to change our reality are used with an escapism purpose in mind could lean us to situations in which we fall into one of them, evading in this way confrontations with the realities that we don't want to experience. Thereby avoiding the chance of improve those ones.

"Use VR just as an escapism tool would be one of the biggest mistakes we could ever make. VR should be enjoyed as one of life's treats, but not as an alternative to life" (Lanier 2017).

As it have been shown in this chapter, enrich our knowledge through the dialogue between physical and digital, familiar and unfamiliar, human and virtual embodiments...In short, through the contrast that we experience when the VR system is on and off is the path that we should keep exploring, and not being ignoring realities or creating isolation shelters.

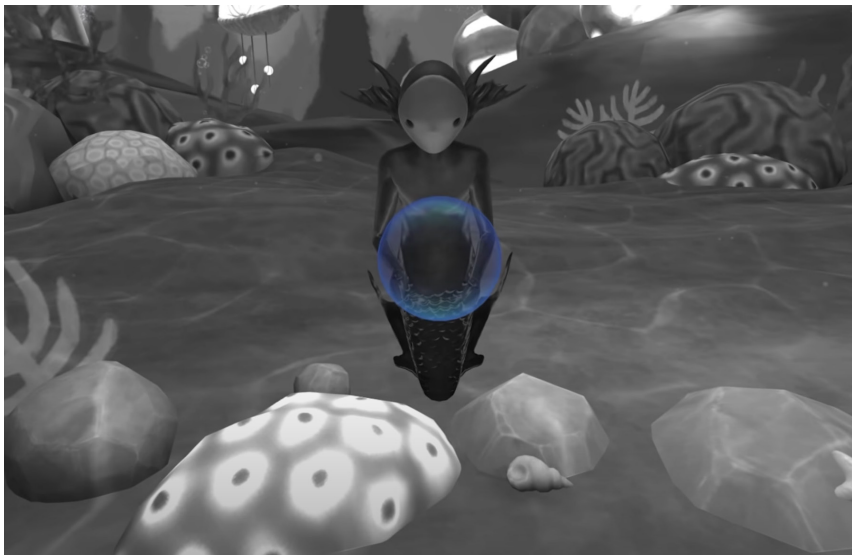


Figure30 This figure and the following one are screenshots of the VR experience *The Key.* This one is showing the moment when the mermaid comes to give you an oxygen bubble. A metaphoric way to represent those that comes and give you a hand to confront your fears.

Figure31 This screenshot is showing the moment of the revelation, when the user realise that it was experiencing emotions that to a certain degree empathised with refugees.

Figure32 Photo of Celine Tricart holding one of the keys that were given to participants. Extracted from: cnet.com

Education

The increasingly adoption of new technologies has undeniably change education in the field of architecture.

Although two-dimensional representations made in CAD software are largely accepted and 3D computer representations start to have more intentional uses in conjunction with other medias in architecture's education, VR applications, offering interactivity and the possibility of being immersed in a space, are not yet widely adopted. Partly because the high cost of implementation and partly because a lack of awareness about their possibilities on the educator's side.

As virtual reality technology continues to rapidly evolve and overcome those constraints, it opens up new possibilities for learning. While there is excitement about its potential, it is important to remember that VR is just a tool, and tools by themselves do not represent knowledge. The effectiveness on education of this tool depends on how educators implement it, and only then it can be a powerful part of an overall educational strategy.

This chapter about education will offer an overview about some of the potential that resides in VR as complementary tool for educators and for space representation. By any means it will try to create a fixed framework about how VR should be implemented in education, since such a proposal would be outside the scope of this work.

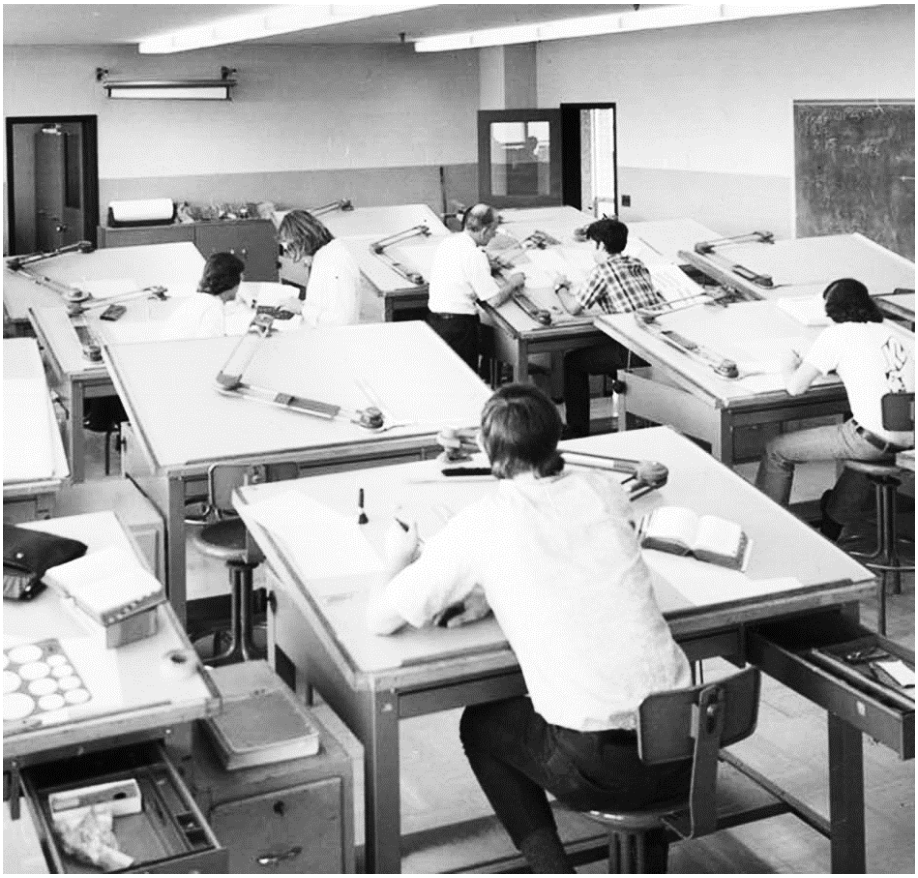


Figure33 A drafting class in the early 1970s. Source: rarehistoricalphotos.com

EDUCATION

Teachers will use VR as an additional tool for their explanations

Studying the correct and applicable use of virtual reality is a challenge beyond the scope of this dissertation. Therefore, this section will not try to propose a closed framework of how VR should be used educating in architecture, but will be focussed on indicating potential directions that educators may follow.

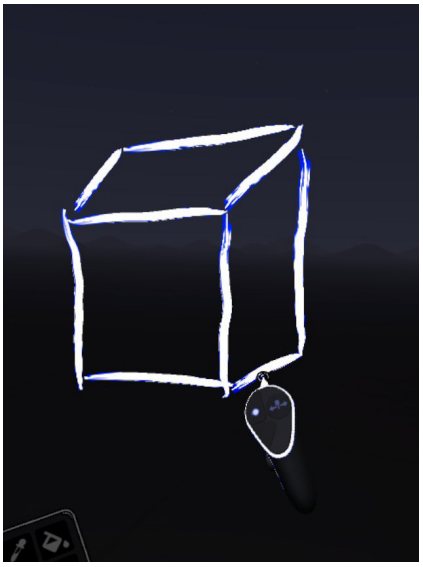
The ultimate tool for understanding architecture?

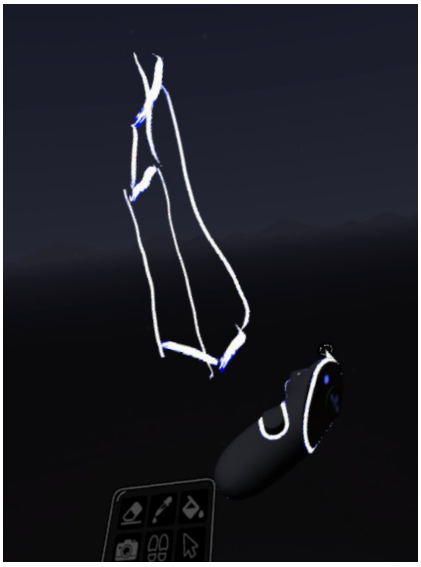
When it comes to VR, is easy to fall into assumptions like believe that it is the definitive tool to understand space. But one thing that this chapter would like to state is that the process of understanding architecture is not going to be easier because of VR.

Education is part of a formative process highly linked to someone who accompanies you in the process. VR can be an incredible tool for understanding, but if the apprentice is not guided by someone, if there is no a figure who have a clear structure of thought and is able to bring to the learner the contents in a synthesized and effective way, the transmission of knowledge will not occur.

A revolution in education is not going to happen because students and teachers have their VR headsets on. VR is not a magical portal that immediately give learners access to knowledge, in fact it does not guarantee that the user will understand more easily what learners needs to understand. It is an instrument that in the good hands of someone who has interest in making knowledge reachable to their students, has the potential of being a powerful teaching instrument, but its potential is on the hands of who is teaching or designing an educational experience, not in the tool.

As a quick example, in the process of this research there was a day that 2 individuals without any background in spatial knowledge were exposed to a VR drawing app called MultiBrush. The individuals were asked to draw a cube, and the result is what appears on figure 35.





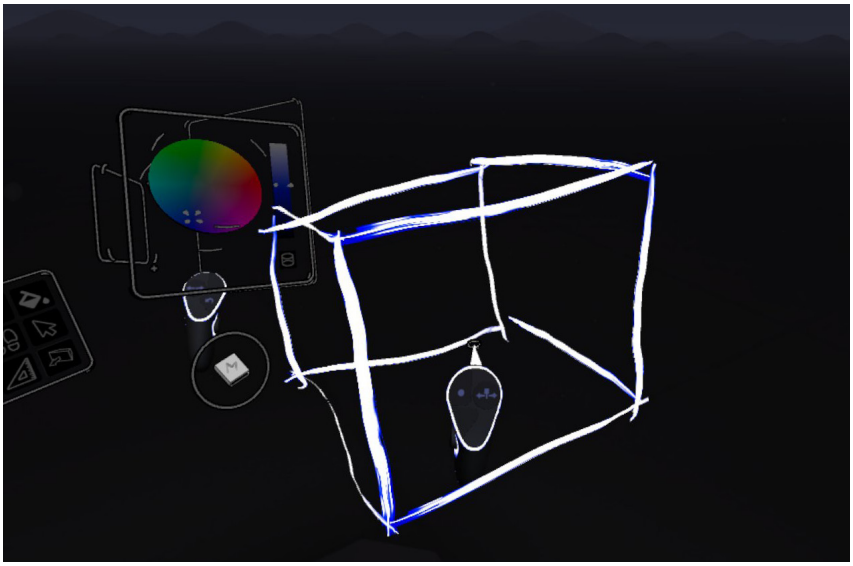


Figure34 This figure and the following ones are screenshots from the app *Multibrush*. In this one, it can be seen some of the tools.

Figure35 A screenshot showing the result when I asked them to draw a cube. Even being having the chance of drawing in the air in three dimensions, they did a planar projection.

Figure36 A picture of the result that was expected given that prompt.

The tool does not teach

They both draw a two-dimensional projection of a cube in something close to a cavalier perspective. When I asked them why they represent in that way a cube, they answered that basically it was the only way that they have been taught when it comes to interpret a cube and represent it.

It could be argued that the lack of familiarity with the medium played an important role, but they were previously left some minutes for begin to get familiarized with the control scheme, user interface and the possibilities of that app (Figure 34). They were completely aware about the interactions as being able to draw in a 3 dimensional space.

A larger sample size is necessary to reach stronger conclusions, but this short test could be used as an example of how VR is not a magical key that bring access to knowledge and to think in spatial terms. Even having a tool in their hands to draw in a three-dimensional space, they were lost when it came to think and interact in those dimensions. This brings to surface the important role of an educator.

Having a supportive educator that believes in the potential of VR and research actively about how VR should be used is what could build a supportive educational path where VR could be an additional tool to increase the comprehension of students.

Potential directions when embracing VR

Having all of this into account, some potential ways of using VR as an additional instrument for educators are:

- Another media of communication between teacher and student.
Taking as a basis the Shannon-Weaver model of communication (1941) for architecture, we have seen until now how teachers have been using as a channel to transmit their knowledge objects like models, drawings, photos... Each one used it with specific goals in mind, like use a synthetic physical models to identify the volumetric relation of a building with his context without the noise that would produce having more details in a photo or offering clearer point of view that being on site. VR has to be explored as a new channel where sender and receiver are connected not just trough a digital system, but inside the system. Once inside, the sender can choose a huge variety of ways of encoding his information for

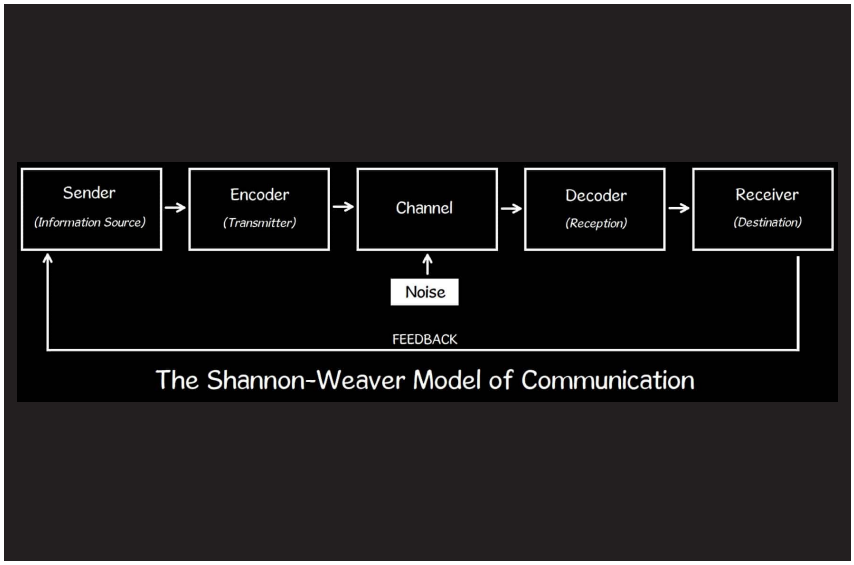


Figure37 Graphic showing The shannon-Weaver Model of Communication. Extracted from: helpfulprofessor.com

Figure38 A screenshot of VRSketch showing their capabilites for educating.

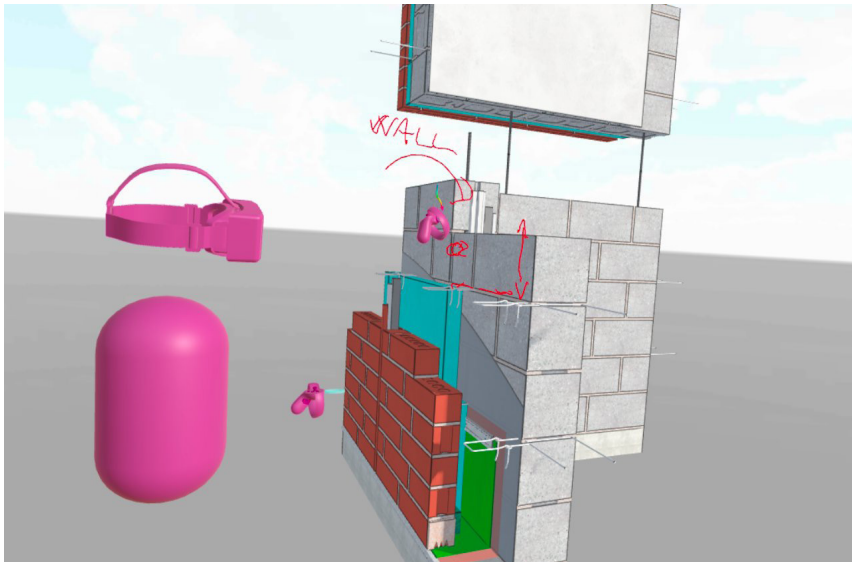


Figure39 A screenshot of VRSketch showing their capabilites for make annotations in the air.

the transmission.
Encode the information in similar ways of how they are being in the physical counterpart is the easiest though that first come to mind. That's why we are seeing things like expositions of virtual models through VR. But presumably, new creative ways will surge, like models that are not static and can be sectioned or that can show a building in different stages.

- Bring different individuals to a same environment without the need of being physically present. Since individual virtual reality systems can be connected to the internet, teachers and learners, either at a different or the same geographical location, are able to interact together in a shared virtual space. If the educational experience is properly designed, will without any doubt produce a collaborative and active learning that could be more engaging that current media for remote education.

- Learning by doing. VR has already been widely used in other disciplines such as engineering, surgery and pilot training. These have proven their effectiveness in learning-by-doing in virtual environments. Thanks to this technology, these professionals can train without risking any lives and in a more cost-effective way. When it comes to architecture, this could be useful to immerse students into the construction process. In this way, they could be more aware about different things, like the coordination needed between different agents to confront some tasks or raise the awareness about the importance of thinking in the order of the various building phases.

- Learning by simulating. As the augmented reality experience *graspit* shows (Figure 41), VR could be an interesting tool to interact with abstract models that simulates the behaviour of architectural objects.

There have been topics that have not been explored in depth, such as the use of VR in the design process or its potential for representing space, but that is because they will be explored in more depth in the next sections.

In sum,these are some of the directions that educators should preferably follow to achieve an effective implementation of VR in education. Never forgetting that the tool does not replace their labour.

Figure40 Other industries have been using VR as a training tool. In the picture the VR experience *Spine Days VR* by the studio Numena. Extracted from: numena.de

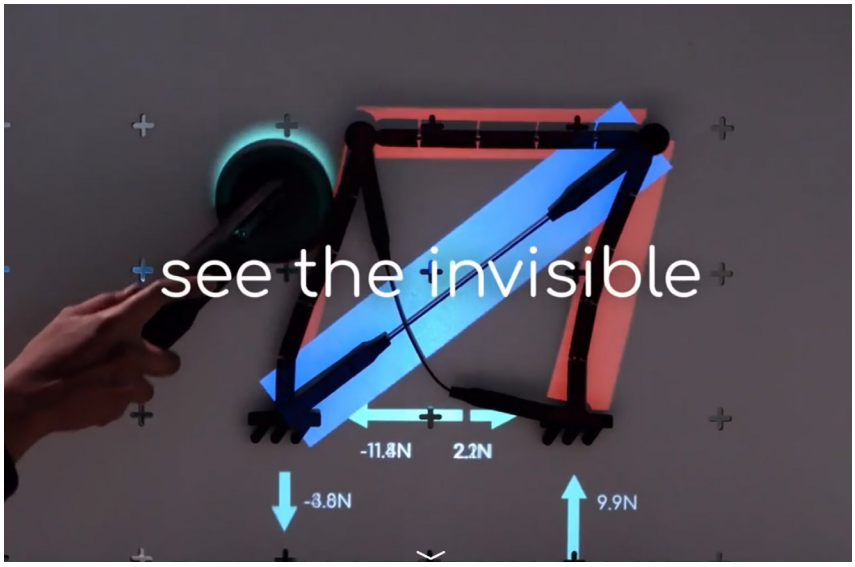


Figure41 A picture showing the augmented reality compatibilities of *graspit*. Extracted from: grasp.it

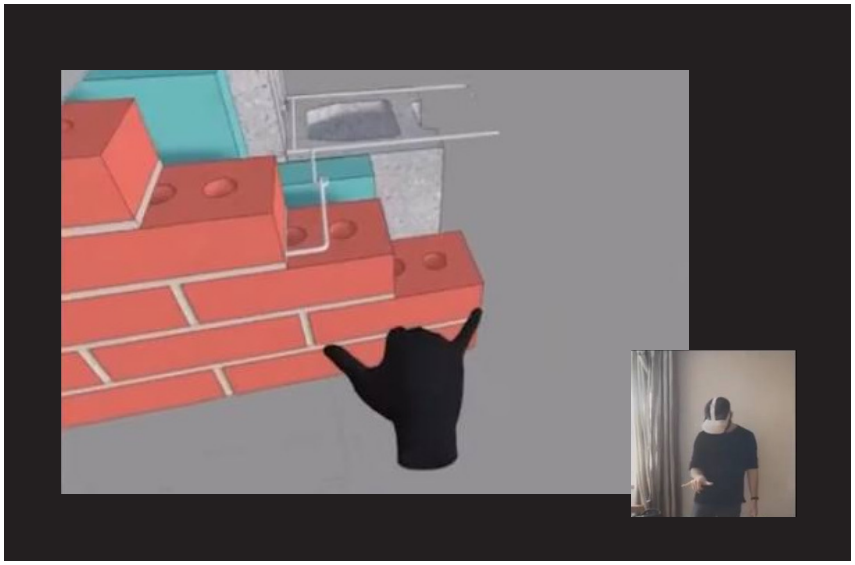


Figure42 A screenshot showing the interaction inside VRSketch with a construction detail.

EDUCATION

VR will be an additional media to represent and visualize space in different ways

Architecture is a discipline that is strongly dependent on the different ways of representation since It is difficult to always be able to count on the appreciation of the a building on its true scale.

Representation not only arises from this need, but also acts as a filter to focus attention on learning a particular things, as Alessi suggested about how the level of fidelity affects learning, simplify the complexity of a simulated problem will produce better learning for a novice learner than a high fidelity simulation. (Alessi 1988)

In this way, planar representations made from vertical and horizontal sections, models, hand-drawn or computerised perspectives and pictures form part of the compendium of media through which the educators have been carrying out their explanations. All this accompanied, whenever possible, by physically guided visits to the buildings.

VR will most likely not arrive to the classrooms with the intention of eliminating any of the aforementioned media, it will simply be one more medium. As highlighted in the previous chapter, it will not revolutionise the way we learn about space. What VR can do is provide a different perspective to the ones we have been using to understand space and, consequently, increase understanding of space.

A new blank canvas

A blank canvas is capable of containing different ways of representing a space. It could be drawn in a mathematically correct perspective with its vanishing points, or could be a series of plans, even the essence of a space could be extracted by creating an abstraction...

Likewise, VR is a blank canvas, where different methods can be followed to translate and represent architecture through this tool (these methods will be explored in the next section). Is a medium that accepts different levels of fidelity in representing architecture, from attempting to mimic physical architecture to more abstract representations.

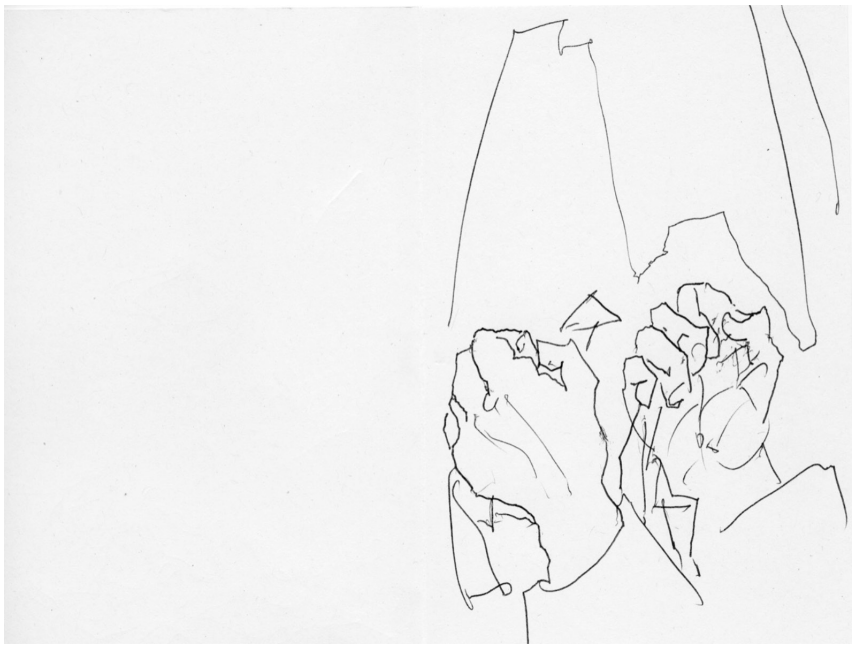


Figure43 Illustration by Álvaro Siza. Extracted from: archdaily.com

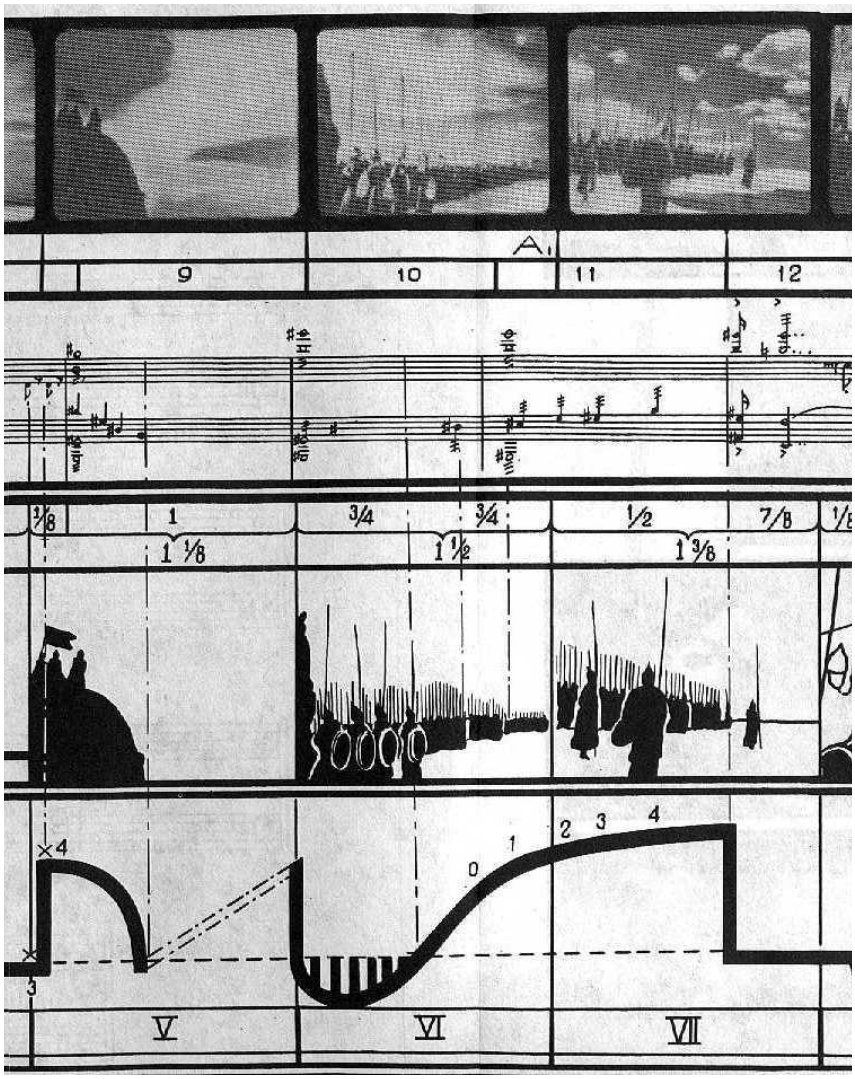


Figure44 Sergei Eisenstein. Diagram of a sequence from his film Alexander Nevsky (1938). Extracted from socks-studio.com

With this in mind, this chapter will take a look at the different examples that show the possibilities and characteristics of VR representing space.

Capturing and representing the physical

The first is one of the most common uses at the moment, using VR to represent a physical existing building in order to immerse students into architecture from all over the world. To capture the physical there is different options. The simplest approach would be to collect different 360 degrees pictures with a special type of cameras (Figure 45). Examples of this type of implementation would be the initiative Google Arts & Culture, which collects a series of places like museums or temporal exhibitions and give free access to the public on internet. Architectonic events like various serpentine galleries or a tour through iconic buildings made by Frank Gehry are examples of some of the contents available. However, this way of representing architecture has one major disadvantage, the lack of six degrees of freedom (6DOF), this means that users are limited to experience the space from the point of view that was captured, they can only rotate their heads, but not walk forward or crouch. In addition, this way of representation does not allow to have co-presence with other agents in real time. On the other hand, capture a place through the use of photogrammetry does not have those drawbacks. A good example would be the app for Meta Quest *OtherSight* , developed by Raiz Media. In this app, users can explore locations such as a Street in Tokyo or Sorolla's painting Studio. Unlike in the previous case, navigating a 3D model that was made using photogrammetry technique is possible with total freedom. Even interaction with objects and the inclusion of other agents (like some guides that are present in this experience) is something that can be made out of this. The inconveniences that could be found with this way of representation are that the geometry generated by photogrammetry is highly demanding on hardware, so it has to be optimised. Lastly, another software that deserves a mention when it comes to represent the physical world is Google Earth VR. Compared to his counterpart for 2D screens, Google Earth VR provides the possibility of seeing parts of the world from an aerial point of view with a high sense of immersion and scale. It can be at a reduced model-like scale or at a 1:1. In sum, when it comes to represent physical reality, VR has demonstrated a certain level of solvency and that brings value when it comes to represent already existent architecture. But, those are not the only way of representing space...

Figure45 Different types of 360 degree cameras. Extracted from: roadtovr.com

Figure46 Screenshot from the application *OtherSight* showing a tour through a street in Japan.

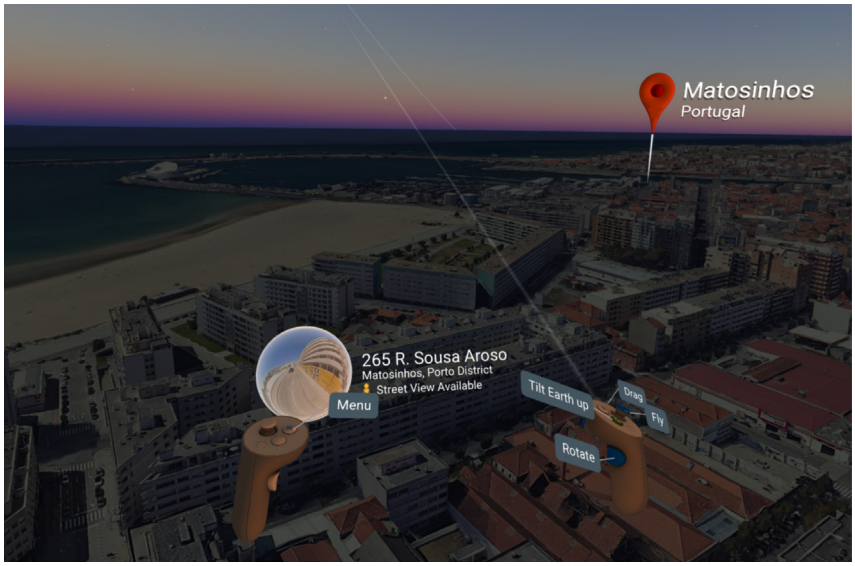


Figure47 Screenshot from Google Earth VR, it gives a totally new and immersive experience in comparison with his plain counterpart.

Bringing the mental building to tangible bytes

Representation has always been involved in the process of transmitting the mental building to others. Necessary for the design process, taking what a subject is thinking and communicating it to others without actually building it is a fundamental step.

Plans can show the organizational logic behind the design, perspective drawings allow us to see some points of view, models enable us to check volumetric relations at a reduced scale... What is the value of VR into representing unbuilt architecture?

VR can create a very immersive experience that can help teachers and learners to understand a design proposal in a much more intuitive way. VR allows to explore a designed space and understand how it feels to be there (to a certain degree). In comparison with other media, scale and co-presence is present, so students and educators are able to discuss being inside the space. There is different ways to achieve this. The most usual is to bring a 3D model made in some already well established CAD software such as Revit, Sketchup, Archicad... To another software specialised in the part of visualization with VR compatibility, like Twinmotion or Enscape. If for any reason the student/educator wants to have more control over things like adjusting visuals or creating unique interactions they will have to use software that allows for deeper control like Unity or Unreal engine, the most known games engines nowadays. Those allows the user to have a more granular control over the behaviour of light, materials and objects.

New perspectives

This level of control also means that a VR architectural representation does not always have to seek to be as close as possible to what is finally built. It can be used to create abstract, non-realistic or agreed upon visions of a space, visualize data about a building immersed, make the walls behave as clay... As it was said in the start, VR is a canvas, so creators are able to represent architecture with the same freedom as an artist with a paintbrush. Nowadays those kind of representation are not that common, but that is a clear signal of the lack of adoption and mastery that have been to this date on the architects side. Presumably, when this technology reaches the hands of more creative minds, we will begin to see architectural representations that are only possible through VR.

Figure48 Screenshot of the software Enscape on his VR interface. Even being in VR it keeps some of the interactions like change the time of the day. Extracted from enscape3d.com

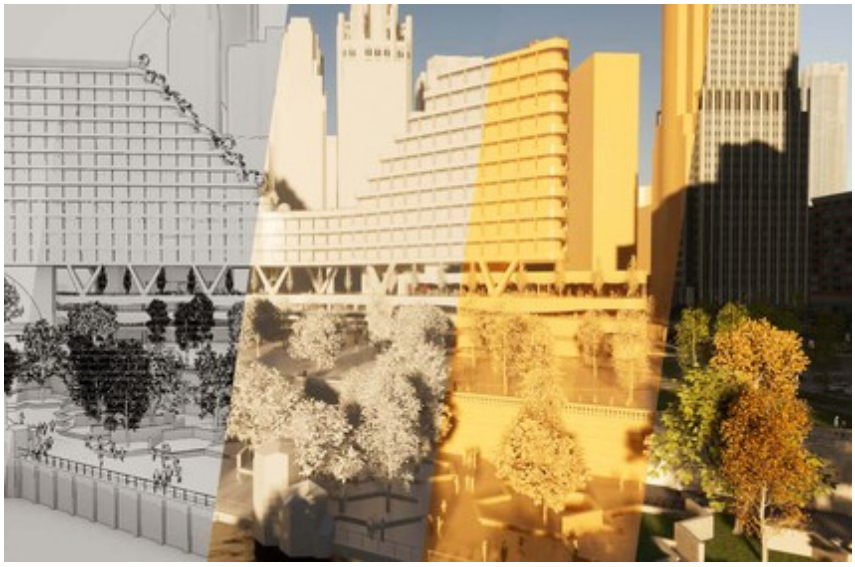


Figure49 Picture showing different styles of representation available in Twinmotion. Extracted from: twinmotion.com

Design

When architects confront the task of designing space, they are not only deciding what feelings want to achieve, but also how to achieve them.

The question about the close relation between the designing process and the tools is always being revisited. Until which point the tool influence the process and the final output?

Zaha Hadid, for example, used to expressed her architectural intentions through paintings in the early stages of design, as it was a tool that allowed her to express her thoughts with rich expressiveness. Then, those intentions were further developed through other different media like models and computer aid drawings. It would difficult to deny that the final building wasn't influence by the tools and process that were involved in his development.

This begs the question, with the advent of VR, can we expect changes in the design process?. It would be tempting to position VR next to the current CAD software that we use on a 2D screen, but that would be wrong assumption. VR brings his own language and expressiveness, and things such as immersion and remote collaboration are game changers.

Nevertheless, VR brings such a range of possibilities when it comes to designing, that in conjunction with all the previous mentioned, it can even make us question our role as architectural designers.

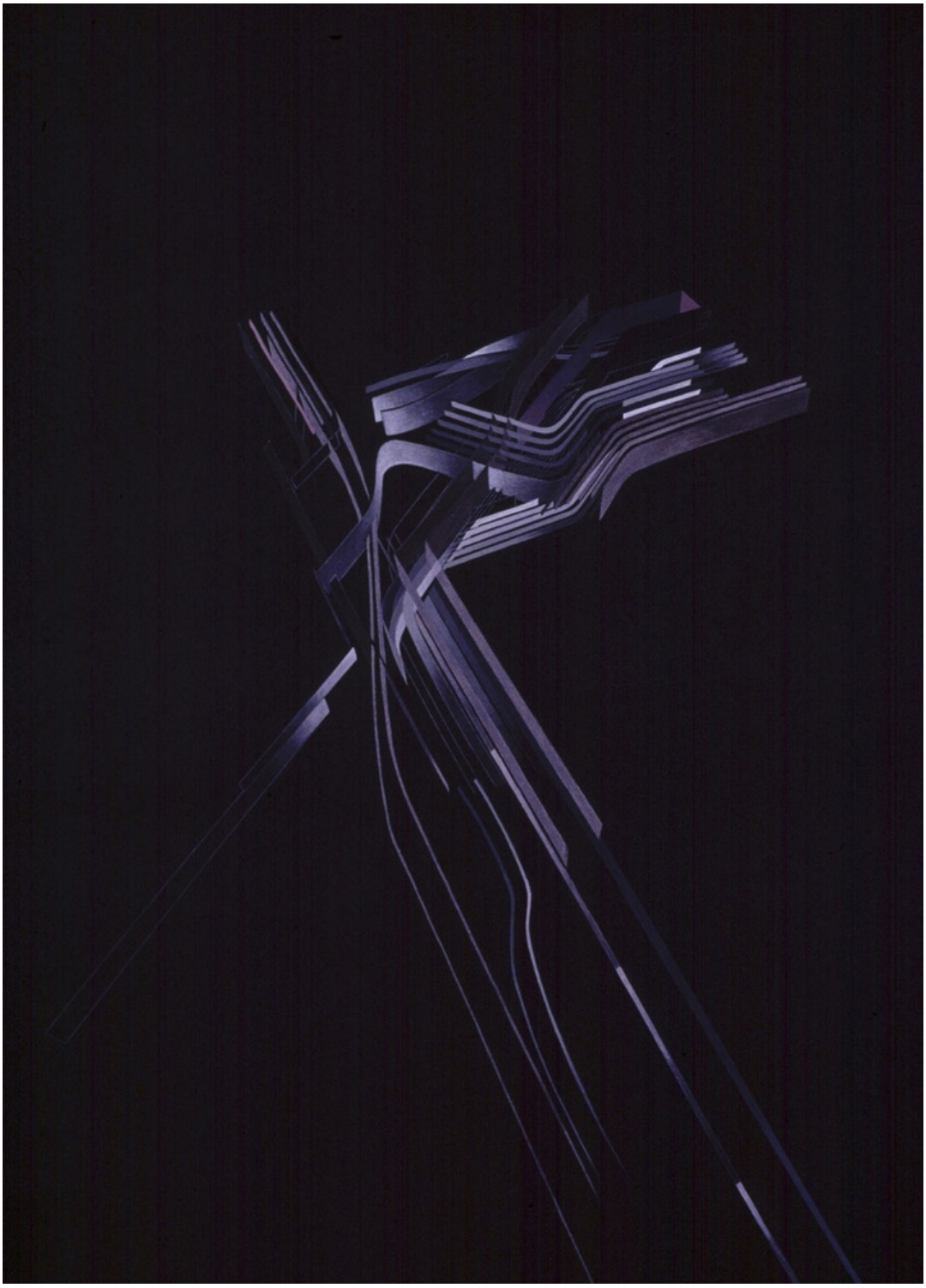


Figure50 *MAXXI Museum.* Painting by Zaha Hadid

DESIGN

Architects will enter on VR for designing

Digital tools and creativity

The way technology is changing the architect's workspace is having a large impact on the design process. Design studies are evolving in order to keep up, and the overall efficiency of the design process is improving. Despite this, there are still many ways in which productivity and creativity in architectural design can be increased regarding digital tools. Being able to efficiently develop projects on digital media is extremely convenient, but the tools we use should also help us to improve our design at every stage of the process, including the earlier stages of design, where digital media does not usually have a good reputation.

When creating representations of our ideas during the early design phase, it is important that we are able to read more information from them than what was originally put in (Goldschmidt 2003). This is something that should be taken into account when designing digital tools for early design.

However, many of the computer-aided drawing software programs that are currently in use do not allow for this type of behaviour, or else limit it in some way. That sense of wonder that occurs when a designers are using physical tools as a pen, a brush to make a watercolour painting, a model that is being cut and assembled piece by piece...All those process leave space to improvisation, to have "happy accidents", in sum, for wondering and expand our thoughts beyond.

VR, finding the digital expressiveness

In this regard, VR could potentially provide a way for architects to experiment with their designs in a more intuitive way in the digital media. VR use to be treated as a medium mostly concerned with content consumption of things that were made in well-established software in the production pipeline of architects, and then reviewing them inside VR. This is also a useful use of VR in the design process, but this question will be developed later on in this chapter. Nowadays, tools like Sketchup or Rhino are being used to create 3D models in early stages ,however, these tools exemplify what is the current biggest flaw when it comes to represent the architect's

Figure51 Illustration by Laura Arrieta Vinaixa. Physical drawing tools like watercolours leaves lots of space for wondering.

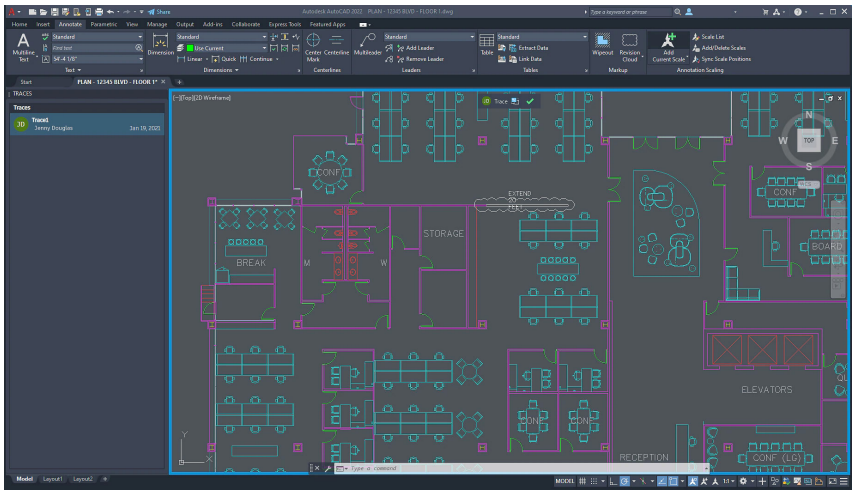


Figure52 On the opposite side, CAD tools are to rigid and specific when it comes to design. Screenshot of the software AutoCAD extracted from: autodesk.com

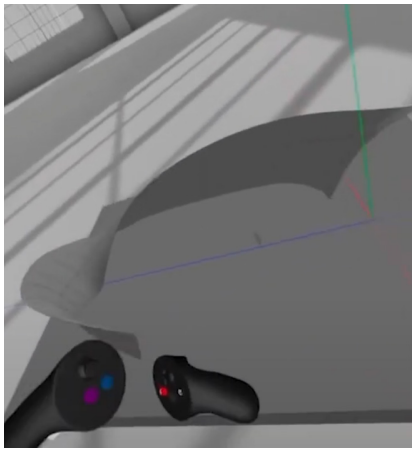
thoughts on digital media, those tools are constantly asking for too specific and precise information, in a moment of the process of designing where those questions are not that relevant. The current workflow that is available in CAD tools is too procedural to bring one idea from your mind to space. Moreover, these questions are constant interruptions for the designer's flow. So this begs the question, how can we create a digital tool that is able to be more expressive and a direct translation to turn our thoughts into a spatial digital representation?. This is the question that shaped the development of a VR tool called Gravity Sketch.

Gravity Sketch is a software that was born from the master thesis of two designers. Their vision was to create a more expressive tool for designing in the digital medium. They wanted to avoid the navigation around excessive panels and skip as much as possible intermediate steps to create a model. You have to be able to do something and produce something, just like you put your pen to the paper, you drag across the paper, you create a mark, that was a fundamental thing that need to happen (Sosanya 2021). Since the first moment they were focused on VR, and they were exploring how to bring a sketching feel to this media. As a result, Gravity Sketch is a software whose tools are unique to VR. Tools like the surface generator can operate in a way that couldn't be possible before. Just holding both hands to a desire position and pressing two triggers, you can start to generate a surface floating in space(Figure 54). That same intuitive behaviour can be expected with the rest of tools, you choose one and start creating immediately.

At his core is working as a regular CAD software, generating geometry by triangulated meshes or nurbs, but since the possibilities of interaction are much more natural, as it can be grabbed, shaped and scaled by your hands it blurs all the barriers that architects used to have when it comes to think through digital media. In addition, it is a software that accepts the limitations of his media, like the lack of precision that comes with the use of user's hands that doesn't have a supporting surface.

So Gravity Sketch is in sum, a software that really takes into account what VR offers, and more than translate what already exist in physical or digital media to VR, it tries to find his own expressiveness.

Figure53 An augmented reality point of view to show what is like to being designing on the air with Gravity Sketch.



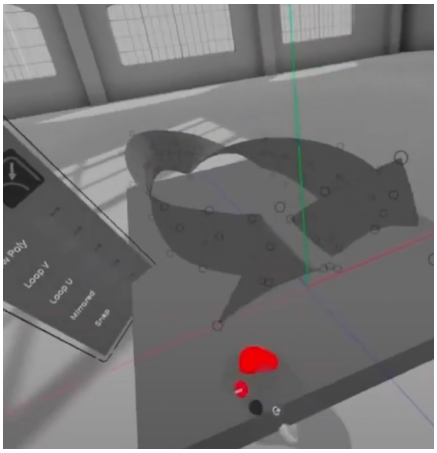


Figure54 Create shapes like curved surfaces is incredibly intuitive. And is possible to even make adjustments.

Figure55 Final result of that experience, rendered with Blender.

Gravity Sketch is not the only one of his kind and will not be the only way of making things for creative tools in VR. There are already other software for VR that offers interesting characteristics like *Quill by Smoothstep* for animation or *Medium by Adobe* for digital sculpting artists. As VR keeps evolving, it is to be expected that new ways of interacting within VR applications will emerge.

Exploring the middle ground experiences

But until that happens, we can also count on more transitional experiences, which lie between these unique ways of doing things in VR and more traditional CAD software. In this regard, a practical experience was conducted for this part of the dissertation, whose main goal was explore how to make a combination of what we already know regarding CAD software in a plain monitor and a unique way to interact that could just be possible with VR. The name of this tiny project was called Blender inside Blender.

Blender is a open source software that offers a set of tools for a complete 3D pipeline. In his last version up to date (Blender 3.0) developers added compatibility for the use of VR headsets. In this moment is limited to visualize the model, and the only interaction that is enabled for VR controllers are change scale and move by dragging or by teleport. Inspired by the videogame *A Fisherman's Tale* (Figure 56) a though came to mind, how would be being inside a space while the user was modelling that same space on a familiar software? Or in other words, how would be designing a space at two scales simultaneously?

The setup that the experience required at hardware's level is a VR headset, and preferably, any kind of VR controller to punctually interact. In this case, the headset Oculus Quest 2 and their Oculus Touch Controllers were used. On the software side, was needed Blender and OVR Toolkit. This last one is an application that is needed in order to have a floating window showing the PC's desktop inside any VR application.

As it can be seen on figure XX, the result once the setup was done and the user had the headset on, was an experience where in front of the user appeared a floating monitor showing the complete interface of Blender, meanwhile he/she was immersed in that same space. Any change on the floating monitor was instantly reflected in the space that surrounded the

Figure56 Screenshot from the game *A fisherman's Tale*. The main game mechanic of this game is to being simultaneously at smaller scales and bigger scales to the infinite simultaneously, as a Droster effect.

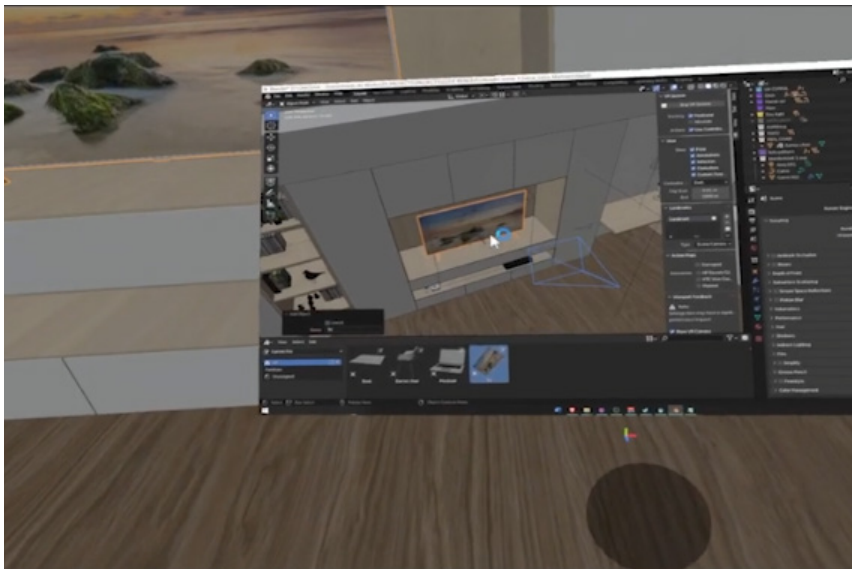


Figure57 Point of view for the user in Blender. The floating window is showing the plain interface in a floating window inside that same space.

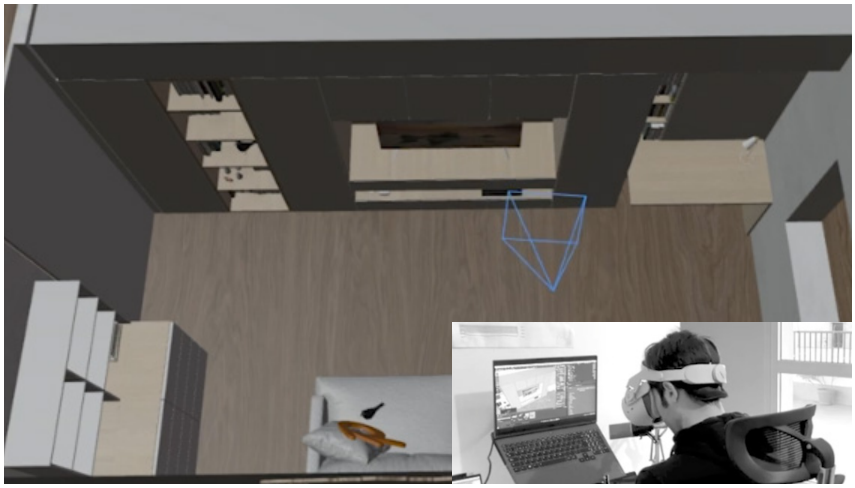


Figure58 Point of view from outside, in any moment the user was able to turn his head to see the changes in space or even stand up, leaving the floating window behind or bringing this one with him.

user. And with the use of BlenderXR (an independent branch that already has implemented interaction with the model within VR with controllers) would be possible the opposite, make changes in VR that would be reflected instantly on the floating 2D screen. This mix between the familiarity of using a software designed for a plain experience and the novelty of being inside the place that was being created was highly surprising.

Tools and procedures were not new, since they were already present in the plain experience. Being simultaneously representing space at two scales isn't unique neither, you could be inside the Panthéon while holding a model of it on your hands and that could be very close to what is happening here at a first glance. But what is truly unique is the possibility of being interacting with that space at two scales simultaneously. Experience those changes on space in real time on both scales.

Designs tools, from 2D to VR

Lastly, after being exploring tools that are trying to bring unique ways of interaction to VR, let's move on to talk about a software that it's purpose is to move some tools that were present in a 2D software to virtual reality, called VRSketch

VRSketch is a software that acts as a translation layer to virtual reality for the software Sketchup. In consequence, this software offers the same possibilities and limitations, but with the addition of immersion. Tools are not accessed in the same way, since in the monitor experience they are clicked on a plain interface and in VR they are accessed by some gestures in 3D space, but still being the same ones available. Geometry behaves in the same way as in Sketchup, being faces defined by some edges which can be modified by operations as extrusion, subtraction... Although the way of operating geometry is not the same (since mouse and VR controllers are different input methods), their operations in the end are the same. Even though VRSketch is not a tool exploring unique interactions that could be made in this media, the intrinsic value of sense of being that VR offers, and some new possibilities when it comes to collaborate(but those will be developed further in the next statement) makes this experience a valuable one.

Figure59 Screenshot of VRSketch showing that almost all the tools are the same as in Sketchup.

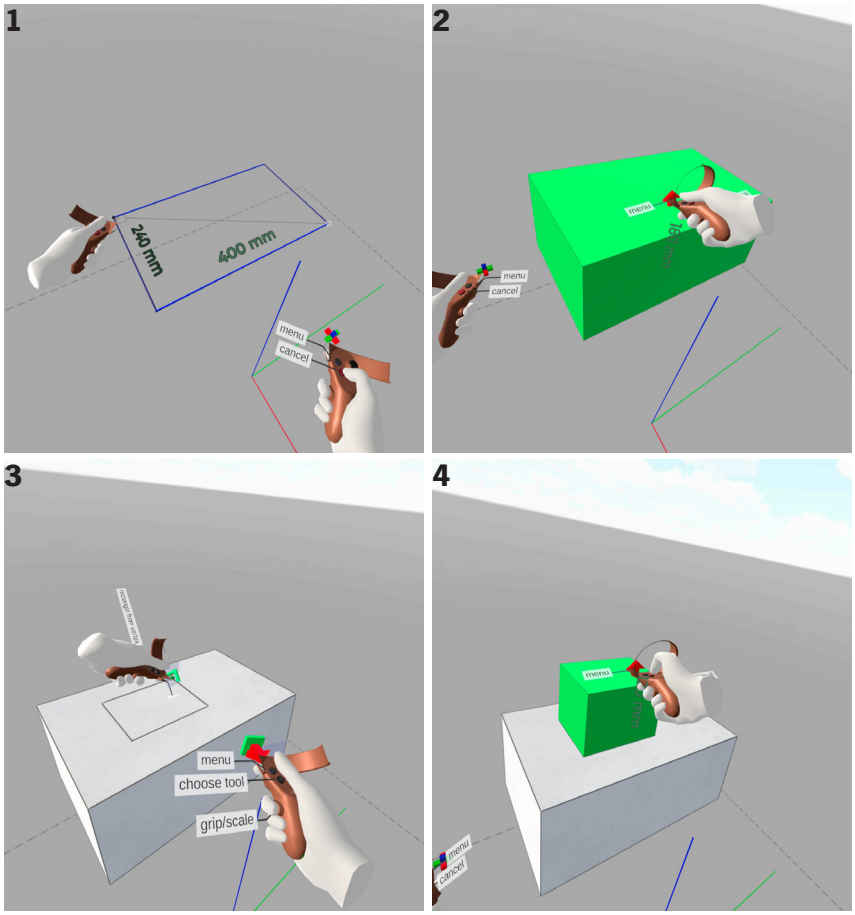


Figure60 Sequence of screenshots showing that the way of generating geometry is the same as in Sketchup.

DESIGN

VR will be a useful tool for remote collaboration

Collaborating in the design phase?

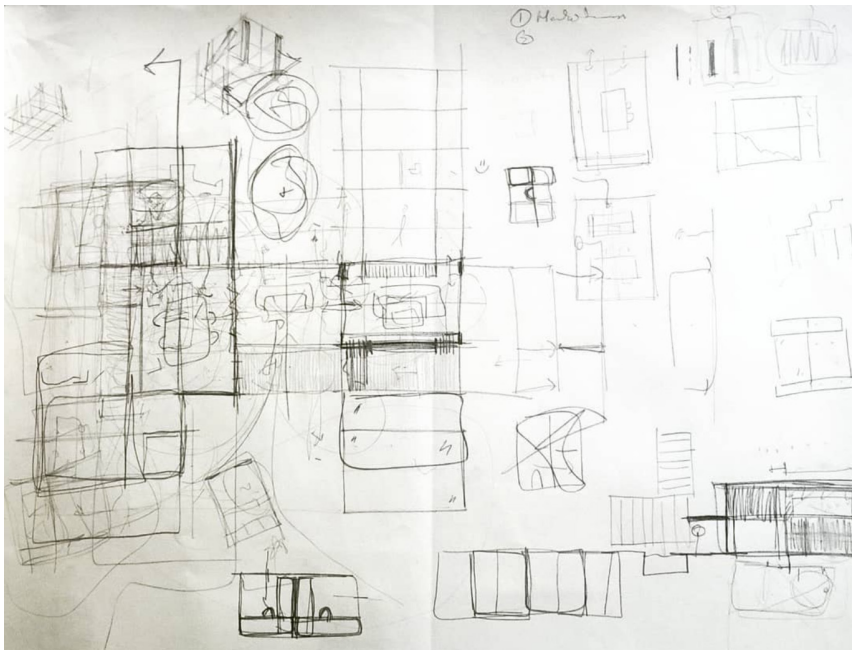
Collaborating at the moment of starting projecting is a complicated task. When projects are developed in a team, the first stages use to be rather individual. You could definitely put a piece of paper in the middle of 4 teammates and start to sketch thinking out of loud (Figure 61), but after those first brainstorming sessions usually collaboration is relegated to asynchronous checkpoints between the members involved in the design. Each architect goes on their own, and when they finally have a representation accompanied by a verbal explanation they give a glimpse of their thoughts to others. Information is shared, but the task of being designing/ thinking together simultaneously is not.

When it comes to remote collaboration in the practice of architectural design the range of possibilities when it comes to collaborating effectively with others is even smaller. Shared folders in the cloud with BIM/ CAD files, videoconferences with terrible image quality where the most collaborative thing you can do is share a screen and point at things... Designers miss the possibility to share volumetric representations tied to the physical, such as scale models, samples of construction details, etc. Could be a way to really think space simultaneously together? Sketch space together? And furthermore, in a remotely way?

VR as a dislocated space for collaboration

These were some of the questions Zoe De Simone and Yuzhen Zhang had in mind when they developed their first collaborative architectural project trough VR. Due to Covid-19 isolation periods, these students decided to experiment with the possibilities VR offered them. One of their goals was to integrate VR early into the design process from the initial analysis with basic diagrams to almost the final result. The design analysis, the massing design, and the bridging schemes were all drawn in VR.

They used the tools Arkio, Gravity Sketch and Tilt Brush. Arkio(figure 63) is a VR tool which provides the user with basic tools to work with volumes.



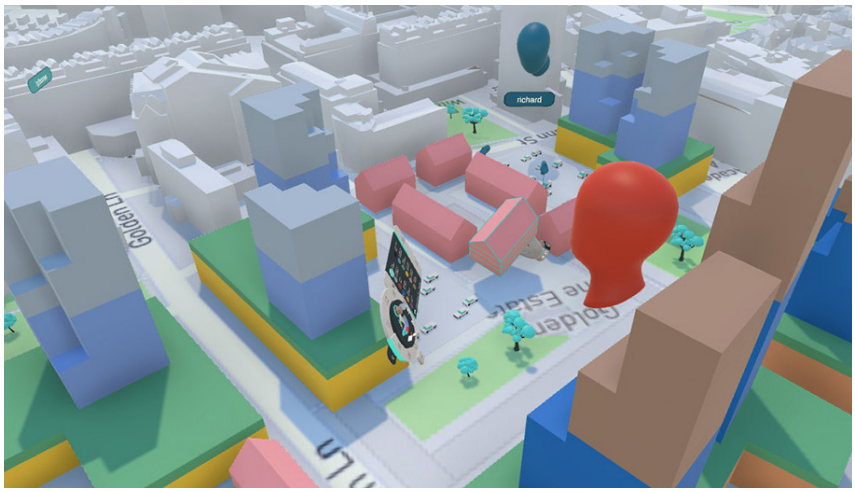


Figure61 4 hands drawing. By Laura Arrieta Vinaixa, Pablo Gomar, Carlos Silvestre Baquero and the author of the present work. This was one of the sketches behind the design for a contest about modular housing. We started with some blank A3 papers over a table and giving shape to our spaces sketch after sketch.

Figure62 Picture from the architecture studio BIG, reviewing some models for a project. Picture extracted from: big.dk

Figure63 Screenshot of the software Arkio. Extracted from: arkio.is

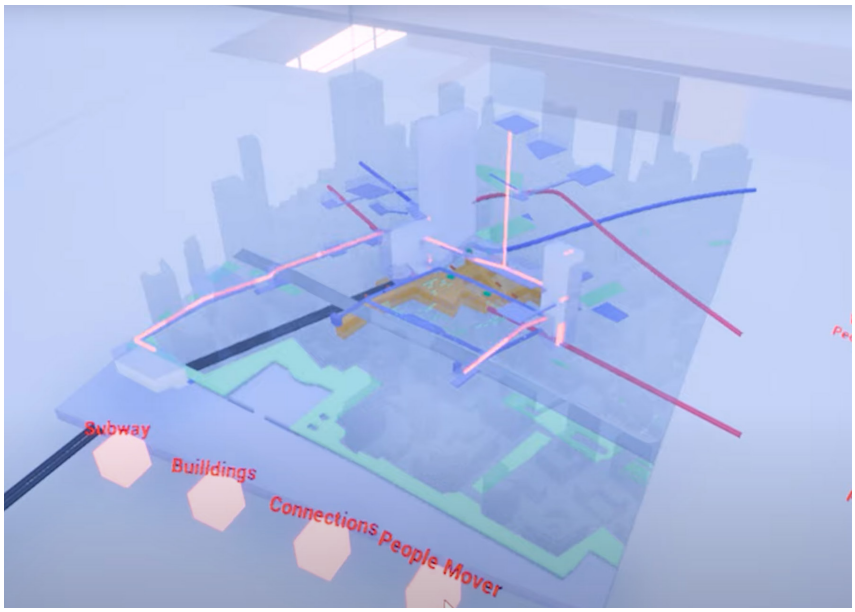
In addition it gives some useful information as the volume and area of the different program parts. But the key feature of Arkio for them was the possibility to create a remote collaboration session. At that time Arkio was the only one that gave them that possibility for free, but nowadays Gravity Sketch and Multibrush (a port of Tiltbrush when it became open source software) are able to do that too. As they declared, the multiplayer aspect of Arkio allowed them to collaborate on the same sketch and quickly iterate and discuss design options.

This shows one of the greatest potential of VR regarding collaboration. Never before architects had this possibility of sharing a space and its content with another person remotely. Now architects are able to be inside a virtual dynamic space where they can discuss, simulate and interact within the designed space together.

This even can be explored further, as in the experience designed by ZHVR Group (Zaha Hadid Virtual Reality Group) *Project Correl* . As defined on his website:

"Project Correl is a collaborative experiment in multi-presence virtual reality (VR) illustrating the development of complex assemblies inside virtual space. A shared, digital extension to our physical reality that proposes a dynamic new relationship between human creators and machine logic. Powered by Unreal Engine, Project Correl demonstrates the possibilities of emerging immersive technology in architecture.(...) Project Correl invites visitors to the exhibition to collaborate in real-time, experiencing scale and digitally augmented design to collectively build a virtual structure that will grow over the coming months. (...) While the virtual construction components and the guiding principles informing the placement algorithms have been designed by Zaha Hadid Architects, the scale of the components and their positions of placement is entirely up to the visitor."

On the one hand, this project experiments with democratic collective design by empowering visitors to create an sculpture immersing them into a virtual space. On the other, it show our capacity for being agents that can design through different realities, and we can interchange the results of our work from one to another, since the result was 3D printed (Figure 67).



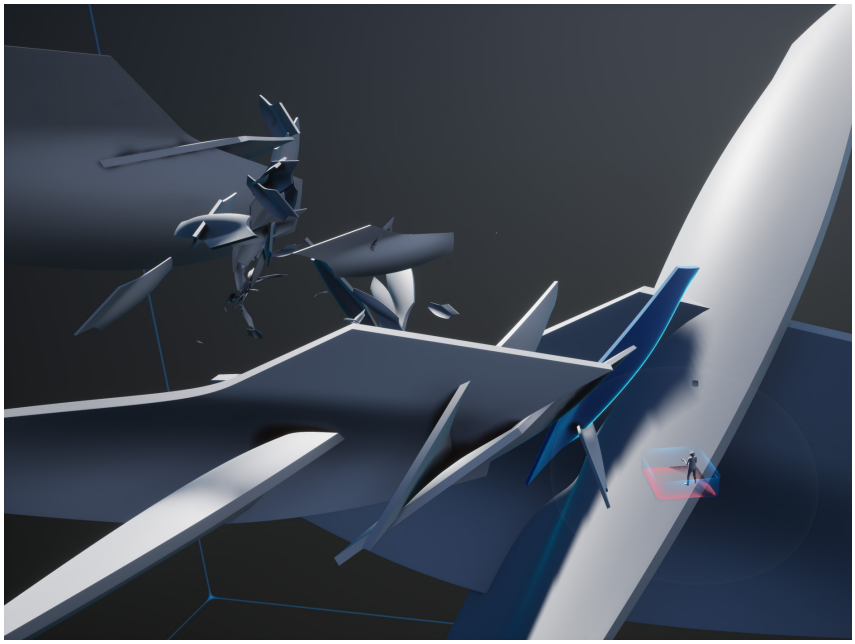


Figure64 Diagrammatic and interactive view in VR of the project, was made running Unreal engine 4. Extracted from: zoedesimone.myportfolio.com

Figure65 Screenshot of the VR experience at human scale. Extracted from: zoedesimone.myportfolio.com

Figure66 Screenshot of the experience Project Correl. Extracted from: zhvrgroup.com

Reviewing with others

Lastly, apart from these experiences that focus on collaborating in the early stages, VR is already being used for reviewing purposes in some studios. During the development of this present work, it was put into a test if VR could be a useful tool when it was time to make corrections in the architecture studio Paulo Martins Arquitectura & Design.

This architecture studio had the advantage that it was already working in a fully BIM oriented environment through Archicad software, so there were no extra tasks such as converting the 2D drawings into a 3D model for review. The most effective way found was to export the BIM model to skp (Sketchup file format) and use the aforementioned VR software VRSketch. When it was time to share the evolution of the project with others, there was a table ready with printed plans, a tablet with the BIM model, physical models and two VR headsets (Oculus Quest 2) ready with the project already loaded. If there was any doubts looking at the plans about if a space was working properly or not, or maybe just to check from another point of view the project, two people were able to enter intermediately into the space. The experience was more effective than expected. Being inside the project exposed some of the weak and strong points that were not that evident after hours working through 2D representations. Doubts about if a space was to narrow, or if the views from a window were right are detected instantly just being experiencing the space on scale. The co-presence with a teammate encouraged the interchange of ideas and impressions of being there, and we even simulated how would be living there to check things like the different spatial transitions by walking, accessibility of the building, or ergonomics when it came to use the furnitures.

In sum, VR has shown in real world scenarios his potential to foster collaboration between designers that can or cannot being physically together. Collaborate through VR for architectural design is not a hypothesis anymore, is already possible and present. Nevertheless, this dissertation believe that more research and effort should be put into this field, since more ways of collaborating are surely to emerge and help the architectural design process.

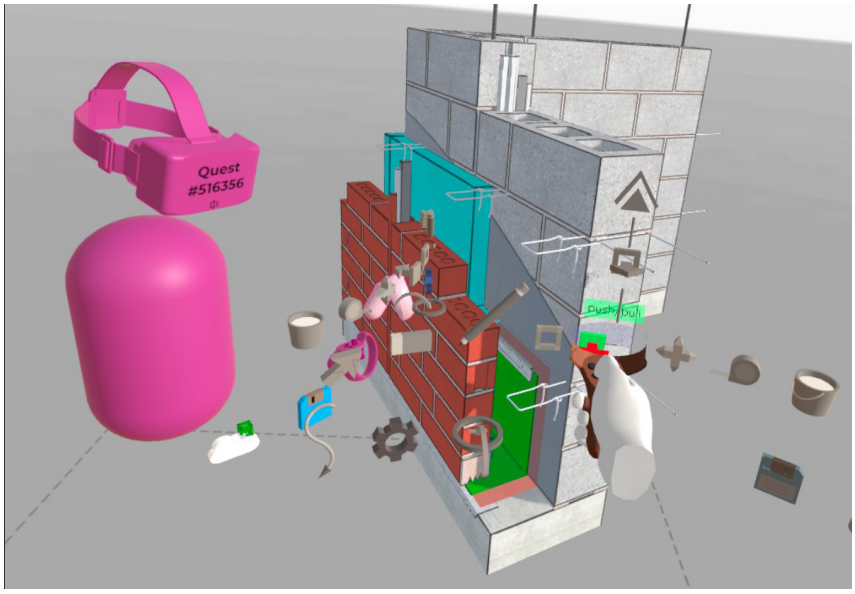


Figure67 3D printed sculpture result from Project Correl.

Figure68 Screenshot of VRSketch showing their collaborative capabilities when it comes to design together

Figure69 Screenshot of VRSketch checking some of the measures in relation with the human scale

DESIGN

Will architects start to be involved in the design of virtual spaces?

Architect crisis of identity

This final question has been omnipresent throughout the development of the work. The opening section, Reality, was probably one of the greatest contributors to this. If physical and virtual reality are equally real, we humans will be embodying different entity forms easily, and from those explorations we are taking more knowledge, a question raises: why not being involved into designing space with the exclusive goal of being virtual and for virtual beings?. Furthermore, the following sections, Education and Design, have even been giving certain hints that they were being slightly limited by the thought of: Remember that this space ultimately has to be built and inhabited by a human in physical reality.

What if architecture is a discipline independent from the type of reality?, What if architects are experts on the task of purely designing space?, How would it be designing virtual spaces for virtual inhabitants?...So many questions without a clear answer.

This puts us architects into a identity crisis: we never had before this possibility of being immersed into synthetic space, so until now it was clear that our purpose was design for the physical reality and for physical beings...Or wasn't?

The eternal debate. Rational vs physical

The previous questions bring out once more a long running debate in architecture. What is considered architecture? In broad terms, architects use to fall into one of the following two categories: the ones that firmly believe in the importance of the final execution of a building, and consider all the previous representations and toughs about it, as something that cannot be consider architecture, since architecture is attach to its physical quality; and those who not only include the rational part of the design process of a building in the definition of architecture, but argue that even that alone, regardless of whether it is built or not, is considered architecture. These are the two opposing views of what can be considered architecture. So, in this range, how does this work position itself in terms of whether or

not these synthetic spaces that we can access through VR are considered architecture?

Curiously, at the beginning it was said that this dissertation took some of the foundations of phenomenology to talk about the perception of reality and the subject, and phenomenology is a philosophical movement opposed to rationalism, the movement that is linked to those who consider something as architecture regardless of whether it has been built or not. So how can a VR experience be aligned with a phenomenological point of view?.

If one accepts the existence of two different types of buildings, the mental and the physical, we could argue that there are two selves too, the rational one and the phenomenological one. The phenomenological designer has been always limited to think within the limits that the physical space contains, but what happens with VR is that this phenomenological one is suddenly able to access and experience the spaces that are generated by the rational one. So for the present work, an space experienced through VR can be considered as architecture in the same way as a built one.

A new path or a specialisation area?

Being in this situation, does this mean that all architects now have to jump on this boat immediately and mandatorily? Of course it does not. Apart from the fact that this point of view is still subject to debate, we should maybe start to think if this can be the start of a new path of virtual reality designers or if this is going to keep attached to the traditional term of architects. Some would argue that the designers of virtual spaces already exist, and they are called game designers, but this is considered as a wrong assumption for the present dissertation. A game designer does not have into account the same factors as an architect. Game designers are driven by the game mechanics, and all the decisions they take are in order to enhance the game feel. Architects on the other hand have been trained to design space in relation with the subjects that will inhabit them and the surroundings. Their goals and background are totally different.

Coming back to the question, the field of designing spaces for VR remains in a very premature stage, so in this moment is impossible to predict if the designers of future virtual spaces will be considered as architects

or their own thing, but at least it is important to start to have all of this in mind. To continue, it will have to be assumed that, at least to some extent, architects will be involved in the design of exclusively virtual spatial experiences. But in this scenario, what values can an architect bring to the design of virtual spaces?

What architects could offer?

"As designers, what shall we become? Meta-modern strategists, trans-media storytellers, world-builders that manipulate geometries and events, confronting the multi-dimensionality of the world by delivering meta-worlds that can emancipate themselves from totalitarian closures."
(Ruberto 2021)

With the capabilities that VR brings to architects, we should start thinking in terms of new topologies. Virtual reality, as a dynamic virtual space whose rules about his behaviour are chosen by the designers, open up new narratives when it comes to design space. Gravity can be present or not. Structures can behave in an static way or in new procedural dynamic ways. Things like genre, ethnics, age... all of them fall apart when it comes to VR. As it was said, VR is a new canvas. If an architect wants to be involved in the design of a virtual space, is important to open up the discourse and accept that the design of cybernetic spatial concepts implies a new paradigm.

Once this paradigm is accepted, our background into the study of the relation between the architectural object and the subject could bring us those new interesting and unique typologies and ways to inhabit that we are seeking for. It can be in a completely detach from physical reality way , or creating hybrid spaces as in the experience Microutopia by Paula Strunden.

In conclusion

All this work showed how the impact of virtual reality on architecture goes beyond a couple of screens that produce the illusion of being in a place. The emergence of this medium turns upside down everything we thought we knew about what space is. From the very roots, questioning what is reality, to make us rethink about our role as designers of space.

The level of implication with this media should be up to each one. A tool

must never be imposed to designers, since each one confront the task of designing space under their own believes.

For those who take a leap of faith, VR will generate on you lots of doubts. As you have probably realised through this work, we are just scratching the surface. VR is a tool, a system and a blank canvas. The future about how is going to be used is in our hands, what means that this could bring us to better or to a worse scenario.

The worse scenario for the present work would be a future where VR is being used as a substitute or alternative of a decayed physical reality. Where VR means scape. Where virtual spaces and experiences are trying to replicate what once was a better reality, like the characters in the book *The Three Stigmata Of Palmer Eldritch* using their Perky Pat systems. Where these virtual worlds are being designed by entities that wants to take advantage of the cognitive manipulation machine that is VR to their own wealth. That would probably be the worse scenario.

In contrast, a better scenario would be one in which VR is used in conjunction with physical reality in order to increase our knowledge. Where humans are able to be more plural beings. Where virtual spaces have escaped from architectural symbols and typologies that comes from the physical...

In sum, a scenario in which the limits of designing space for virtual reality lies only in what a computer is capable of simulating and what we as humans can imagine.

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Statement of integrity

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.