Tampere University of Applied Sciences

Human Element of Virtual Reality: Implementing Perception Psychology into VR Design

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BACHELOR'S THESIS

November 2020
Media and Arts
Interactive Media

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Degree Programme in Media and Arts
Interactive Media

LIYA PIRKULIYEVA:
Human Element of Virtual Reality:
Implementing Perception Psychology into VR Design

Bachelor's thesis 74 pages, appendices 11 pages
November 2020

Virtual reality stopped being science fiction in 2016. The first commercial head mounted displays made VR available and brought VR into the field of entertainment and learning. Nevertheless, VR leaves many sceptical because it is far from ideal. Technological progress will improve the current VR equipment with time; however, little is said about the psychological aspect of VR. The objective of this study was to gather data on perception psychology and its uses in VR design. Optical illusions were used as a tool to explain perception psychology and its significance. These illusions were a parallel to VR: the importance is in not what we see but how we see it.

The thesis starts with acknowledging problems in current VR equipment: technical and psychological. Extensive research on the topic of immersion and how to achieve it in VR was conducted from a scientific literature review. Subsequently, the findings on immersion were applied to an analysis of popular VR games. During the analysis other use cases of perception psychology implemented into design were identified. A short VR demo called VR Lab Rat#133 was made based on solutions from research on immersion and game analysis. It involved optical illusions.

The final chapter summarised the immersion factors, game analysis and demo results. Other concepts for increased immersion were presented together with ideas for further research on the topic.

Key words: virtual reality, perception psychology, optical illusions

CONTENTS

GLOSSARY

AR	augmented reality
DOF	degrees of freedom
ESM	experience sampling method
FOV	field of view
FPS	frames per second
HLA	Half-Life: Alyx
HMD	head mounted display
MR	mixed reality
PC	personal computer
PPI	pixels per inch
VE	virtual environment VR virtual reality
VR	virtual reality
VRTK	virtual reality tool kit
XR	umbrella term for AR, VR and XR

1 INTRODUCTION

A virtual reality headset transmits computer generated data into human sensory channels. Screens are located very close to user's eyes and blocking the rest of the view. Headphones provide three-dimensional audio of a simulated virtual environment. Two out of five main human senses are directly affected by VR equipment, but the rest is not or is affected very little. Smell or taste data for virtual simulation is not available. Haptic or touch data comes from controllers and all it can do with the current equipment is translating movement, activating actions with buttons and vibrating to simulate haptic responses. Other senses such as balance or body perception are missing. Do they need to be present? The science that studies human senses and processing of sensory stimuli is called perception psychology. (Feldman 2005, p 2) This thesis is concentrated on how to make VR *real* with the help of perception psychology.

To create a reality, one should know what reality is. Reality in dictionaries is equated to a fact or things as they are (Merriam-Webster Dictionary 2020, Oxford Dictionary 2020); in philosophical terms reality is the opposite of non-existing (Psychology Dictionary 2020) and in physical terms it is a totality of a system (Saridakis 2016). None of these explanations made the matter clearer. VR equipment controls the signal input into human brains, hence produces so called facts. What if these visual/auditory/haptic signals are random? Signals exist, although their existence merely is not enough for a physical or a psychological explanation of reality. Therefore, one can assume that for reality to be real things need not only to occur but also make sense. That is why this thesis mostly deliberates on a right psychological approach for VR.

First, this thesis recognises what is wrong with VR at the moment: problems with hardware that do not deliver ideal sensory inputs; motion sickness being one of the main side effects of VR and directly involved with perception and, finally, immersion and presence, that is the closest definition in context of VR to psychological presence of users in a virtual reality. After accrediting problems that are directly connected to how users perceive reality, the thesis continues with a short explanation on perception psychology: how it functions and what could be taken into consideration when designing VR experiences. After the basics of perception are introduced, some virtual experiences are analysed according to the findings from previous chapters. This paper is essentially based on scientific literature review and researcher's own experience with the media. As I have little background knowledge in technology and psychology, only basics are explained. Several VR conferences and talks are also mentioned as a source of information. Analysis of the games in this research are hypothesised on the theories of perception psychology and findings of this research.

Several disclaimers are identified before starting:
The text is concentrated on VR *head mounted displays* (HMD). No history of VR is given and when referring to VR, this research writes about *modern* VR, or VR starting from 2016, when the first HMD like Oculus Rift and HTC VIVE were introduced.

This thesis explores VR mostly in games, as the author regards this field the most immersive. It is important to mention that VR is often used as a learning tool. Simulated environments for training that is either costly to produce or dangerous to recreate in real live are regularly used in military/medical/construction areas. VR can also be used as a creative tool – to draw in three-dimensions or compose music. These use-cases are not discussed in this thesis.

2 VIRTUAL REALITY

When searching for a definition of virtual reality (VR) online, many different sources offer slightly different explanations. Merriam Webster online dictionary explains VR as: “an artificial environment which is experienced through sensory stimuli provided by a computer and in which one's actions partially determine what happens in the environment”. (Merriam-Webster Dictionary 2020) Dictionary.com writes about VR: “a realistic and immersive simulation of a three-dimensional environment, created using interactive software and hardware, and experienced or controlled by movement of the body.” (Dictionary 2020) Oxford dictionary defines the term by “images and sounds created by a computer that seem almost real to the user, who can affect them by using sensors” (Oxford Dictionaries 2020). All these definitions have in common an artificial environment and manipulated user’s sensory organs. However, the first-time when the term “virtual reality” was used is in the works of German philosopher Immanuel Kant back in 18^{th} century, he referred to “virtual reality” as to something “not in a physical world” (Kant Critique of Pure Reason, 1781, 126). In that context virtual reality has no technological involvement at all and does not coincide with definitions used by online dictionaries now. If the term is separated into word by word meanings, where “virtual” is not real and “reality” – real, then the term is oxymoron itself.

In this thesis ‘virtual reality’ is referred to a computer-generated environment perceived in modern head mounted displays with motion tracking such as Oculus Rift, HTC VIVE, etc. (Picture 1) These headsets were first introduced in 2016, and the thesis leads a discussion about this type of technology. With the current VR equipment, several big problems occur that do not allow users to perceive computer simulation as real because of the poor performance of the hardware. The next chapter tells about those.

Picture 1. Users wearing HTC VIVE PRO (blue) and HTC VIVE (black) headsets (htcvive.com 2020)

2.1 Current problems in VR experiences

This chapter discusses common problems in VR. The most relevant to the topic of perception psychology in VR are problems of the technical nature - hardware faults resulting in an unpleasant experience. Motion sickness is a frequent side-effect of VR. However, before continuing with these, other issues should be mentioned too. They are concerned with the industry and market in general and affect consumption and development of VR.

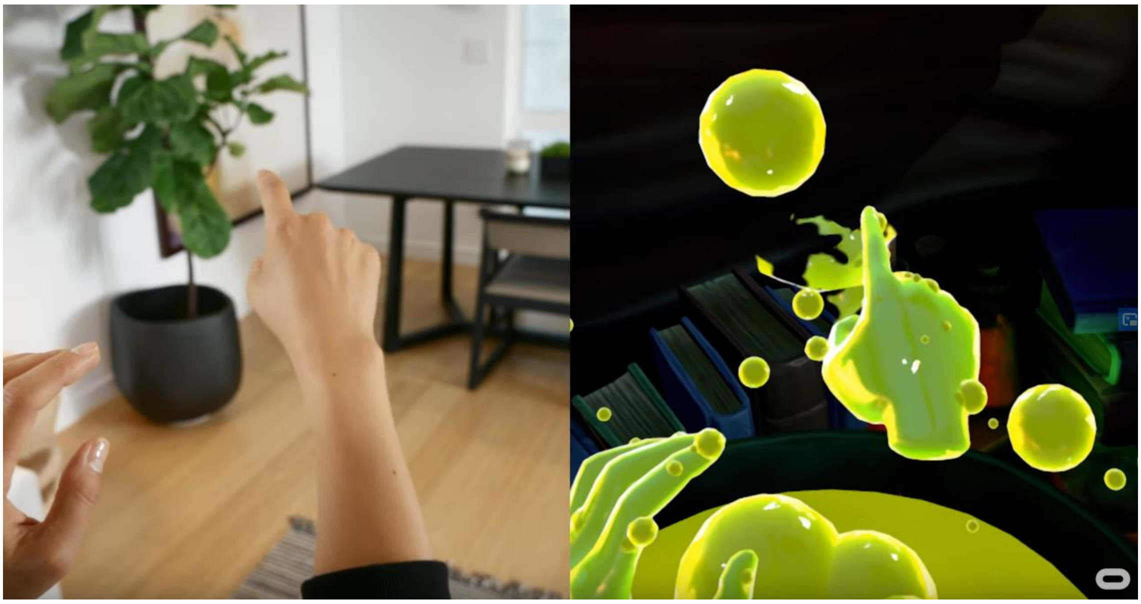
To experience VR with an HMD, a VR compatible computer is needed. These computers need components that are powerful enough to make calculations for a virtual world, have enough memory to keep the generated information and produce good visuals. The price of a graphic card GTX 960 (a component that is responsible for visuals) with minimum requirements for HTC VIVE headset, marks 280 dollars on the official website of Nvidia company (Nvidia 2020). This is just one of the components required for a VR compatible PC. The power unit for making calculations are usually priced even higher than graphic cards. The prices for VR headsets vary between 299$ to upwards of 6000$. The cheapest standalone or tethered (connected to PC) headsets are Sony Playstation VR and Oculus Quest 2; the most expensive is Varjo XR-1 that costs 11995$. (vrcompare.com 2020) **High prices** for the equipment result in a small market of VR. Small market results in equipment being less accessible and less opportunities for VR development.

Another issue reported from users is equipment's **discomfort**. Headsets can be powered by computers or be standalone. (Picture 2) The first ones are more powerful as all the calculations are done on the PC and transferred through cables. The second ones have a power unit integrated into a headset and are wireless. This power unit needs to be light weight and ergonomic, because it is sitting on user's head. Users need to choose between comfort or power.

Picture 2. Oculus Rift S on the left – tethered headset that runs with PC and Oculus Quest on the right – standalone headset (no cables). (oculus.com 2020)

Any kind of HMD are accompanied by a controller system that differs from company to company. Picture 3 shows different types of controllers available right now. During Mindtrek 2019, Steven LaValle, an early founder of Oculus, commented that holding a controller for a long time period will result in hand exhaustion, or so-called gorilla arms syndrome. The eye tracking feature that is implemented in many new headsets might replace basic controller needs and with inside out hand tracking available - hands are tracked just as they are, might solve the issue of gorilla arms. (Picture 4) Both eye tracking and hand tracking are just being introduced to the market.

Picture 3. Different VR controllers from left to right: HTC VIVE, Valve Index, Oculus Touch. (cnet.com 2020)



Picture 4. Screenshot from Oculus trailer of hand tracking feature in Oculus Quest. (youtube.com 2019)

A small market, pricing and equipment's design are major issues for the industry; however, they have little to do with perception of VR. The thesis will discuss more thoroughly below the problems of VR that affect perception systems such as:

- Hardware (restrictions of it comparing to human senses)
- Motion sickness (most common side effect of VR)
- Immersion (results in overall perception of the experience)

Discussion on immersion starts in the chapter 3, as it is a problem of psychology rather than technology.

2.1.1 Limitations of VR hardware

This is by no means a comprehensive discussion on the technology, only important factors are mentioned that affect visual perception and might form a wrong overall image of the experience.

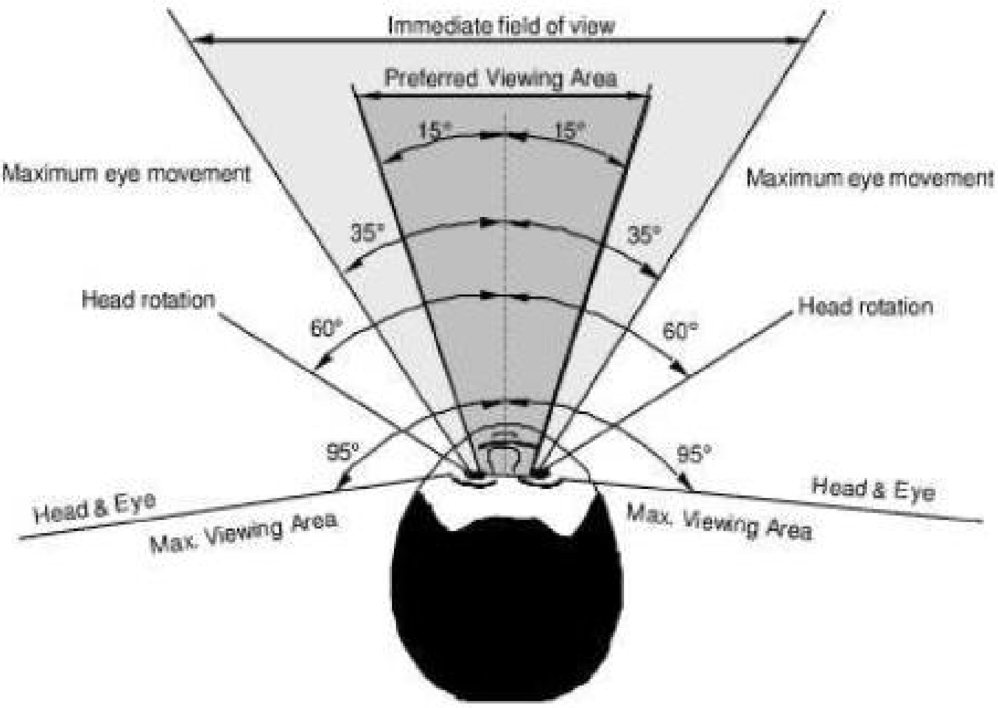
Right now, VR is a screen, sometimes two, depending on a headset model, which is placed very close to the eyes. The quality of the picture the user sees is dependent on the quality of the screen. VR screens are required to have high **resolution**. Resolution is pixel density: the more pixels the sharper image users see. Steve LaValle aside from being an early founder of Oculus is also a computer scientist and now a professor in Oulu University. He has a book on VR, that is featured in the thesis multiple times. In his book LaValle suggests that the minimum PPI (pixels per linear inch) is around 2292 units. (LaValle 2015, 149) Here is the table with resolution for different VR headsets based on information provided by benchmarks.ul.com dated November 2020 and PPI numbers from the article by Tyler Lindell (benchmarks.com 2020; Lindell 2020):

Headsets	*Pixels per eye*	*Pixels per inch*
HTC VIVE Pro	1,440 x 1,600	~404 PPI
Oculus Rift S	1,280 x 1,440	unknown
Valve Index	1,440 x 1,600	~598 PPI
Pimax	3840 x 2160	~400 PPI

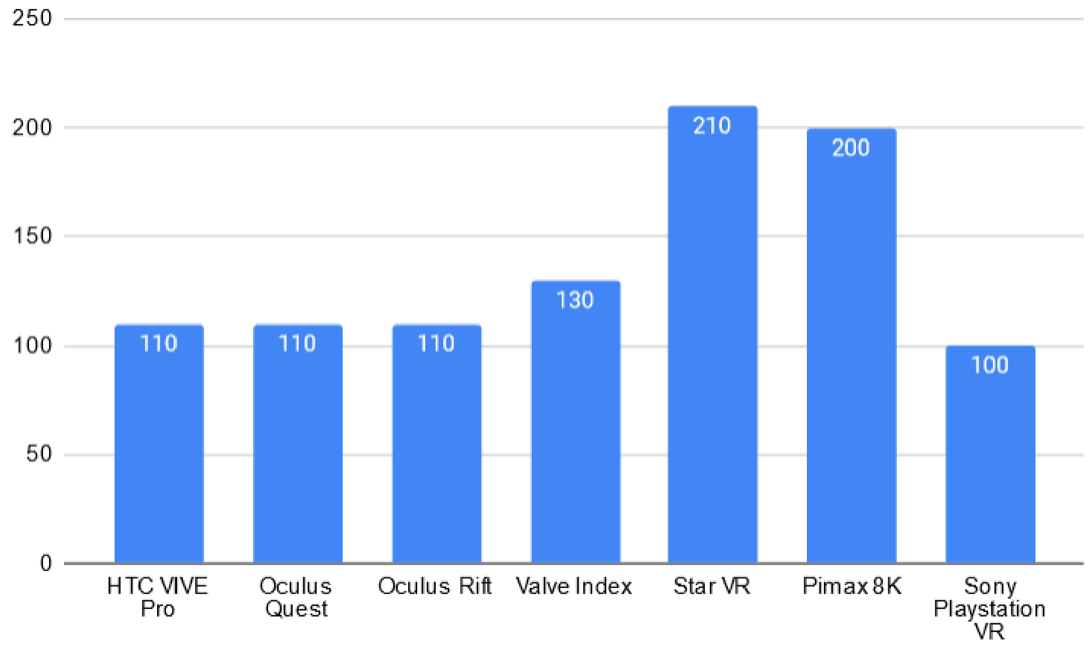
Table 1. The resolution and PPI numbers of different VR headsets.

With pixel density comes a question of **focusing** – not everything is sharp in our field of view. How can VR simulate focusing on objects of different distance from the user? Research on the topic is done in the sphere of eye tracking. Being able to track the human pupil makes it possible to generate focus only where needed and blur the rest. This technique is called *foveated rendering*. (LaValle 2015, 148) Foveated rendering eliminates the necessity of rendering the whole image and saves computing power.

Field of view (Picture 5) is “the angular measure of what can be seen at a single point in time”. The horizontal field of view in total is roughly about 200 degrees, and by rotating the head it expands to an additional 50 degrees on each side. (Jerald 2015, 89). When it comes to vertical field of view, it is more limited than horizontal due to the position of eyes on the face. The vertical field of view is a total of 135 degrees. (Spector 1990, 147). Graph 1 shows that current VR headsets offer between 90-220 degrees of horizontal field of view.



Picture 5. Field of view. (LaValle 2015).



Graph 1. Comparison of horizontal field of view for different VR headsets (benchmarks.com 2020)

Images on screen are constantly changing. Having a high **frame rate** in a VR headset is important. Gaming industries suggest 60 fps (frames per second) for smooth experiences and VR having screens way closer to the user requires frame rates above 90. It is done in order to minimise any flicker or judder. (LaValle, 2015, 167-169)

As mentioned before, VR headsets can be tethered (connected to a PC) or standalone (no wires). **Wireless** data transformation remains slower than the old-fashioned cable way. During Helsinki XR Match Up event in December 2019, Steven LaValle refers to a Cambridge professor Rafal Mantuik and his calculations on the ideal VR headset. They say that the headset should be able to transfer 3.2 terabits of data per second. It is a huge number, and to simplify it some developers suggest distributing calculating operations among cloud services or additionally attached gadgets, so the headset remains lightweight and ergonomic.

Technology is not able to provide hardware to match human sensory organs yet. However, development in technology is constantly continuing not only in the field of VR but generally for all media. Smartphones and personal computers share the same “insides” as VR headsets. Modern day demand on smartphones and computers is huge, forcing components to become better and cheaper. In the near future, specifications like resolution and frame rate will meet the threshold of the human eye.

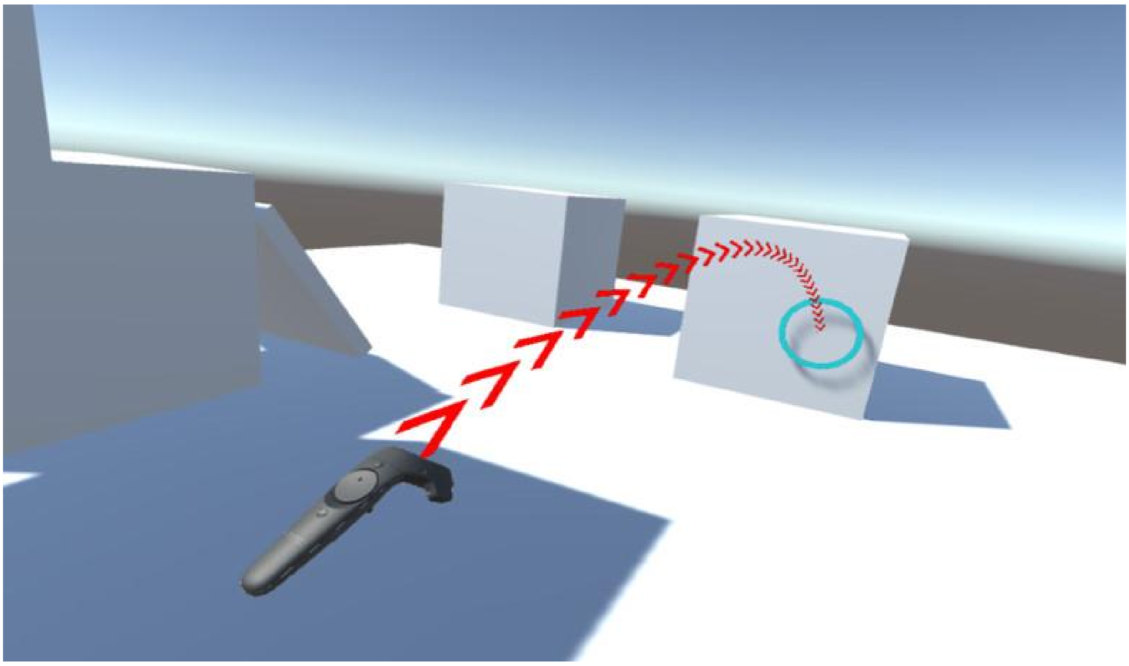
2.1.2 Motion sickness

In 1995 Nintendo announced their first virtual headset – Virtual Boy. The biggest problem of this piece of hardware was users getting heavily motion sick. (Bordelon 2020). Since then, technology has improved massively though motion sickness remains a problem.

Vection, or the illusion of self-motion, the most common side effect of VR happens when one perceives *motion* while *being stationary*. (LaValle 2015, 238) Many small technological problems lead to it: pixels that constantly update, latency, curved lenses distorting images. Achieving perception of *stationarity* with current VR equipment is very challenging. Even if the users do not recognize all the above errors, the brain does detect any mismatch. After continuous exposure to these elements, users start feeling nauseous, tired and get headaches. (LaValle 2015, 239)

The main reason for getting motion sickness from VR is *moving* in VR. While visual data delivered to the brain reports of user moving, vestibular organs do not perceive any changes in our physical state (as the user is usually stationary in the real physical world or moves very little). Visual perception dominates over other senses, therefore, the disbalance between visual and vestibular systems outweighs towards the first one. (LaValle 2015, 243)

Movement in VR usually occurs via teleporting, using touchpad/joystick or translated physical movement of the user. During teleportation user sees fewer moving visuals and, therefore, this locomotion method causes less vection. (Picture 6) Translating physical movement is limited to available physical space and vast distances this way cannot be passed. Usually VR experience combine several means of locomotion.

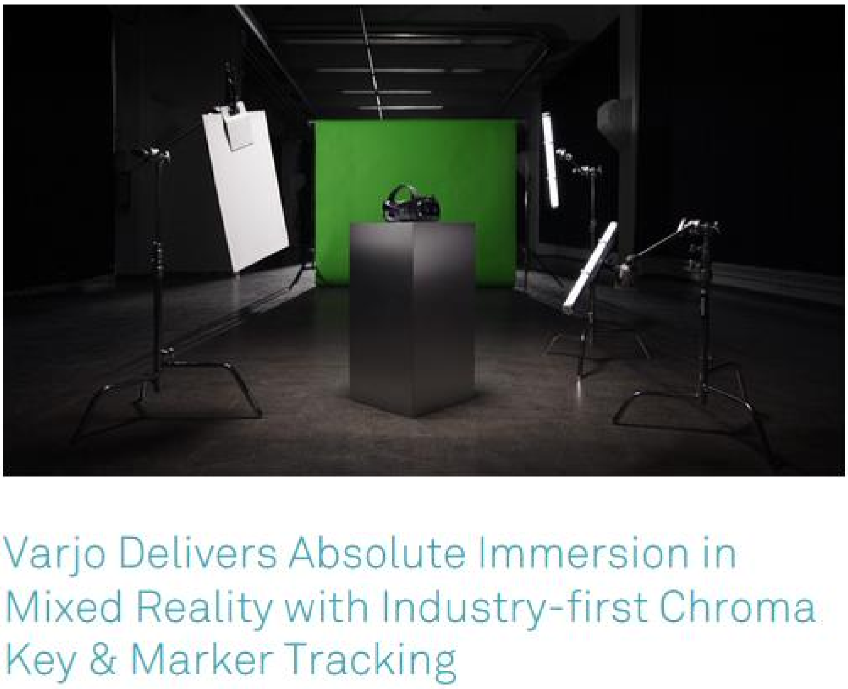


Picture 6. User moves via teleporting. (sematichsccolar.org 2019).

Motion sickness complies with the limitation of the current technology and lack of understanding psychology. It is a question how to make the user perceive objects as stationary when they update on the screen at a very close distance and curve from lenses. This simple action of moving cannot be yet done in VR without causing distress. Other means of locomotion should be designed. The problem leads to a new discussion of how else an understanding of psychology can benefit VR design.

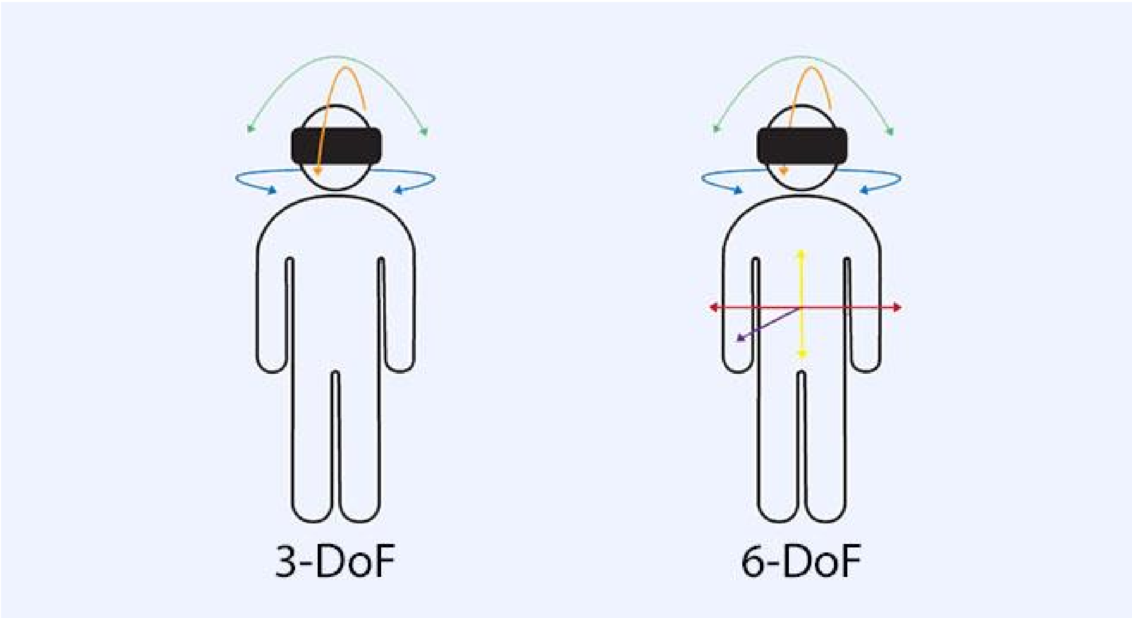
3 IMMERSION, PRESENCE AND FLOW

Some businesses based on VR technology would advertise themselves with a fancy term “immersion”. (Picture 8) What is it and why is it a selling point of VR?



Picture 8. “Immersive” advertisements for VR. (varjo.com 2020)

Finding a clear and constructive definition for word “immersion” is as difficult as it is with “virtual reality”. Eeva Jäntti the CEO of “Arilyn” – the biggest AR company in Finland, in her master’s thesis focused on immersion suggests that immersion has two main ramifications - *technical quality* and *psychological aspect*. (Jäntti 2019, 32). The first criterion is easily explained: the *more technically advanced* the equipment is, the *more immersive* it is. For example, let us compare two VR systems – mobile VR (requires a mobile phone and a headset) and PC VR (runs with VR compatible computer and a headset). Phone based VR headsets work on the principle of 3 DOF (degrees of freedom) allowing user to pitch, roll and yaw head movements – only rotational movements; whereas PC based VR headsets has all 6 DOF (degrees of freedom) – rotational and translational. (Picture 9) User with motion tracking enabled equipment (PC VR) has ability to walk, jump, crouch. Mobile VR does not translate user’s movement. Therefore, user has more possibilities with PC VR because of technical advancement of that equipment over mobile VR. (Virtual Speech, Barnard 2019)



Picture 9. A headset with three degrees of freedom movements and a headset with six degrees of freedom movement. (Barnard 2019)

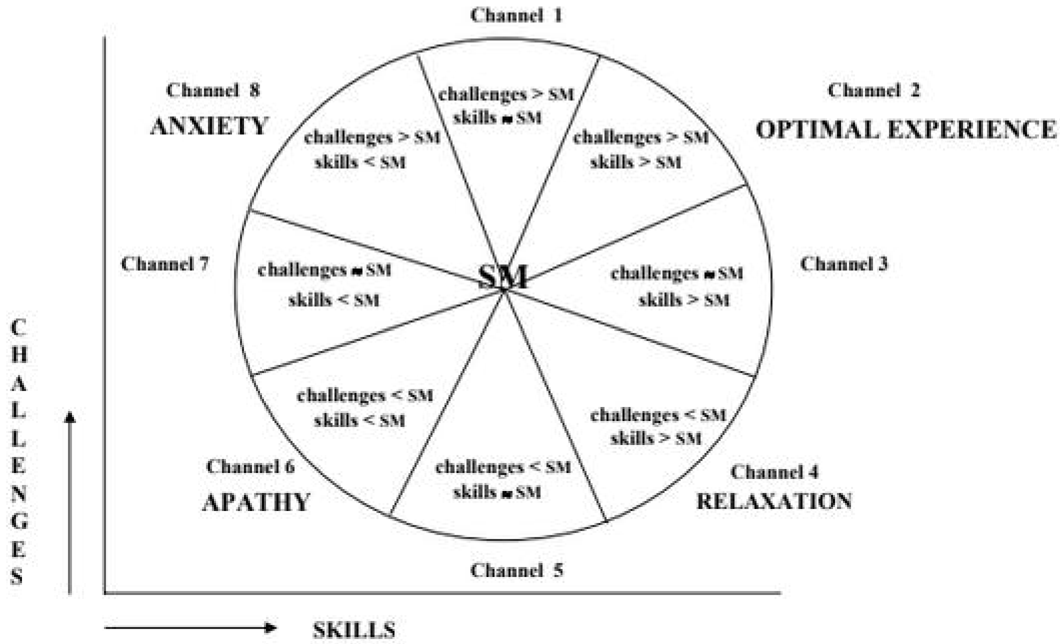
Continuing this theory, one can say that VR is right now the most immersive media format. The equipment it requires is more advanced than the equipment for computer gaming or any other new media formats be it augmented reality or mixed reality. However, does it mean that being in VR is necessarily being more immersed than in a computer game? This is where the psychological aspect of immersion comes into review, which is subjective to the user and their overall experience.

Presence is another term widely used together with immersion. *Presence* is a feeling of *"being there"* (Gaggioli, Bassi and Dele Fave, 2003, 5) when physically you are not. Thus, one can refer to presence in this context as a psychological side of immersion: everyone experiences things differently and what feels immersive to one for numerous psychological reasons, can feel different for others. However, when immersion is in its pick, one would refer to feeling "present" in the virtual world. While searching for data on immersion and presence two authors would always be encountered. *Bob J. Witmer* and *Michael J. Singer* are psychologists from 1980\s and 1990\s, whose main topic of research was immersion.

Before the new era of VR, researchers were mostly focused on the aspect of presence users develop during engagement with virtual places, such as television and computer games. Witmer and Singer in their work “Measuring Presence in Virtual Environments” suggest that the more users are involved with the virtual environment: *story wise, concentrated on tasks and socially* - the more present they feel (Witmer and Singer 1998, 3).

It was established people prefer to participate in actions resulting in positive and rewarding state of consciousness. (Gaggioli et al. 2003, 6-7) This usually acquires a challenge and skills to complete it. These two characteristics in a right relation to each other form an optimal experience or **flow.** Other features to achieve an optimal experience according to the same source are *involvement, clear rules, control on situation, positive affect and motivation*.

When talking about optimal experiences, the above-mentioned authors in their paper mention the ESM or Experience Sampling Method. This is a method of study where researchers ask experiment subjects to fill questionnaires whenever they get a random signal. The questionnaires gather information about actions subjects are doing at the moment of the signal in order to establish what is an optimal experience. (Gaggioli et al. 2003, p. 8-11) This method was introduced in the 1980s and was widely used by many psychologists. According to a data gathered from the biggest ESM experiment held at the time, (Massimini, Csikzsentmihalyi and Carli, 1987, 285-303) Graph 2 presents that optimal experience requires higher challenge and skills more than subjective means. It means, for a user to be satisfied with an action, it requires a challenge and skills that will allow user’s progression.



Graph 2. The experiment fluctuation model. SM = subjective means (Gaggioli 2003)

To summarise the views on immersion from “Measuring Quality of Virtual Environments”, Gaggioli, Bassi & Dele Fave offer four main features required for optimal VR experience:

- opportunities for action - tasks to complete;
- skills - usually refined during the session to complete the tasks;
- feedback – VR world responds correspondingly to all user actions
- control - users have a clear understanding of what is happening and can use their abilities accordingly to control certain aspects of the experience.

Another scientific research called “A Framework for Immersive Virtual Environments: Speculations on the role of Presence in Virtual Environments” by Slater and Wilbur (1997, 603-616) claim that immersion happens when VR produces stimuli for users’ senses *in “extensive, matching, surrounding, vivid, interactive, and plot informing”* way. *Extensiveness* stands for how many senses are involved, (audio, visual, haptic); *matching* – how those sensory stimuli correspond to each other; *surrounding* – how panoramic are sensory stimuli (spatial audio or wide field of view); *vividness* – quality of input (sharpness of image, frame rate); *interactivity* – to be able to make changes in the world; *plot* – consistency of experience, its narrative and behaviour of the world and subjects in it.

Jason Jerald in his book “The VR Book: Human-centred design for Virtual realities” also proposes four main categories to attain presence. According to him these components for presence should be active: *illusion of being in a stable space, the illusion of self-embodiment, the illusion of physical interaction and the illusion of social communication* (2015, p. 47-49).

Combining the information from these diverse researches on subject of immersion, for VR to be immersive these important features should be enabled:

- *physical interactions;*
- *ability to learn and develop;*
- *consistency of the virtual world and its story;*
- *responsive and self-logical virtual environment;*
- *social interactions;*
- *emotional connection with the experience.*

To simplify, I would like to from a rule, where immersion factors are divided into technical and psychological. (Picture 10) When it comes to the virtual world, it needs to be responsive and coherent – for maximum presence and flow. Interactions in this world need to be physical and social and motivation for user should be manifested as technically – acquiring new skills or completing tasks and getting rewarded as well as psychologically – driving the story.

Picture 10. Immersion factors for VR

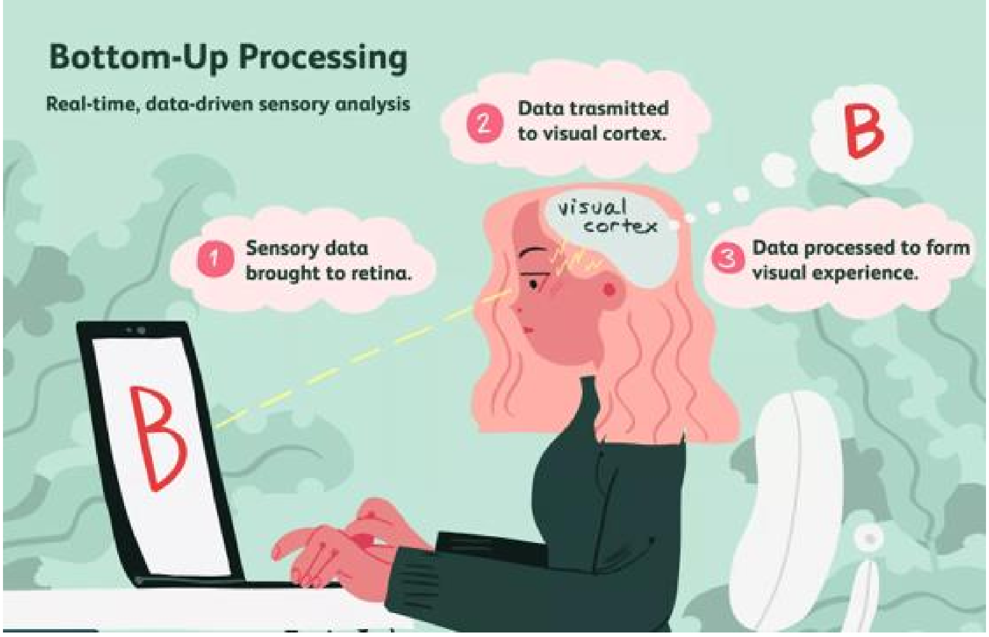
All these features are both technology and psychology dependant. Technological influence on VR has been discussed before: hardware and its faults were explained in the first chapter. Now it is time to talk about psychology.

4 PERCEPTION PSYCHOLOGY

Author of ‘The VR Book: Human-Centred Design for Virtual Reality’ says: “If we (researchers) do not get the human element correct, then no amount of technology will make VR anything more than an interesting tool.” (Jerald 2015, 1). Steven LaValle specifies: “human perception and psychology is the biggest blind spot of the current VR”. (XR Match Up, 2019, Helsinki) VR is the most immersive media considering technical explanation of immersion when the more technologically advanced equipment is the more immersive. However, talking only about technological aspects of VR is not enough. A psychological approach of how people accept and perceive realities is very important for VR design. One cannot make a VR experience based only on the technological opportunities of the equipment. Understanding how human perception works might help to create new realities that are believable and pleasant.

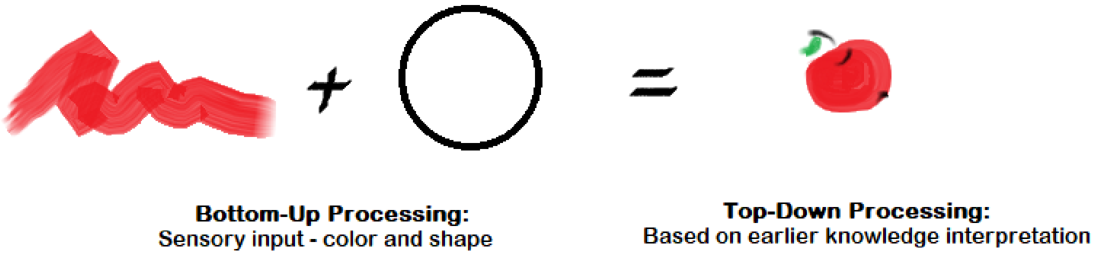
4.1.1 Basics of perception psychology

Perception is receiving information from the senses, processing it and interpreting into a conscious meaning that causes us to act correspondingly. (Feldman 2005, 22) Perception happens not only in the physiology of our organs but also with the help of previous experiences and knowledge obtained about the subject. The first part – receiving stimuli, processing them by sensory organs and transferring to brain is called *bottom-up processing*. (Picture 11) Knowledge based or experience-based processing of information that happens in the brain is called *top-down processing*. (Feldman 2005, p. 133) Top-bottom processing is a very important step in visual perception, as the rest of the sensors demand less interpretation and provide direct signals. (Picture 12)



Picture 11. Bottom-up processing. (Roberts 2020)

VR manipulates user's sensors – gives visual, audio, haptic data through technology as a display, headphones and controllers, therefore directly influences bottom-up processing. The way virtual environment functions within itself, for example, basic physics laws or relations between the objects, is absorbed by users' top-down processing. If a user stops holding an object, it is expected to fall (unless in zero gravity or similar exceptional situations) because that what was experienced through life.

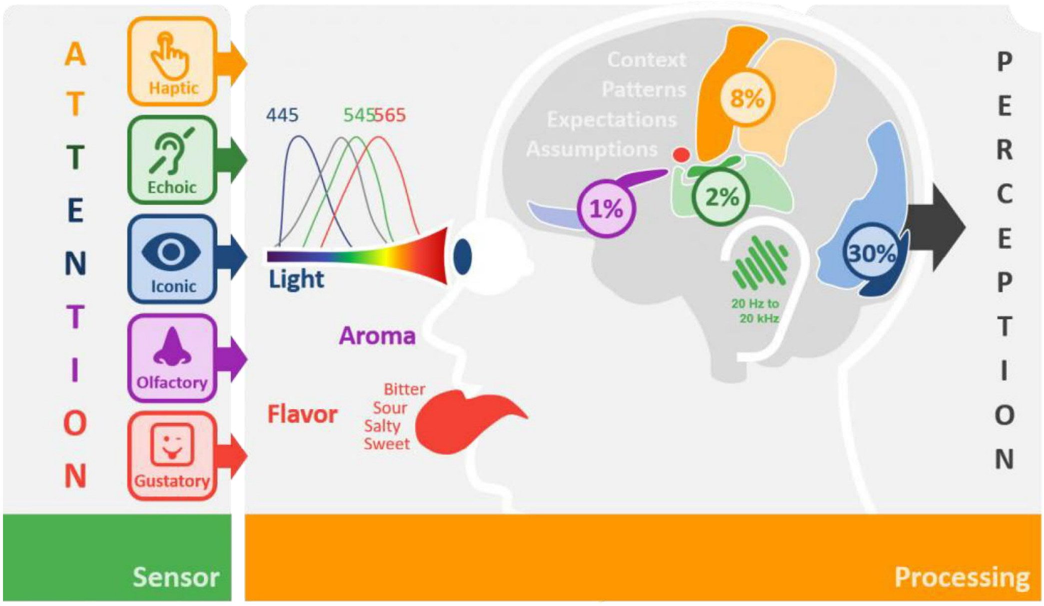


Picture 12. Bottom-Up and Top-Down Processes. (Pirkuliyeva 2020)

While bottom-up processing is reliant on the quality of technology and input it provides, top-bottom processing responds to the human part of perception. Keeping in mind top-bottom processing is significant while creating VR experiences. VR interactions should resemble normal life interactions to make the user feel familiar and in control. Interactions can and should be modified in order to make the user learn new skills. Several academic works indicate that challenging users and providing them with the means to develop newly acquired skills results in motivation. When succeeded in user's goals, satisfaction and positive feedback culminates from the experience. (Eysenck and Keane 2014, 115; Slater and Wilbur 1997, 50-53) Simulating an existing reality is not creating one; yes, it is important *to replicate the functionality* of the real world in order to convince the user things are real. However, *which functionalities to use and replicate* into a virtual reality is upon the creator of VR experience and the needs of the application.

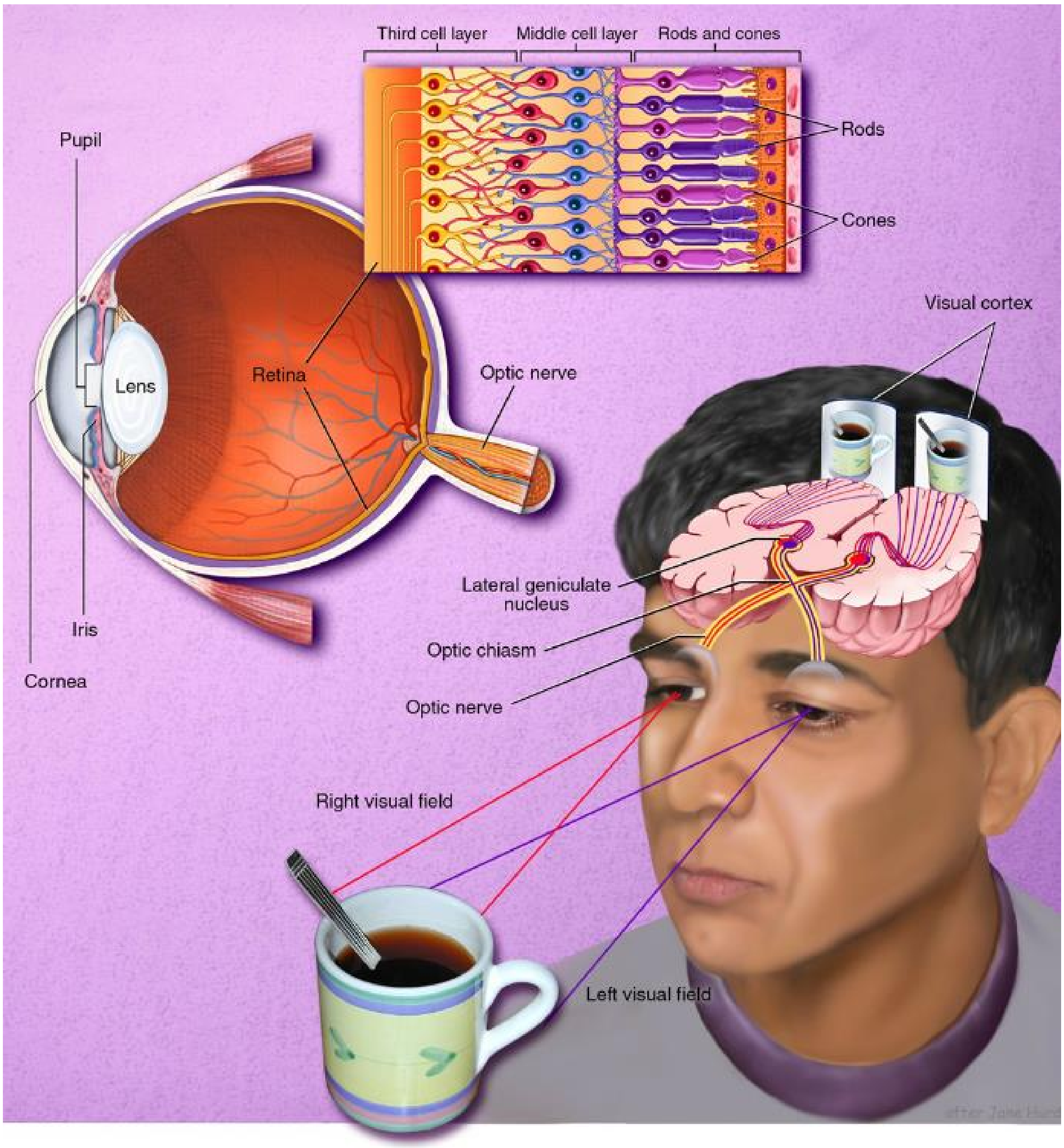
4.1.2 Visual perception

Most of the information perceived is based on visual data. (Eysenck and Keane 2014, 128)



Picture 13. Sensory processing. (Roman 2017)

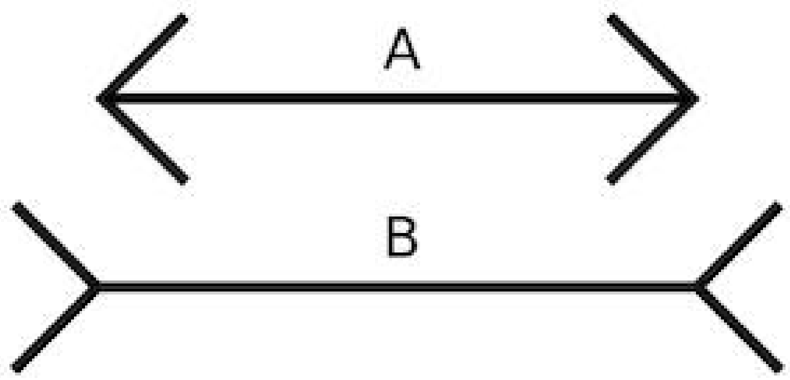
The physiology of human vision is complicated and VR headset's display is the only source of visual signals during the experience. The display is placed very close to the eyes and, therefore, should provide numerous visual cues for three-dimensional space as if eyes would be looking at objects at a different distance. Visual processing starts with light entering the human eye. Light inside the eye is converted into electrical signals and transferred to the brain. The visual cortex – a part of brain, is divided into subparts that are responsible for recognising shapes, depth and motion separately or together. (Picture 14) Visual information is combined with data from other sensors: vestibular, audio, haptic, in order to fill the gaps and form a bigger picture.



Picture 14. Visual Processing (brainfacts.org 2012).

Received electronical signals are interpreted into meaningful information by our brain based on recognition processes formed during evolution and on general knowledge from our previous experiences. (Eysenck and Keane 2014, 36) This is the part that is crucial for the research: *forming conclusions according to earlier knowledge* and believing things are something rather than another.

Picture 15 shows two lines, that appear to be different length. They are, however, the same length. This optical illusion happens because we see not just lines but little corners in the end of each line that affects the overall perception of the length. These kinds of optical illusions happen often as visual information is dependent on many visual cues such as depth, space, size and cannot be perceived separately from each other.

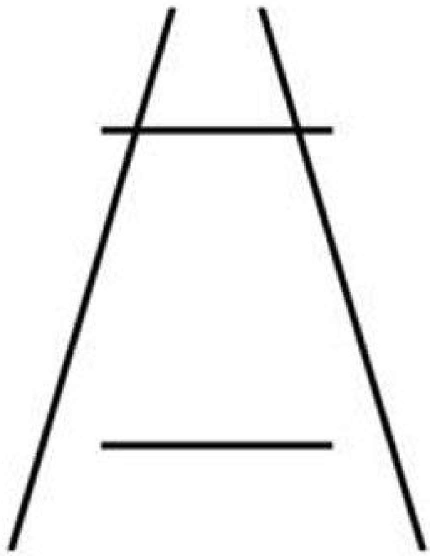


Picture 15. Optical Illusion (Muller-Lyer 1889)

Before jumping into illusions as an example of perceiving things that are not, it is important to mention that VR is not only about visuals. It is important to remember that different sensory modalities are more dominant than others in different individuals. Some receive information better with visual cues, in shape and colour; while others prefer audio-based information input. (Jerald 2015, 82) When designing content for VR, different sensory modalities should be involved in order to guide different individuals equally. The more data from different senses is available, the more credible it is considered by a human brain.

4.1.3 Optical illusions

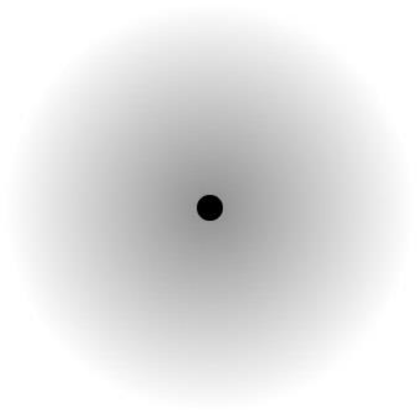
“Our brains have been hardwired to predict certain things based on repeated exposure over a lifetime of perceiving”. (Jerald, 2015, 60-62). To work efficiently and faster, the human brain seeks for already known patterns and suggests the outcome before even processing all the signals. Sometimes these patterns fail and when information processed is different from what is usually perceived or does not coincide with some other visual cues – illusions occur.



Picture 17. Optical Illusion. (Ponzo 1910)

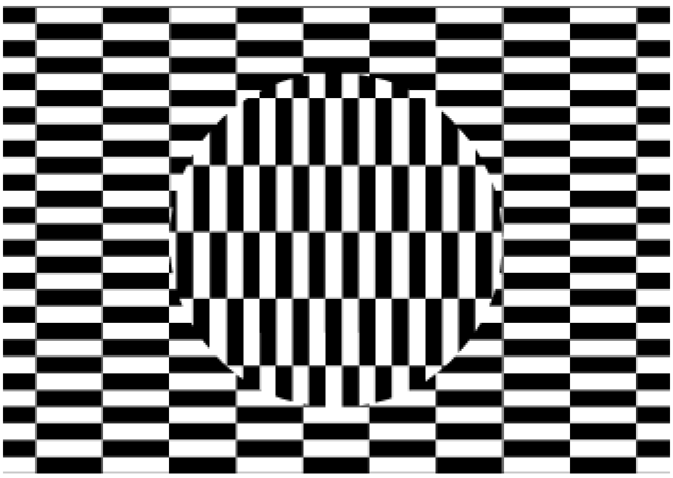
Picture 17 illustrates two lines that are the same length but the lower appears shorter. It happens because the upper line is perceived further away. Two vertical lines on the sides get closer above, as a road would shrink further it gets from the viewer. People are used to see rather in *three dimensions* than two, and this illusion is a two-dimensional picture with a false depth cue. Several cues exist that help the brain perceive depth. *Relative size* - objects further away are smaller; *texture gradient* – the further from viewer the less details are visible; *motion parallax* – object closer to viewer move faster than objects at far; *linear perspective* and *shadowing* are automatic visual processes that convey depth information. (Feldman 2005, p.136; Gleitman, Gross and Reisberg 2011, p. 200-203) Manipulating these cues will trick observer into seeing false distances.

Sensory adaptation is another reason for optical illusions. If the stimulus is constant for some time, the brain does not regard the sensory information after it has already been detected and analysed. (Gleitman, Gross and Reisberg 2011, 145)



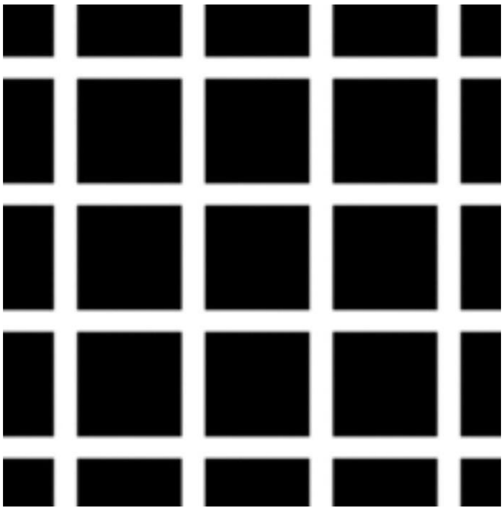
Picture 18. Troxler Effect (Troxler 1804, modified)

Picture 18 is an example of sensory adaptation. After looking at the dot for a while, the surrounding haze starts to disappear or shrink. The haze has very little contrast or other visual differences, therefore it is easier to “erase”. However, if one stares at the pictures with high contrast figures and sharp edges such as Picture 19, movement will be perceived.



Picture 19. High contrast image that will be perceived as moving. (Ouchi 1977)

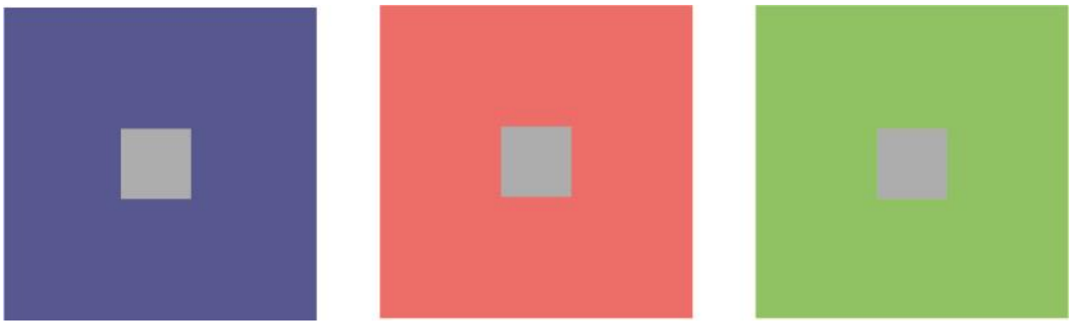
This happens because the difference in visual stimuli such as strong contrast and acuity - details, are perceived stronger. Slight unconscious eye movements trigger false movement perception. (Gleitmann et al. 2011, 165).



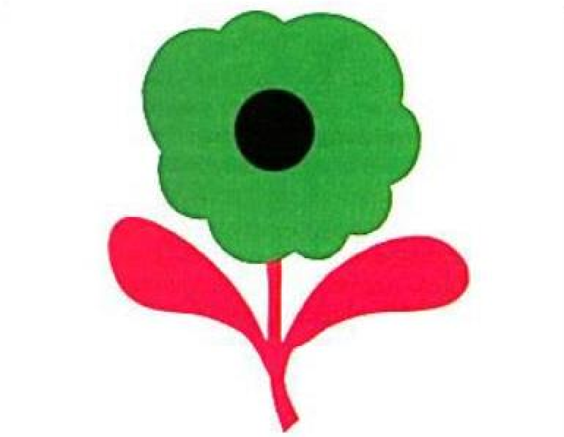
Picture 20. Black and white lines with grey dots appearing at intersections. (Hermann 1870)

The difference in brightness contrast also causes more illusions, like on picture 20. This illusion occurs because the difference in contrast helps the brain differentiate where one shape ends and another one starts. Thus, the visual system amplifies this process of distinguishing contrast and causes false perception. (Gleitman et al. 2011, 166)

Contrast illusions can also happen with coloured objects. Rods and cones are photoreceptors in the eye; first are sensible to light sensitivity and others are sensitive to light wavelength and details. Cones can be distinguished in three groups that are more sensitive to red, blue and green colours. Colour contrast causes perception of a complementary colour. (Gleitman et al. 2011, 169-171) For example, Picture 21 has a grey square inside colourful squares. The grey squares will acquire tints of approximate complementary colour of the surrounded square. In red square centre looks cyan or bluish; in blue square centre looks yellowish; in green – magenta.



Picture 21. Illusion of complementary colours. (modified seattleartistleague.com 2020)



Picture 22. Example of negative afterimage.

The complementary colour perception helps our brain to see the negative images. Look at the flower for a minute or two and then look at white space nearby. Blink and a negative after image will appear, showing the right colours of the flower - red petals and green leaves. This illusion is a combination of perceiving a complementary colour together with sensory adaptation – so called afterimage. (Thomson and Machpherson 2017)

Designing virtual experiences with perception in mind will help bringing the missing pieces together and fix the problems that comes from technology. To avoid motion sickness in VR, one needs to have an illusion of stability or avoid perception of movement. Placing users in vehicles is also a well-known trick to avoid motion sickness, as the vehicle blocks part of the moving visual field. Knowing that high contrast visuals cause wrong perception of dimensions it should be avoided. Correct depth cues should be applied to big background objects. Blurring edges that are displayed for a long time like in example with sensory adaptation, avoids perceiving unnecessary movement. Continued similar visual exposure can cause afterimages if a user looks at something plain. To convince users the environment around them is real, real world imperfections need to be simulated such as hazy mountains or a bigger moon closer to the horizon.

In the next chapter, several games are analysed and searched for good examples of perception psychology applied.

5 IMPLEMENTATION OF PERCEPTION PSYCHOLOGY INTO VR DESIGN

Implementing perception psychology into VR design is not new but not extensive either. In the case of vection, several methods are known that contribute to reducing movement in the visual field. It is advised during fast and extensive moving in VR to put the user in some transportation and block a big part of the visual field. (LaValle 2015, 240) The background during movement should contain less details to not fixate the eyes on the changes. The background can also be blurred for the same reason. Researchers also suggest that motion perceived from further away causes more vection than closer stimuli (Jerald 2015, 137; Howard 1986, 107) In real life, background objects are usually stable (mountains or a horizon line), therefore, when something big at the background moves vection occurs on a level of top-down visual processing - it is wrong for big environmental objects to move.

Now the research will review several VR games in order to find other perception psychology tricks that are used in VR design and how they help the experience.

5.1 Analysing popular VR games

The games that are chosen to be analysed are familiar to me and are popular VR games. They are popular on Steam and have positive reviews. Steam is an online library for games and by 2020 this platform has hit over 20 million concurrent users. (statista.com 2020) Steam has a sophisticated user review and ranking systems, where users can write reviews, rate others' reviews, sort games by reviews and see their friends' recommendations. (PCMag.com 2020; steam.com 2020) The analysis is made regarding information gathered in this thesis on immersion. The categories that are looked in the games can be divided into *technical* – functionality of the virtual environment; complex interactions; new skills and tasks and *psychological* – logical environment, social skills and side characters and emotional involvement with the application.

5.2 Pioneers: “Job Simulator” and “The Lab”

“Job Simulator” and “The Lab” are first VR games I ever tried. They truly are pioneers – both were release in 2016, together with the Oculus headset and HTC VIVE.

5.2.1 “Job simulator”

“Job Simulator” is one of the first VR games introduced in 2016. It is literally a job simulator; the story tells that 50 years in the future most of the jobs are done by robots, and professions such as auto mechanic or cook chef do not exist any-more. (Picture 24) These jobs can be experienced only virtually. Being a robot, the user gets to try these ‘ancient’ professions and do whatever they want to in a workstation setting. The game’s website claims that they have sold over 1 million copies and the game is still being mentioned in online articles like “Best VR games you have to try” 5 years after its release (indigames.com). This game was a good demonstration for abilities of VR equipment at the time providing a smooth and pleasant gameplay.

Picture 24. Job Simulator. (jobsimulatorgame.com 2016)

Interactions in the game are *physical* but not sophisticated: the user needs to pick up objects and place them somewhere else. Virtual spaces also adapt to the user’s available physical space, what is a good way to make the virtual world more appropriate. When starting the game, the user is asked the dimensions of the playing area they have, and the virtual places will scale accordingly. (Picture 25) This is a good example of adaptive virtual environment. Social interactions are limited to a mentor that guides the player in the first scene through the game mechanics and later with each job player gets customers. Dialogue is simple and these clients serve as a task – they ask for a specific service from the user.

Picture 25. Different scales of an office in Job Simulator – bigger on the left and smaller on the right (owlchemylaboratory.com 2016)

The motivation in “Job Simulator” is simple - to have fun. There is no narrative or other emotional connection; the player’s skills are not evolving. The game is short and only allows the experience of four different professions. It is a simple game that everyone can play, be they trying VR for the first time or an experienced user. Physical interactions enable different possibilities of achieving the same goal: you can make toast by putting a slice of bread into a toaster or building a tower from products and collapsing it on top of a pan to see what happens.

The environment fits the game’s motivational needs – it is fun, with a simple and appealing artistic style. All objects are toy looking, big and round, almost like inflated; robots levitate and so do user’s hands that look like big white gloves. Everything is responsive, can be moved or pushed. The style is consistent and unique.

I would like to point out an interesting design choice for the big white gloves. Developers of the game had a podcast and several blogposts on their website about the phenomena they called “tomato presence” that I consider a successful example of implementing perception psychology.

5.2.2 “Tomato Presence”

While developing the game, designers came across an interesting phenomenon with the user experience of object interaction. Several testing sessions reported that picking up objects was more intuitive *by replacing a virtual hand with an interacted object*. To pick up a tomato, the player takes a tomato with their virtual hand and once it is taken the hand is replaced by a tomato. Picture 26 illustrates this. (owlchemylaboratory 2016)

Picture 26. On the left - virtual hand is about to grab a tomato. On the right a player is holding a tomato (no hand visible, only the interactable object). (owlchemylaboratory.com 2016)

In podcast “Voices of VR” the developers tell how they had several testing sessions regarding how to pick-up objects. These sessions showed that users feel more natural when the tomato replaces the hand rather than holding the tomato in the virtual glove. (Voices of VR 2016) They called this interesting case “*tomato presence*”. (Picture 26) “Tomato presence” can be explained by perception psychology: holding an object is an action requiring several perception processes in proprioception. Proprioception is perception of self-body in space and physical forces applied to it or incoming from it. (Azim & Tuthill 2018, 1) Grabbing is a common interaction happening all the time and any errors in it will cause decrease in immersion. Introducing a new method of interaction that is consistent with the whole experience is more beneficiary than poorly simulated real-life action. A floating tomato feels intuitive in the world of “Job Simulator”, with levitating robots and hands.

The virtual hand in Job simulator is *slightly bigger* than a human hand in real life. This is done in order to fit the style of the game – cartoonish, low polygonal look and to create a feeling of wearing a glove. (Voices of VR 2016) Any errors that happen to controllers during game play will be easier accepted by our perception system because *it is not a hand but a glove*. This design introduces a new variable in direct communication between user and action. This imaginary glove might malfunction and cause less perception problems rather than a malfunctioning real looking hand would.

5.2.3 The Lab

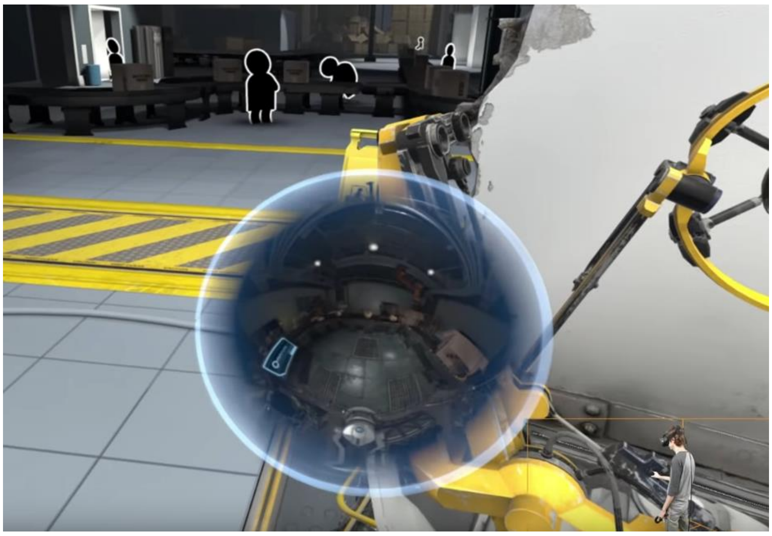
"The Lab" is a game made by Valve, the company that produces HTC VIVE and VALVE Index headsets. (Picture 27) "The Lab" contains more playing mechanics than "Job Simulator", however, they both are the same "sandbox" type games – do whatever you want. These two games were one of the first modern VR games and it feels these games were a showcase of VR being a gaming medium.

Picture 27. "The lab" (steam.com 2016)

Not much can be said about **motivation** in this game. The game does not have a story, it is a room filled with different demos. The player can improve their skills by repeating the gameplay and improving reaction time and there are point systems in some mini games. In a collective perspective there is no main motivational drive.

Interactions in this experience are hard to call physical, the controller remains to be the main bind between the user and the virtual world. The player needs to press buttons on the controller to activate actions. One interesting physical interaction of "the Lab" is teleporting into another mini game. To try a demo, the user needs to pick up a sphere and put it on their head. (Picture 28) This is another good example of using perception psychology in VR design.

"The Lab" method of teleportation into a new place helps with eliminating possible vection. By physically interacting with the world sphere (grabbing and moving it), our brain accepts that this world object *can move*. Any unwanted movement later in that world, be it lagging of the application or bad tracking, is perceived better because movement is already registered as a *previous experience* with this object. Jason Jerald in his book refers to another scientist - Howard I. P. from 1980s, who held experiments on perceiving the motion of big environmental objects. Top-bottom processing plays a more significant role in these actions meaning previous knowledge concerning environmental objects dominates over what users see. (Jerald 2015, 137,342; Howard 1986, 107).



Picture 28. "The Lab" sphere. (youtube/sadlyitsbradley)

One of the demos in “the Lab” is an archery room. (Picture 29) This demo introduces a good physical interaction. To shoot a bow, the user needs to use both hands: one to hold a bow and another to stretch the string. Translating direct motion of the player into the game in this distinctive way is something only VR games can do.

Picture 29.” The Lab” Archery demo (steam.com 2016)

The Lab does not have many social interactions. A little robot dog follows the player in the main room. If the dog is petted, the controller starts to vibrate. The player can also throw branches and the robot dog will bring them back. (Picture 30) Some enemy systems in mini games have simple artificial intelligence, as attacking the player, however calling that a social interaction is disputable.

Picture 30. The lab Dog playing catch with player and being petted. (youtube/sadlyitsbradley)

Environment in “the Lab” varies from demo to demo. No consistent style is present. Even though this game provides more things to do for the player than “Job Simulator”, each demo feels like a separate game. This is said from my own experience with the game. I can only propose, that if “The Lab” had more clear and structural connection between the mini games, other than them being a demo in this VR laboratory, it might be that the overall experience would be more coherent and complete.

5.3 Something different: “Boneworks” and “Beat Saber”

5.3.1 “Boneworks”

“Boneworks” is a new VR game introduced in December 2019 by company named “Stress Level Zero”. (Picture 31) I would like to talk about it because it is a new game and it was received by players as overwhelmingly positive. (Steam 2019)

The game was designed for headsets that allow accurate hand tracking because the game involves a lot of advanced physical **interactions**. The physics in the game are based according to a new system where every bone in a virtual body is connected and has physical impact on the virtual world. Users have a whole virtual body, not just hands. This method simulates direct physical communication with the environment in more natural and intuitive way. User can touch enemies, push them away, punch. Enemies can be shot from different guns or hit by different objects. (Picture 31 & 32) Physics is the main drive of the game, as the player needs to solve numeral puzzles to get from place to place by climbing or building passages.

Picture 31. Boneworks. (steam.com 2020)

When it comes to the social aspect of the game it does not offer much. There are enemies and those can be destroyed in many ways. The last chapters of the game introduce mimics – characters that look exactly like a player and mimic their movements. This behaviour for artificial intelligence is new and interesting to observe but it does not help the player to progress.

Picture 32. Player pushes an enemy away in Boneworks. (steam.com 2020)

“Boneworks” is a story-driven game, where the main character tries to escape the new virtual world. The main goal - the **motivation** is to get out. Through the game, the play character learns what has happened in this world and who they are. The story is *engaging* as it contains many mysteries about the environment and its unique inhabitants. No point or reward system exists in the game, players can collect and save different weapons, buy some souvenirs.

As mentioned before, the **environment** is designed so the player has several options to achieve their goal – for example, climbing over the gates or finding a battery and turning it on. Everything is designed that it can be interacted with in different ways. As it is a virtual world, spaces are mostly closed – museum, sewers or dungeons but once user gets out, the sky of the worlds is a grid of screens. (Picture 33) It creates the same illusion as in “The Lab” - the world is not real: it is a box made from screens. All the places in the game follow the same theme, abandoned and chaotic, displaying that something bad has happened there.

Picture 33. Skies in Boneworks (Markiplier 2020)

5.3.2 “Beat Saber”

“Beat Saber” is a game where the player has laser swords and slices flying cubes. (Picture 34) Figures fly according to the beat of the chosen song; in a main menu, the player chooses a song and then slices things to its beats. The game became popular because it is intense, graphically pleasant and has extensive choice of music.

Picture 34. Beat Saber (beatsaber.com 2019)

The **environment** is simple, the space is dark and only the main components have lights – figures and swords. Reflections and neon lights represent an arena or a stage, which fits the goal of the game, dancing.

The **interactions** are also simple – the player swings controllers to cut the cubes. The game expects from players good reaction and a lot of movement as cubes need to be sliced in a direction of an arrow on it. The rhythm the figures are flying is the song's rhythm. This game resembles old dancing arcades, hence the club like look of the environment. Even though the game does not have any social interactions incorporated in it, "Beat Saber" is played during parties or often in groups. Game's online community also provides different songs that players can download and play.

The **motivation** is a score system. I would suggest that rhythm plays big motivational role, however, I am not familiar how rhythm and systematic repetitive sounds affect perception. Watching people play, the drive in the game obviously exist.

The appeal of the game is its auditory guiding - moving to the beats. It is the only example of a VR game known to me, that emphasise audio information as much as visual. This game is a good representation of VR not being solely dependent on its visuals.

5.4 Game Changer? Half-Life: Alyx

Half-Life: Alyx (later in the article referred as HLA) is a game by Valve released in March 2020 (half-life.com 2020). The game became a selling point of the Valve's new headset – Valve Index. Once the new half-life was announced, headsets were sold out in the USA and Canada in a few months (Road to VR 2020).

Half-life is a well-known series of games. Two first games and a couple of episodes exist, the last release dated in 2006. (Picture 35 & 36) It has been 14 years since then and the series ended with the cliff hanger. Making a new HL game in VR did not come as a surprise to many, as the company implemented new mechanics in previous games too. The previous HL games impressed players with their cinematic approach and precise physics system. (Half-life 2020) HLA is a first full length (around 25 hrs) AAA game in VR industry. Triple A implies big company productions, such as EA, Ubisoft and Valve etc. These companies can spare big expanses on a full feature VR game. However, a resurrection of a loved franchise does not make any game a killer app for the industry. However, big online magazines as IGN and Tech-radar have been calling HLA a turning point for VR gaming industry. (IGN 2020; Tech-radar 2020) Why?

Pictures 35 & 36. Haf-life 1 on the left and Half-life 2 on the right. (steam.com 2020)

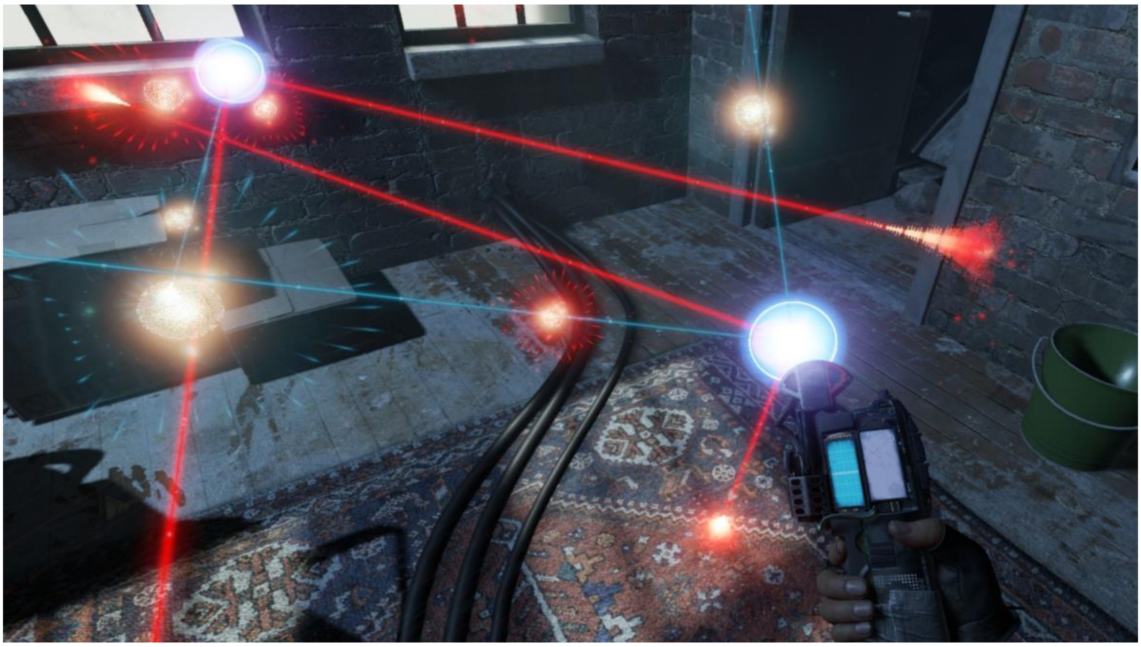
Picture 37. Half-Life: Alyx (half-life.com 2020)

The game is narrative driven and tells about a girl who journeys to rescue her father. The girl, Alyx, is a character from one of the previous games. In HLA Alyx goes to save her father, who is a member of resistance movement against authoritative state by an alien race. The **goal (motivation)** here is to get from point A to point B through tunnels and quarantined zones facing zombies, mutants and aliens. Different resources can be collected and then used in improvement of weapons. Resources are limited, becoming valuable later in the game and forcing users to think before acting. During the gameplay, the player meets different types of enemies and learns their behaviour and is forced (due to the lack of ammunition) to use these findings in order to minimise the loss of resources.

HLA is full of physical **interactions**. First, the player is given a pair of gravity gloves that allow them to pull objects or grab mid-air. This concept is not new for VR, however in HLA it has strong narrative connection – antigravity equipment is a big part of the game series. (Picture 38) The second game alone is based on a gravity gun. Therefore, gloves are not just a VR interaction here, they have big emotional impact as a nostalgic piece and are needed for the story.

Picture 38. Player uses gravity gloves to pull objects. (ChrisQuitsReality 2020)

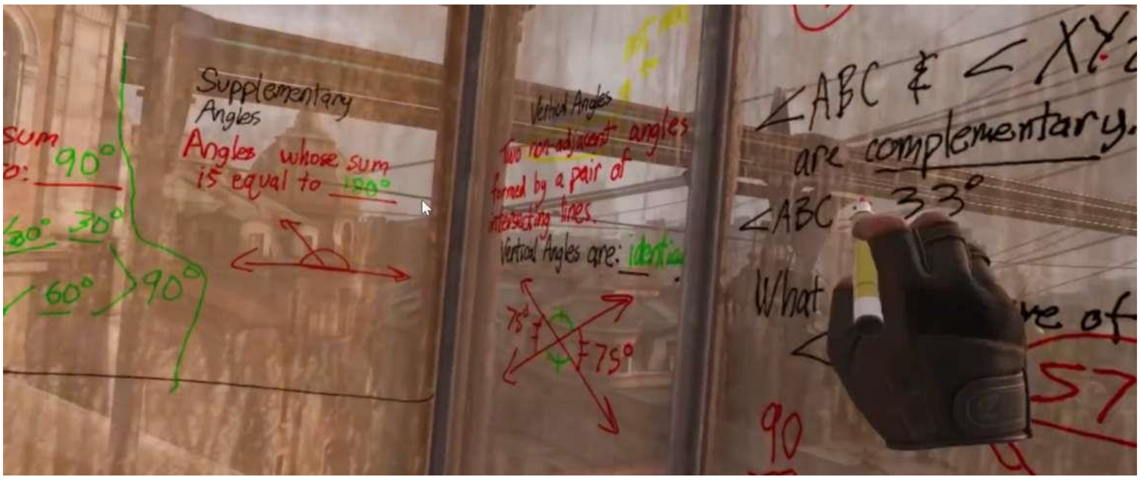
The game is full of three-dimensional puzzles. (Picture 39) For example, in order to unlock a door, player needs to connect some pieces in a 3D hologram. A lot of movement is involved in solving these puzzles: the user is required to turn valves and pumps, draw lines etc. Unfortunately, after a few hours of the game, the puzzles become repetitive, with three or four different types, but this concept of user's movement as a game mechanic is promising for VR.



Picture 39. Player connects blue spheres in a 3D puzzle. (Segers 2020)

Usually, firing guns in computer games happen by a single button press. In VR this process is more complicated. In HLA player needs to drop the empty magazine, take out a new one from the backpack (swing hand behind their shoulder), insert the magazine in the gun and cock it. It is a series of actions that involve kinaesthetic memory (memory of body's physical movements). No other media format can use kinaesthetic memory. This method of reloading signifies timing and makes shootouts more intense. "Boneworks", "Pavlov VR", "Arizona Sunshine" and many other VR shooters use similar reloading systems. Prevalence of this method suggests that it is effective

The opening scene of HLA offers player several interesting objects to interact with. First, a radio with adjustable knobs and antennas. Then a marker that can draw on glass surfaces. This marker was a big hit on the internet, people recorded videos drawing in VR and even solving math problems like in Picture 40.



Picture 40. Teacher explains geometry problem in VR. (Coomber 2020)

Not all objects are so specific with details. Later in the game player would see books that have no covers, lighters that cannot be clicked, cans that cannot be opened. It is strange when some objects that are clearly put in front of the player are interactable and others, in corners, are not. No distinctive line is set for physical interactions in the game – what can be interacted and what not. The player learns by trying. It is hard to claim that the environment is responsive for this matter. A questionable damage system is practiced in enemies in HLA. The player can damage enemies only by shooting a gun or can block an attack. The player cannot hit or push away an enemy or damage them with these in game objects. Enemies can harm each other. No clear consistency is visible in this damage system.

Social communications are limited in the game. The main character has scripted lines and exchanges information over a radio with the mentor figure that leads the player through the game. The lines are scripted, and player cannot affect these anyhow.

The **world** of the game is very detailed and well thought out. The surroundings remind the player that this is an apocalyptic world. The atmosphere of this game never keeps the player focused. Not being able to interact with everything, and enemies that do not always correspond to the physics system of this detailed world do leave a feeling of incompleteness.

In conclusion, HLA has good examples of physical interactions for VR, but not being consistent with them; offers a beautiful and stylised environment but not always responsive; gives very little social communication but also does not leave a player alone.

5.5 Conclusions on the game analysis

The analysis of the above games demonstrates what works for the current market and what could be better in terms of VR design. Well-functioning game environment and narrative create immersion and flow, what is important for perceiving reality. More sensory stimuli create stronger bonds between the player and a new world. The physicality of VR is a new dimension that no other media formats have. VR poses many challengers for developers, such as locomotion (how to move around without getting sick); 360-degree camera view and more computing power for rendering. The limitation of VR equipment requires new game design methods.

The next chapter describes a VR demo called *"VR Lab Rat #133"* produced to demonstrate some findings of the thesis. VR development requires moderate coding knowledge, and doing this project solely, no complex interactions were implemented. During my studies at TAMK I practiced creating three-dimensional environments and that is what I concentrated on in this demo. Optical illusions are the theme of the demo as I would call it a metaphor to VR: illusions demonstrate that not everything is seen as the way it is.

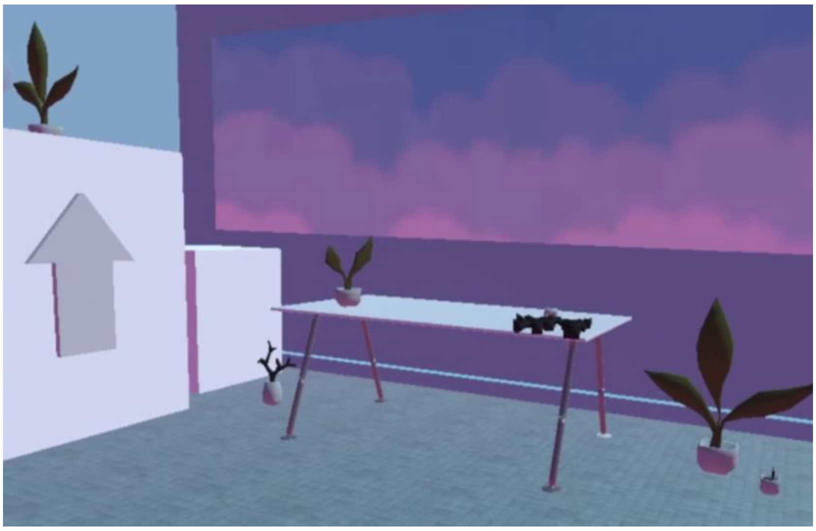
6 CREATING “VR Lab Rat #133”

Initially, a short VR game was planned with different optical illusions as puzzles to implement the findings of the thesis in practice. Another objective for the game was to explore optical illusions and visual phenomena in VR, how their effects change or reinforce in this medium. "VR Lab Rat #133" made has five different locations with different illusions. I specialise on creating environments and know how to implement basic navigations if free assets used. To apply my own methods of analysing immersion in this demo would be insufficient, as the end-product does not deliver physical aspects such as responsive world or artificial intelligence. I concentrated on “human” part – psychology and explored perception of visual illusions in VR.

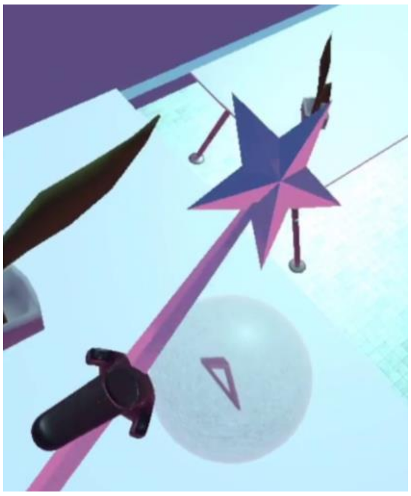
Testing this VR demo was intended, however, the development happened in 2020, when global pandemic hit. It was not possible to test the demo on users as it was strongly recommended not to gather people in groups. Using the same VR equipment also raises some hygiene related questions: how to disinfect the headset and controllers after every use. Unfortunately, no information on how this demo is perceived by other users except the developer is available at the moment.

6.1 Description of "VR Lab Rat #133"

The demo starts with the player placed in a laboratory looking room, some basic furniture pieces to interact with and pictures of illusions on the walls. (Picture 41) Two pictures in front of the user show how to use controllers and what to do. Pictures in this chapter are screenshots from the demo. The little rat in the room plays an audio where the same instructions are given. The main concept is introduced – a glass sphere and a magic wand; when these two items put together the surroundings change. The magic wand is located next to the rat and the sphere needs to be found. Big arrows help to find objects quickly.

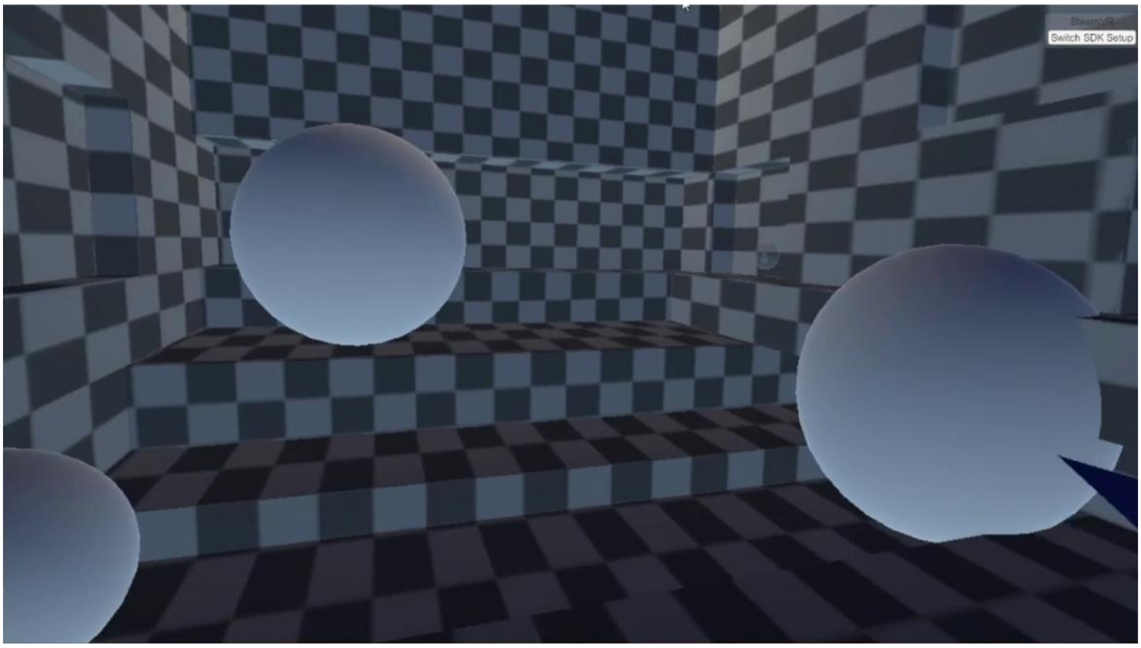


Picture 41. First room with some furniture and plants that can be grabbed.



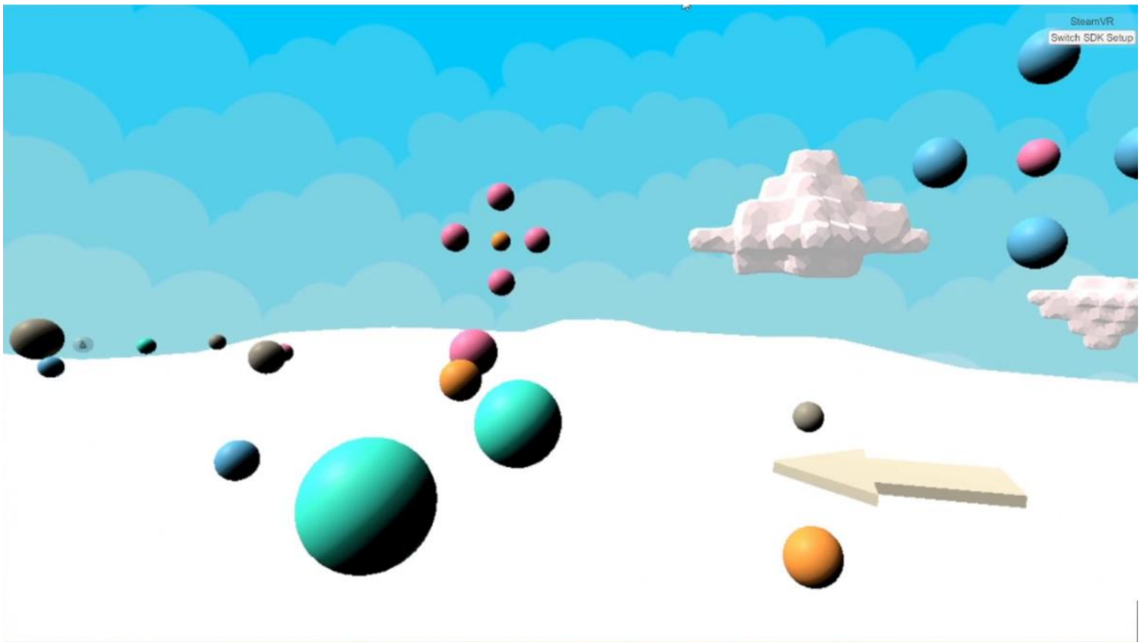
Picture 42 & 43. Main objects in the demo: the rat, the magic wand and the glass sphere.

The second scene of the game is a “geometry room”. (Picture 44) The room’s walls and ceiling are straight and flat, they do not look that because of the specific texture. This way I explore how monotone texture with high contrast affects depth perception.

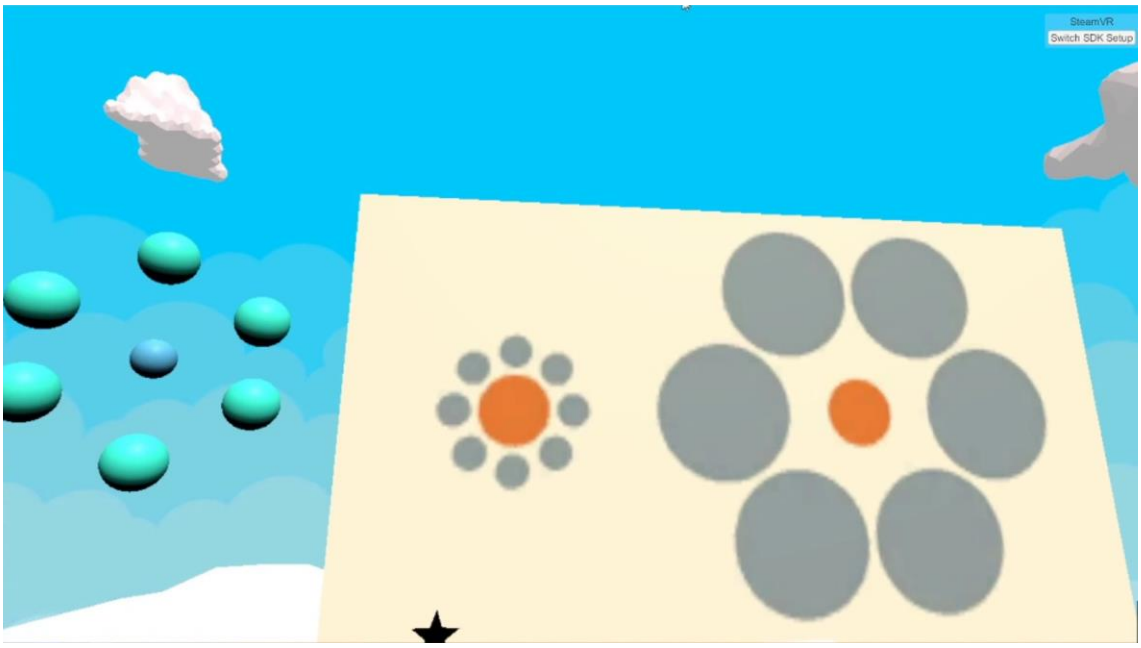


Picture 44. Geometry room.

The next place is clouds with Ebbinghaus illusion. (Picture 46) This illusion shows how tricky scale perception can be, how much we rely on colour, space around the objects and other visual cues. In the game, the player would be asked to find the right sized sphere among many others and spheres would fall from clouds. In the demo, the spheres are stable on the cloud and can be picked and thrown.

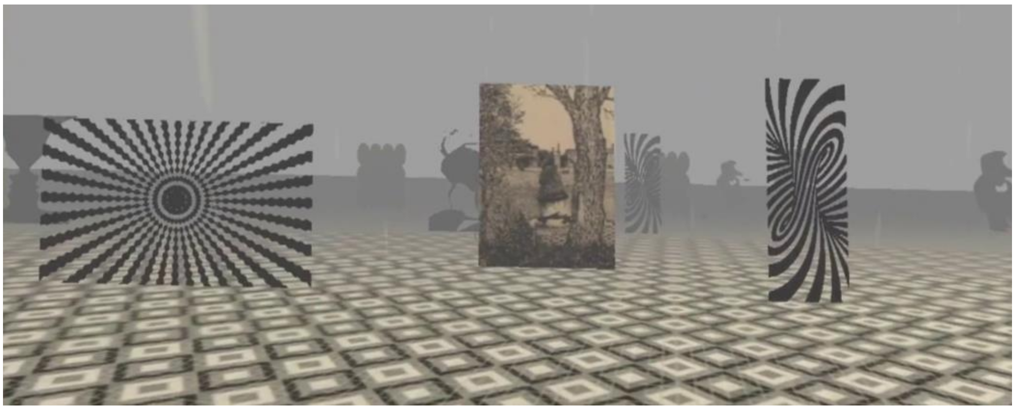


Picture 45. Spheres on the cloud.

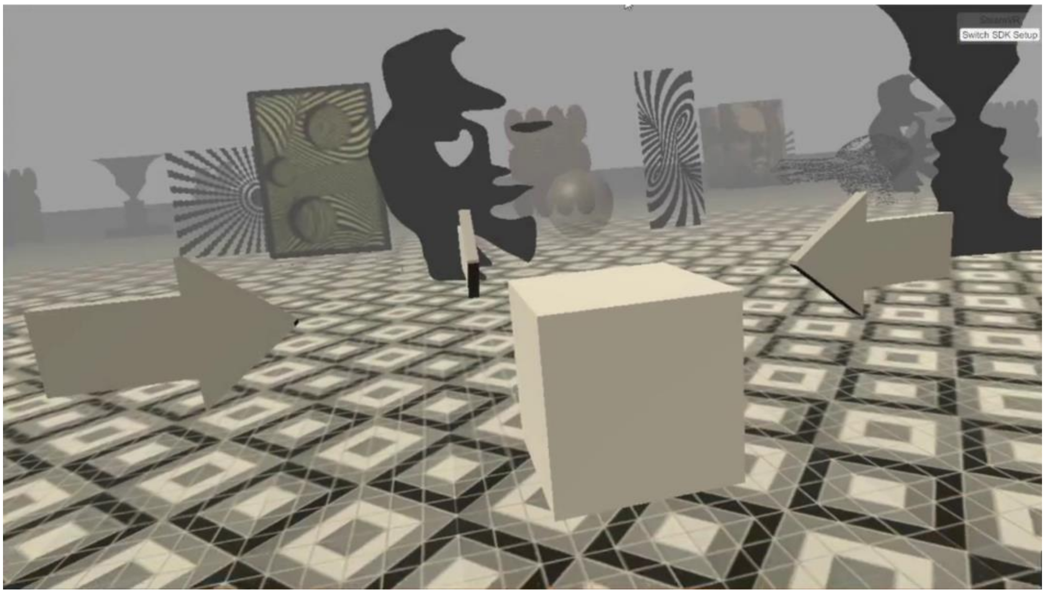


Picture 46. Ebbinghaus illusion.

The next place has very gloomy sky, it is raining and foggy. Face illusions are surrounding the player and they turn towards the camera, creating the feeling of being followed. (Picture 47) Perceiving faces amplifies the feeling of anxiety and in the initial game plan, a big narrative change would have happened.

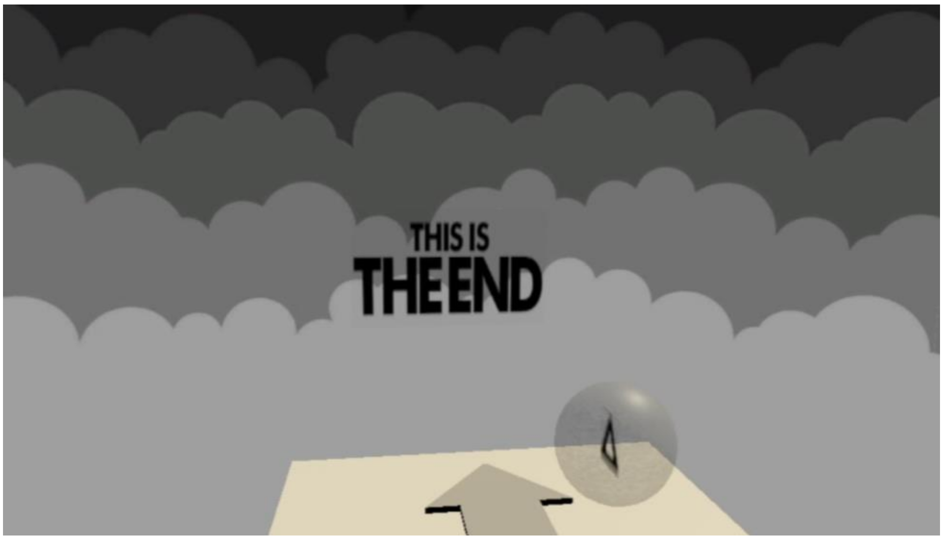


Picture 47. Illusions of following.



Picture 48. Arrows showing where the sphere is.

"VR Lab Rat #133" ends with the platform with the text “the end”. (Picture 49) Player can throw the rat from the platform. The demo can be downloaded from itch.io/liyap. (Appendix 1.) In appendixes I attach a link to the video of the play-through. (Appendix 2.)



Picture 49. The end of the demo.

6.2 Development process

Below the process of the demo development is explained more detailed: what software and sources used.

6.2.1 Software and framework used in the demo

The demo is designed for HTC VIVE headsets in the Unity game engine. It has many available resources online and accurate documentation. Unity also has been used in TAMK during my studies, therefore I am familiar with the software.

The framework for basic VR navigations and interactions used is VRTK (Virtual Reality Toolkit). It is a package of scripts that implement navigation, grabbing and teleporting. The problem with VRTK is that the scripts are not very flexible and modifying them according to your own needs is almost impossible. Other free framework alternatives were:

- Newton VR
- Steam VR interactive package

Newton VR does not have instructions that are up to date with new Unity and other in game assets. Steam VR interactive package is more difficult to implement than VRTK. This asset is more technical and involves modifying scripts.

Picture 50. VRTK logo. (unityassetstore.com 2018)

Three-dimensional models used in the game are custom made in Blender. (Picture 51) Two ambience soundtracks used in the game were downloaded from freesounds.com under royalty-free license. The voice-over for the rat was recorded and modified on a mobile phone. All of these were done by me.

Picture 51. 3D models from the demo.

6.3 Original concept for the game

The original story of the game is simple – the user is placed in several tests and asked to solve them. The tests are based on optical illusions. The user is accompanied by a small robot, in the demo it is a little rat that breaks down in the middle of the game. After breaking down the robot becomes an observer who can sees the test results. This character compares his artificial intellect and its superiority to the user. However, the tests were designed for human players and the robot does not perceive or understand illusions. The robot feels resentment and starts to mess with the tests. In the end this robot turns off visual stimuli one by one in order to illuminate illusional factors which results in complete darkness. In the appendixes I attach the script for the original concept. In the demo, the story is simple, the rat tells the user what to do and asks to find the spheres.

6.4 Conclusions of the demo

This demo combines the skills I received during my study time in TAMK: game development and 3D modelling. It is a short VR experience, done by a single person. It allows basic physical interactions, includes different visual approaches and it integrates simple audio use. The world is not responsive because of the lack of coding skills; it is visually consistent in its own weird way. Illusions appear in every scene. The interactions are walking and grabbing. Despite the simplicity of the interactions, I tried to create more complex game mechanics with what was given. In the first scene I had a ladder from simple cubes for the player to get up. In the scene with clouds, the spheres from the Ebbinghaus illusions have no gravity and can be launched into the sky. The rat is the only object relating to the social criterion. The voice-over is the easiest way to show its presence in the game and the audio also helps with adding more sensory data. Motivation in this demo is the shortness of the experience. After interacting with everything in the scene, the player has no choice but to move to the next place.

The demo demonstrates that creating a simple outline for a VR game is not difficult. It can be done with a free software - Unity has a license for personal use; scripts for VR navigation can be found in asset store as well as 3D models. Basic teleporting and grabbing with a bit of creativity can result into interesting solutions for simple game mechanics. Just bringing your own 3D environments into VR to look at them and walk around is exciting.

7 SUMMARY

To summarise this thesis, I would like to go through main aspect of each chapter and conclude them briefly.

Technology for VR is not perfect; however, it is progressing rapidly. In the near future, frame rate, resolution, data transfer will meet the requirements for VR to simulate human vision. As said before, technology is not the only fundament of VR. Psychology and its use in VR design need to be explored more thoroughly.

Immersion factors I condensed from different research are not the magic formula for good VR. A purposefully created experience to test these factors would be the next step to research immersion in VR. Nevertheless, combining these factors and analysis of the games we can confirm the factors below:

- Making interactions as physical as possible should be one of the main goals for any VR application.

However, when interactions involve major psychological concepts like the user's body or world environment, *a new intermediate variable* should be introduced. For the body concept it might be a costume or a new piece of technology like a glove in "Job Simulator". Thus, any malfunctions are easier accepted by our perception system. Environmental objects should not be visible or do not simulate realism and leave a possibility for them to be moving (a box of screens, a sphere, a virtual room). Letting users to move world objects beforehand will assure our perception system be familiar with the concept of this new world moving. *Reinventing simple actions* such as grabbing to fit the new environment will also result in increase of immersion like in case with "Tomato Presence". Once accurate hand tracking is enabled in new headsets, removing controllers is the next step. Activating different interactions can be done with help of *gestures* or specific hand movement combinations. This way user integrates *kinaesthetic memory* – movement memory. Imagine learning playing guitar in VR. Would it be possible with the controller?

- Social interactions in VR should be possible, be it between the player and generated characters, or artificial intelligence among themselves forming communities.

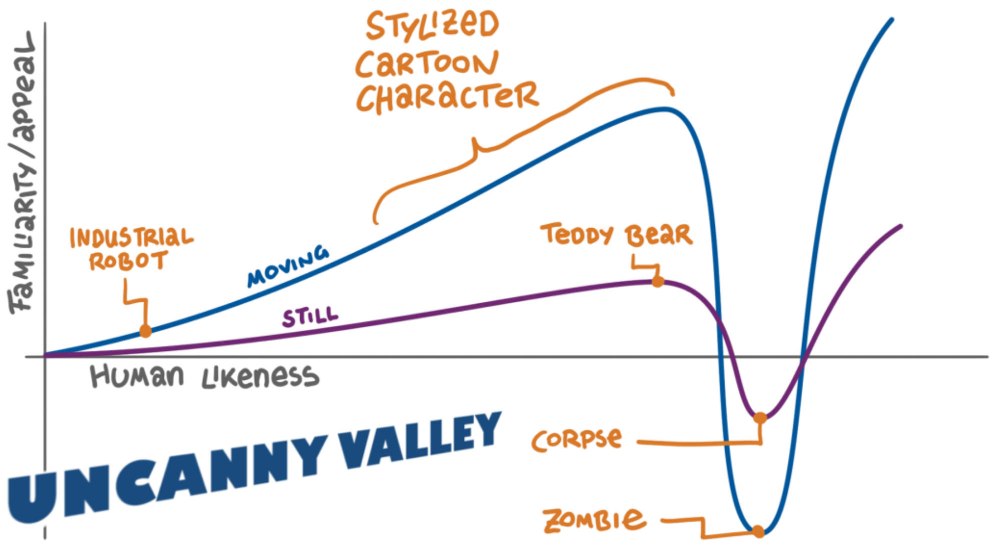
Human beings are social by nature and to leave them alone on their own in a simulated environment is not “reality” friendly. New technologies do offer artificial intelligence that has *voice recognition* and ability to form simple dialogues (intelligent assistants in smartphones and speakers, like Alexa and Siri). Having these kinds of social interactions in VR could benefit it.

- Virtual world needs to be responsive.

This depend on the technical execution of the experience. To keep the feeling of presence and flow, experience should be as smooth as possible.

- Virtual world needs to be coherent.

I would say that the virtual world needs to have a specific style that is constant throughout the game. When having an avatar or self-body representation in VR, it is crucial to remember about the *uncanny valley*. The uncanny valley is a term describing the relationship between an object’s resemblance to a human and an emotional connection to such an object. (Kageki, MacDorman and Mori 2012, 2) It is easy to go from a very cute character to completely unappealing one by trying to achieve full human resemblance. This comes from perception of other humans and face recognition; these features are highly developed and important in evolution process.



Picture 23. Uncanny Valley graph. (Engländer 2014)

As with *uncanny valley*, staying away from absolute realism is a better solution for current VR. Realism is not an option for VR as it cannot be naturally achieved yet because of the hardware limitations. *Anti-imitation* - an idea of 'life being a form of art' is better option for VR. Have you heard the phrase "life imitates art far more than art imitates life"? (Wilde 1891) To explain this author gives an example of London fog, as it became an icon of recognition for London once poets and artists started romanticizing it in their works.

Picture 52. Painting "Keelmen Heaving in Coals by Moonlight". (Turner 1835)

Immanuel Kant, XVII century's philosopher, argues that "beautiful art must look like nature, although we are conscious of it as art." (Kant 1790) He indicates that art does not need to feel real but to evoke emotional connections, excite and delight our imagination. Online magazine Medium published an interesting article "Kant against your Oculus Rift" by Marc Barnes. (Medium 2018) The writer shares the view that aesthetic experiences from media are more important than its technical progress. Media exists not because it is real but because it is something else, we lack in life. One day VR might become a reality it was supposedly to be an escape from.

- New skills, tasks or other means of motivation that require developing of skills will result in positive experience

To drive the user forward a clear goal needs to be established. This can be done as technical – point system, rewards as well as psychological – good narrative.

7.1 Further research

The ideas on improving VR design in this thesis are based on superficial knowledge of perception psychology and engineering. For serious VR development, more extensive research on this topic by a team of psychologists and scientists is suggested.

Testing is another significant approach for resolving current issues in VR. Simple experiences can be made to present different solutions for important VR interactions. For instance, locomotion and self-body representation does not have one prevailed method yet. Should user's virtual body be an intermediate object – costume/exoskeleton, or more natural looking? ESM like practice from chapter 3 can be applied during the testing sessions to establish what ways feel more immersive to users. If the virtual body is not natural looking, should its movements be slightly modified to fit the style and not translated straight as they are? Does the solution for locomotion rests in simulating human nature or VR equipment and its possibilities?

Immersion factors presented in this thesis should be tested. In this text they are theoretical and based on literature review, however, no testing was done to determine if these factors work in practice. Another step can be a more extensive analysis of popular VR games to expose what is received well by the audience.

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APPENDICES

Appendix 1. Link to download “VR Lab Rat #133”

https://liyap.itch.io/vr-lab-rat-13

Appendix 2. Video of play-through of “VR Lab Rat #133”

https://www.youtube.com/watch?v=B027iPeVc0s

FADE IN:

INT. WHITE LABORATORY

The game starts in a white laboratory. There is some furniture and other small and intractable objects lying around so user can start with simple actions like grabbing and moving. A little robot that looks like a LAB RAT, on wheels with cute face, approaches player.

LAB RAT

(beeping)

Hi, thank you for agreeing to participate in our experiment. It is very easy and fun. You have to complete several tasks with illusions. We want to see how your perception changes while being in non-real environment. I will accompany you throughout the tests and help a little.

A 3D shape of a PENROSE TRIANGLE appears in the room.

LAB RAT

By the end of each test you will find these impossible shapes. They will move you to the next level. Shoot a laser beam with your controller at it. Hold it, yay, here you go.

Impossible triangle rotates at the angle that it becomes impossible (all lines connect).

FADE OUT:

FADE IN:

INT. DARK ROOM WITH VIOLET DISTORTED GRID ALL AROUND

(continues)

User is in a small dark room with violet grid. Grid is distorted in some places creating small illusions of holes or bumps in the texture of walls, floor and ceiling.

LAB RAT (exciting)

Uuuh, what a cool place! Do you like these lines? You need to find a door here. I know, it doesn't look like there is one, but there is. I can give you a hint: look for the seams.

User walks around (there are also columns to block the view and to compel user into moving around).

LAB RAT

When you find a door, or anything resembling a door, knock on it three times. The door knob should appear.

When user finds seams (lines that are not connected) and knocks on them three times, an OUTLINE OF THE DOOR emerges together with a DOORKNOB. Behind the door there is another impossible shape - a cube.

LAB RAT

Oh wow, that was fast! Though I found it way earlier. Yes, I am actually not familiar with these tests but I am a robot so not distracted with the illusions and stay more efficient. Come on, new adventures await!

User shoots the impossible cube.

FADE OUT.

FADE IN:

INT: WHITE VOID WITH A PLATFORM

(continues)

Player is standing on a wide platform that has a basket and a pedestal in the middle. Robot drives to the platform.

LAB RAT

Very soon a sample object will be shown. Look!

Above the pedestal SPHERES of different shapes emerge. They form Ebbinghaus illusion where orange spheres in the middle look smaller than they are.

LAB RAT

Mesmerize the orange shape!

Spheres disappear after ten seconds.

LAB RAT

Oh no, I hope you remembered that orange sphere.

Robot drives to a basket. There is a button on the lid.

LAB RAT

After you press this button, you will get many-many different spheres of different shape and colour and you need to collect ones that were exactly the same size as the orange one demonstrated before.

After pressing the button different spheres drop from above. They roll over the platform and fall down from it. User has to pick up required spheres quickly.

LAB RAT

Yes, go for it, put them in this basket!

When the right sized sphere is put in the basket little confetti shower shoots out of it. Spheres drop again from above.

(continues)

4 (3)

LAB RAT

Oh no, I guess it malfunctions... Oh well it’s even more fun!

Robot drives around and beeps happily.

LAB RAT

You need to collect 12 of the right spheres to proceed to the next level. So, chop chop, don’t stop, I want more adventures.

LAB RAT

(whispers)

Why don’t I have my own basket? Could have been in the next level already…

The spheres keep dropping every twenty seconds. They change colour in order to make the task more difficult. The platform also changes colour. Robot gets hit by one of the falling objects.

LAB RAT

(fainted beeping)

Oh no.. wh.. Bzzt

Robot shuts down. (Needs to die before users completes the task).

VOICE OVER of a DEAD ROBOT that sounds different than before.

DEAD LABB RAT (O.S)

Oi, did not expect that to happen. Yeah, it’s me, still with you. Just, em, without a body? It’s fine, I can see so many things now! For example: our results. Oh what? There are only YOUR results... Maybe here? No. Oh I see, not a TEST SUBJECT, okay, alright…

(continues)

5 (3)

Dead robot stops talking.

When 12 right shapes are collected LOUD FANFARE sounds play out of the sky. Impossible Sphere appears. Robot sighs.

FADE OUT.

FADE IN:

INT. TALL ROOM WITH FRAMED PAINTINGS EVERYWHERE

User is in the tall room that looks like Harry Potter staircase hall with a lot of framed paintings everywhere. Paintings contain mostly illusions of faces or other interesting silhouettes that are perceived like personas.

DEAD LAB RAT

Your task here is to collect the white geometrical shapes that are scattered around. Bring them to the platform in the middle and I will tell you what to do next.

All around the room LITTLE WHITE PYRAMIDS, CUBES and SPHERES are hidden. Some of them are behind the paintings that stay on the floor leaning to the walls, some little shapes stand on the frames and some are on top of huge platforms that you need to climb.

DEAD LAB RAT

You know, I like it up here. I’m not limited to the faulty movements and restrictions of the environment anymore. Good luck climbing up those things.

After all shapes are placed on the platform, it starts to glow and shapes align into a SPECIFIC ORDER.

DEAD LAB RAT

Now you need to choose a shape that does not belong here. Take your time, think.

(continues)

(quietly)

I THINK it is a stupid test.

User chooses a shape that doesn't fit the order.

DEAD LAB RAT

Are you sure? I can't help you with this task. I truly CAN'T.

User chooses another shape or not.

DEAD LAB RAT

Put it in the centre.

A sword appears.

DEAD LAB RAT

Break the shape and find out if you were right. Inside the shape there is an impossible pyramid.

DEAD LAB RAT

Oh wow, what a surprise.

After shooting an impossible figure screen fades out more slowly than usual.

DEAD LAB RAT

(coughs)

Actually, there was no wrong answer. The clue was in every single shape. There was no pattern, just like no silhouettes or whatever you are seeing in the paintings.

FADE OUT

FADE IN

INT: DARK CAVE

7 (3)

User falls into a railcar that starts to drive. Surroundings look like an old mine shaft, rocks everywhere, torches on the sides.

DEAD LAB RAT

You can't really do much here, so just enjoy this sweet ride!

Railcar accelerates. It drives past different signs and warnings. There are many flashy lights that user passes by very fast. It causes motion sickness.

DEAD LAB RAT

Not enjoying much? Wait, there's a surprise coming.

A big spiky log falls from somewhere above. Booby trap. It goes through the user in virtual world.

DEAD LAB RAT

(laughing)

Isn't it fun? Okay, okay, you don't seem to enjoy this as much as I do, here, I'll make it a bit easier-

White fog starts to fill up the cave. Now warnings are not visible and flashy lights are far behind. User drives in a white fog.

DEAD LAB RAT

Now I have a task for you. Do you see the fireflies flying past?

Through the fog fly fireflies. They're quite noticeable in the fog and there are not many of them.

(continues)

8 (3)

DEAD LAB RAT

Try to catch those.

User catches flies and put them in a jar that stands in the railcar. Fog melts away. Scenery has changed. Now it’s a deserted plain with rare bushes and mountains in the back-ground.

DEAD LAB RAT

I am improving this experience for you! Look isn’t it lovely? I don’t think I can make it any better… Hmm…

Mountains start to disappear. Then bushes. Then all of the deserted plain fades out. Now it is only railcar, rails and fireflies.

DEAD LAB RAT

Oh, you should catch as many of flies as you can before they disappear too.

Use rotates around in order to catch all fireflies. This disorientates.

DEAD LAB RAT

Can you tell in what direction are we moving?

Railcar looks the same from everywhere, no back or front. Rails Disappear.

DEAD LAB RAT

Are we even moving?

Railcar disappears. User is in complete black void alone.

(continues)

9 (3)

DEAD LAB RAT

And what about now? Better?

THE END