BACHELOR THESIS

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VR changes in the last 5 years, and changes in the next 5 to 10 years

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Abstract

The goal of this thesis is to shed some light on the past, present and future of Virtual Reality to gain some insight into how the technology is developing.

Looking into the past of virtual reality lets us get insight into how the technology has developed and use it to find out where it could be heading.
Exploring the possibilities lets us prepare for what the technology may have to offer.

I have conducted open ended qualitative interviews with industry professionals to get detailed perspectives on the topics I have analyzed. The interviews consisted of a conversation where I was able to ask follow-up questions when something was unclear, or I felt needed clarification.

The result of my findings show that virtual reality is considered a maturing technology that is in its beginning stage. Virtual Reality is a technology in development with clear signs that the technology could become a huge industry.
Looking into findings such as the Gartner Hype Cycle and how virtual reality has followed the curve indicates that the technology is maturing and could become a sustainable technology within the next 5 to 10 years.

Other findings through interviews and research show that the current state of virtual reality may shift into an experience where the user can experience high quality virtual reality experiences without the use of a dedicated computer.

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1.0 Introduction

1.1 The background of the thesis

Virtual Reality is a technology and a medium which has the capability of becoming a huge industry. The medium itself is widely used as an entertainment technology and shows a lot of signs that indicate that the technology will become a sustainable and profitable billion-dollar industry within the next 5 to 10 years.

In this thesis I want to investigate what challenges virtual reality must overcome to advance and mature to become a sustainable technology, and how we could overcome these challenges. The reason why I have chosen this topic is to enlighten myself and prepare for the future as I want to work within the field of virtual reality development.

1.2 The purpose of the thesis

The purpose of this thesis is to shed some light on virtual reality's past, present and future to investigate what improvements have been made to the technology in the past, and what improvements could be made to drive virtual reality further as an entertainment technology.

I will be looking into relevant theory related to improving the technology and interviewing people with experience in the virtual reality industry to compare with the theory to see if there is any correlation between the theory and reality.

I believe this topic is important to investigate as it is advantageous to explore the possibilities of a medium to prepare for the industry if one is to seek a career within the medium.

1.3 Research questions

Research question 1: How has VR technology developed during the last 5 years?

Looking back at virtual reality's development the last five years, can reveal what the technology is capable of and how we could use the knowledge to our advantage if one were to work within the virtual reality industry.

Research Question 2: How could VR develop further within the next 5-10 years?

Looking into how virtual reality could develop may reveal insight that would be advantageous as one can prepare for what the technology has to offer and adapt to the new features that becomes available.

2.0 Theory

2.1 What is Virtual Reality?

Virtual Reality is a technology which has the capabilities of representing a virtual version of our own reality, with the ability to alter said reality through design and development. The technology itself is widely used as an entertainment technology, where it is often associated with video games. Using a computer-generated three-dimensional environment, a user can in real-time, interact and become influenced by the environment depending on its design and purpose.

"Virtual Reality: a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation (a virtual world)" (Sherman & Craig, 2018, p. 16)

Using large projectors or head mounted displays, a designer can take advantage of the user's visual senses by altering the positioning of the image through for instance head tracking, to calculate where the user is facing, and establishing a sense of direction. Stereo sound also plays a key role in virtual reality as when the user alters the direction they are facing, the sounds in the three-dimensional environment will change which ear the sound should reach first using the user's new direction. Making the user feel like they are within this world with more immersion than a standard video game.

"A typical VR system needs to know something about the user's head orientation and/or location to properly render the world from the user's perspective" (Sherman & Craig, 2018, p. 226)

The user is presented with two similar images, where one image is offset slightly to create a sensation of depth. Something we are unable to experience in a standard video game displayed on a standard monitor.

"Graphic images are displayed on a screen or a pair of screens (one for each eye) in the helmet or glasses. A position-tracking sensor tells the computer system where the participant is looking—or at least, where their eyes are. The computer quickly displays a visual image from the vantage point appropriate to the participants position." (Sherman & Craig, 2018, 2018, p. 17)

Virtual reality has a wide range of applications today from advanced high-end flight simulators with large projectors and a housing outfitted with a physical representation of a plane cabin, including real joysticks, buttons and pedals, used for pilot training. To low end, low cost applications such as a virtual reality headset for use as an entertainment technology.

"In vehicle platforms, you can either sit or stand to control, or pilot a virtual vehicle. Most often the user is presented with realistic-looking controls and accoutrements while the virtual world is displayed around the cockpit. Most people are familiar with the use of vehicle platforms in flight simulators; in fact, we sometimes refer to their use as the cockpit VR paradigm" (Sherman & Craig, 2018, p. 245)

2.2 What is Virtual Reality being used for?

One of the most commonly known application for virtual reality is in video games. The user wears head mounted displays otherwise known as HMDs, with lenses to cover both eyes. The lenses magnify a high-resolution screen, so the user sees an acceptable viewing quality. There is currently a wide range of virtual reality headsets on the market, the most known being Oculus Rift, HTC Vive, Samsung Gear VR and PSVR.

"The entertainment industry is one of the most enthusiastic advocates of virtual reality, most noticeably in games and virtual worlds. But other equally popular areas include: Virtual Museums, e.g. interactive exhibitions, Galleries, Theatre, e.g. interactive performances, Virtual theme parks, Discovery centers" (VRS.org, 2017)

For some of the VR headsets, the user can also use controllers that simulate the user's hands within the simulation or game, depending on what they are using it for.

FIGURE 2-1 Tusenfryd's Steampunk Hunters rollercoaster combining a physical rollercoaster with a virtual reality experience.

Other entertainment purposes including virtual reality movies and videos, virtual museums, galleries etc., where the user can experience a virtually physical presence is also available. The technology

has also been applied to roller coasters at amusement parks, combining the physical G-forces with the virtual experience creating very immersive feelings. One amusement park that utilizes this technology is Tusenfryd, located at Østlandet in Norway.

2.3 Where and when did Virtual Reality start off?

The concept of our current type of Virtual Reality is actually very old. The same way we trick our brain into thinking what we see is there and in front of us dates to the 1800.

FIGURE 2-2 Sir Charles Wheatstone's Stereoscope invented in 1838 compared to the Google Daydream from 2016.

The first ever concept device capable of viewing a three-dimensional image was British Charles Wheatstone's stereoscope invented in 1838.
By using two similar images taken from a slightly different pupillary distance simulating the distance of a wearer's eyes, and one mirror for each eye. The wearer would see the two images as a single three-dimensional image.

"Sir Charles Wheatstone researches stereopsis, and invents the stereoscope—a device that presents two separate photographs to the viewer, each photo taken from an offset to produce left and right view of a scene" (Sherman & Craig, 2018, p. 30)

This is the same method used for modern virtual reality headsets such as the Google Daydream. The differences with our modern devices are that instead of it being a still image being displayed, the images are animated as well as the wearer being able to interact with what they perceive and experience the outcome of their action.

The concept of Virtual Reality we are referring to today is only in its beginning stages.
The current experience of immersion is already convincing enough to give a sense of presence

in the virtual world. There are several aspects that can be improved upon to enhance the experience and increasing the level of immersion.

"When the user moves, the visual, auditory, haptic and other qualities that establish physical immersion within the scene change in response. If they walk closer to an object, it appears bigger, it sounds louder, and they can touch and feel it. When the user turns their head to the right, they can see what is there and react accordingly. If they grab an object, they can manipulate it—turn it around, pick it up, modify it." (Sherman & Craig, 2018, p. 660)

2.4 Content Creation

As virtual reality is a growing medium of entertainment, there must be developers who support the platform by creating content. Since virtual reality is a relatively new medium, there are few people who are experienced enough to create immersive and engaging content that would make consumers consider virtual reality a worthwhile investment.

"The biggest barrier to wide adoption of immersive technologies is the lack of good user experience design. 3D interface design is difficult and expensive, and there are few people with the necessary design skills to overcome these issues." (Smarter With Gartner, 2018)

Creating a market for virtual reality experiences will increase the value of a virtual reality device despite its capabilities. A growing healthy market with developers creating new experiences lets users get more value for their money, as there is more content available.

"The main goal of user experience design is to get users to just don their HMD and go to work. However, this is not solely a design challenge. Challenges such as eye strain and sound disorientation need to be overcome. Nobody wants to buy a device or an experience that gives you a headache." Tuong Huy Nguyen (as cited in Smarter With Gartner, 2018)

2.5 Hardware limitations and capabilities

Virtual Reality Headsets today are most commonly using a mobile phone, or integrated displays to display the images we perceive in our virtual experiences. But currently these

displays do not have high enough resolution for the pixels to go by unnoticed. Increasing the pixel density and the pixel resolution in the displays could significantly improve the perception as it will be harder to tell that the pixels are there.

"A visual display's spatial resolution is often given by the number of pixels, or dots, presented in the horizontal and vertical directions where one "dot" may have subdots for the separate color elements. One way to measure resolution is the number of dots per inch (dpi). The size of the screen also affects how well the pixels blend together—that is, how discernible the individual dots are. A smaller screen with a given number of pixels will look much crisper than a large screen with the same number of pixels." (Sherman & Craig, 2018, p. 264-265)

However, having a higher quality image means that it will take longer for a computer to render the image than if it was a lower resolution. This could eventually mean that a consumer would have to pay for a more powerful device to render the images quick enough. If the device rendering the images does not do it quick enough, the user will start to experience latency. This can be a very nauseating experience and could cause motion sickness as the recommended frame rate for a virtual experience is 90 frames per second. At this point, it begins to be very hard for the user to see the individual pictures to the point that it's unnoticeable.

"To reduce the likelihood of nausea in VR experiences, where virtual motion can lead to vection, the visual cues normally presented to the user's peripheral vision can be diminished or eliminated, thus circumventing the offending stimulus." (Sherman & Craig, 2018, p. 157)

"Motion sickness is caused where the visual simulation suggests lack of movement, but the vestibular system recognizes that there is movement" (Sherman & Craig, 2018, p.157)

2.6 Haptic Feedback

The current senses that are being utilized and manipulated with current Virtual Reality technology is vision, hearing and the sensation of touch.

Haptic feedback is a way of receiving information about objects in our world. We are experiencing haptic feedback daily. Everything we touch lets us feel its surface texture, weight, size and other attributes that a specific object has.

"When it comes to believing something is "real" the haptic sense (our sense of touch and proprioception) is quite powerful. By coming into physical contact with an object, its existence is verified" (Sherman & Craig, 2018, p. 357)

Development in haptic feedback can be a game changer for Virtual Reality. There are already many products on the market that utilize haptic feedback in games. A standard video game controller uses motors that spin when certain actions happens in a game, creating vibration. The vibration in the controller can be generated on a specific frequency to make the player feel different sensations.
A short weak vibration could for instance tell the player that they have fired a single shot from a weapon, while several short and weak vibration on an interval equal to the weapons fire rate, can tell the player they are firing multiple shots. If the player is experiencing an explosion, the vibration would feel stronger and last longer.

Several modern video games such as Call of Duty and Battlefield are using this feature to let the player feel more immersed in the game while simultaneously giving relevant feedback about what is happening in their surroundings.

"A convenient factor of the specific vibrotactile rendering is that it is perhaps the easiest to display -simple vibration generators are inexpensive and fairly small and thus can be integrated into other displays or input/output controllers (as have become the norm for game controllers." (Sherman & Craig, 2018, p. 443)

But developing a haptic feedback device that goes beyond the norm, comes at a cost. Most devices are highly specific to the task they are designed for, and it must be convincing enough to feel real.
There are currently haptic feedback suits and gloves being developed for Virtual Reality that stimulate the sense of touch. Some devices are using motors to create vibrations, the same way as a video game controller would, while others use pressure or deformation that push the skin when encountering a restricting force.

"Pressure , or deformation of the skin is another type of sensation. An array of pressure-inducing transducers applied to the palm and fingers could be used to express the shape of an object within the user's grasp"(Sherman & Craig, 2018, p. 443)

2.7 The limitation of space and movement

One of the limitations of virtual reality today is that most people using the technology are limited within the confines of their own space. The user can walk around in the world they are experiencing, but their movement is often limited by the size of the room they are in due to physical space or sensor range. For this reason, many VR games navigate using the controller instead of the actual movement of the user, using teleportation or moving with the press of a button. Depending on what the theme of the game is there are several ways a developer could create movement without the player physically having to move around. For instance, if someone were to develop a snowboard game. The player would not have to physically move but bend forward and backwards to steer the snowboard in the right direction.

One way endless walking can be solved is by using an omni directional treadmill. Similarly, to a traditional treadmill, you can walk as far as you want, without leaving the position you are in. An omni directional treadmill works in the same way, but rather than only letting you walk forward, you can walk in any direction. But with this technique there are several challenges to overcome. Health concerns such as imbalance can cause the user to fall and hurt themselves. Additionally, they are clunky, expensive, doesn't work that well yet and may be hard and expensive to maintain due to moving parts that experience wear and tear.

"Omni directional treadmills are sophisticated devices that permits the user to physically walk in any direction with the treadmill actively moving them back to the central area of the space. It is possible for the momentum of the user in conjunction with the movement of the treadmill to cause imbalance for the user. This situation is problematic both for its presence-breaking nature as well as the potential safety hazards. The safety issue is currently addressed by having the user wear a harness to prevent them from falling" (Sherman & Craig, 2018, p. 244)

2.8 Mobile Virtual Reality

Today our modern mobile smartphones are capable of a lot of things. Our flagship smartphones today are about as powerful as the top laptops from five years ago.
If we compare a Samsung S10 plus to a MacBook Pro from 2014 we can see that the specifications are on par with each other.

	Samsung S10 plus (2018)	Samsung S5 plus (2014)	MacBook Pro (Mid 2014)
Screen Resolution	1440 x 3040 pixels Dynamic AMOLED	1080 x 1920 pixels Super AMOLED	2560 x 1600 pixels LED-backlit display
Processor	8-core, 2.7 GHz	4-core 2.5 GHz	2-core 2.60 GHz
Memory	8GB RAM, 12 GB RAM	2 GB RAM	8GB RAM Upgradable to 16 GB RAM
Storage	128GB, 512GB, 1 TB	16GB, 32GB, Micro-SD up to 256 GB	128GB, 256GB, 512GB, Upgradable to 1TB

Flagship smartphones today have the required computational power to render virtual reality simulations. Additionally, virtual reality relies heavily on the user being able to look and move around. Devices such as gyroscopes and accelerometers play a heavy role when it comes to this feature.
"Given that these devices are also computers that can render 3D computer graphics as capably as a desktop of a few years ago, it makes sense that the phone itself (or tablet) could be used as the main component of a VR display. For many, smartphone-VR will be their first personal exposure to a VR experience; and for others, it may be the way they most frequently experience VR." (Sherman & Craig, 2018, p. 331)

With a headset such as Samsung Gear VR and Google Daydream. The user can simply slide their phone into the headset, put in on and be immersed in a reality constructed by the developer. Not only does this have a huge impact on price, but also ease of use.

With a headset such as the HTC Vive and the Oculus Rift, the user must be tethered to a computer that is running the simulation, unless they pay for a more expensive wireless option. Mobile virtual reality allows the user to move freely around without having to worry about tripping on wires and bumping into sensors.

The technology in these phones are powerful enough to convince users that the things they are experiencing feels real enough to be immersed in the world.
There are also standalone virtual reality headsets in development such as the Oculus GO that does not require a smartphone or any additional equipment to be used.

2.9 Virtual Social Medias

In 2014 Facebook acquired Oculus, creators of the low-cost head mounted display device to be used in virtual reality. Their intention was to use the technology to develop a social media platform where people could meet each other virtually and share their experiences.
This platform called Facebook Spaces is available today and can be experienced with a Oculus Rift or a HTC Vive.

"It is notable that Facebook bought Oculus VR for $2 billion with the idea of VR being a social computing platform." (Sherman & Craig, 2018, p. 633)

The experience allows people from far and wide to meet up in a virtual world where they can hang out and share experiences, for instance showing of their new home, as illustrated in the Facebook Spaces teaser trailer.

"Social hangout: A space which exists primary for participants just to be together with friends or a community with common interests is an area of VR that has been long anticipated." (Sherman & Craig, 2018, p. 749)

3.0 Method

As I wish to go in depth within the topics, I have decided to use a qualitative approach where I interview 3 industry professionals with experience within virtual reality. The qualitative approach lets me compare the answers from experienced people to see if there is consistency within the answers, which opens a discussion about the topics. I believe its important to use a qualitative approach as the topics rely on information from qualified personnel that have experience within the industry to get a clearer frame of reference.

Additionally, to the interviews I have conducted literature searches to get more coverage on updated and detailed information regarding the topics with detailed explanations from sources that play major roles in the virtual reality industry.

3.1 Interviews as method

Using interviews will let the subject describe their experience with their detailed opinion, the interviewer can make sure they understand the subject by repeating the answers from the subject and saying for instance "if I understand you correctly" and "so you are saying" etc. The subject can correct mistakes and if they detect any and the subject could get a good feeling that they are being understood by the interviewer. As stated in Oxford Bibliographies: Interview Methodology.

"The interview can vary from a spontaneous conversation to a highly structured, closed interview style associated with social survey research. Semi structured or open-ended interviews are commonly used in qualitative research." (Heather Hamill, 2014)

Interviews are also a good method to get some depth into the topic and when we want to get into the details of our explanations. The interviews may not give a perfectly clear image of the topics in discussion, but as I am interviewing people within the industry with experience in virtual reality development, it will be important to get their perspectives on what is to come in virtual reality development.

I have used an interview guide that was structured with questions that I expect would answer my research question. The guide includes the questions I would like to get answered while interviewing. I have used open-ended interviews, as it allows me to explore the statements and perspectives that the interview subjects are portraying. It lets me get deeper insight into the topic as I can ask follow-up questions that the subject can answer in more detail if

something is not clear. The guide lets me compare the answers so I can investigate what the differences from each interview reveal.

To make it easier for the interview subject to follow the interview I decided to ask the questions in a natural order so that all the questions can be asked in a structured manner to avoid distractions and confusion.

I was also able to record the interviews so I would not be distracted by having to write down everything said. It also let me go back and listen to what the interview subject said in more detail to get a clearer answer and to make sure that I got their statements right, After the interview, I listened to the recording and created a transcript of the conversation.

As I am writing this paper to learn and gain experience researching I decided to try to use as few academic terms as possible, both for my own understanding of the questions and answers, as well as making sure the interview subject understood me and my questions correctly.

3.2 Interview Guide

For the interview guide I decided I wanted to ask questions that can go in depth without being complicated to answer.

Question number one was, “When did you get involved with virtual reality, and how has it changed since you got involved.”

Getting some insight into how professionals have experienced the development of virtual reality lets me get an understanding of what changes that matters to industry professionals and what these changes has done to develop the technology to the point it’s at now.

The second question was, “What are some of the biggest challenges virtual reality has to overcome to become a sustainable technology, and how long do you think it will take?”

As there are several challenges to overcome, its important to shed some light on the ones that may affect virtual reality the most. Hearing from professionals what they perceive to be the largest hurdles can give us insight into what to look out for while working with virtual reality, so that when these hurdles are passed, we will be able to take advantage of the outcome and adapt to it quicker.

The third question was “What do you think some of the major developments regarding haptic feedback will be within the next 10 years?”

Utilizing haptic feedback to increase the immersion of an experience is already happening, but if we can find out what new ways of haptic feedback can be displayed, we can get an advantage in development processes as we can adapt to these new features.

The fourth question was “How much influence does the mobile market have on virtual reality and how do you think that will change?”

Using our smartphones to experience virtual reality is a common way today, but how will the virtual reality market rely on mobile phones in the future? Will virtual reality still use smartphones as a common way to experience virtual reality, or will they get replaced with devices such as standalone head-mounted displays?

The fifth question was “How could we overcome the challenge of limitation in space and movement?”

Since virtual reality is an experience which should be immersive, it would make sense that someone would be able to walk around in the virtual world unrestricted, but currently one of the problems is limitation of space and movement. We are always restricted to the confines of our own space. So how could developers solve this issue?

I decided to initially ask five questions that could be answered in detail, this proved to work out well as the interviews ended up lasting about 25 to 30 minutes. The questions let the interview subjects answer a lot, where I got a lot of useful information. I wanted to go for a few questions that would give broad answers as it lets me go in depth in each topic.

3.3 Literature searches

When researching, I have investigated sources such as publications and reports to get some insight into what’s going on and what is being developed to enhance a virtual reality experience, and to find out where virtual reality is headed.

“For professionals, they are useful reports that keep them up to date with what is current in the field. For scholars, the depth and breadth of the literature review emphasizes the credibility of the writer in his or her field. Literature reviews also provide a solid

"background for a research paper's investigation. Comprehensive knowledge of the literature of the field is essential to most research papers." (The Writing Center)

The information I have collected are from large companies with information that is detailed and explained which makes is more reliable than articles from for instance a news media as news articles tend to shape the story in their favor to gain more monetization.

3.4 Ethics, personal privacy and anonymity

All the interview subjects where handed an Interview Consent Form where the subject can read what terms they are accepting and what right they have regarding their statements and information.
The consent form asks the subject for permission to record the interview and the interview subject can decide if they want to receive a copy of the transcript of the interview and other data collected to make sure that the data is correct.

The subject can decide if they want their name published or not, where if the subject wants to stay anonymous, they will be given a fictional name that cannot be identified.

As the interviews were recorded, I created a transcript of the recordings and deleted the recordings the same day. This was done to make sure that interview subject would not be identified if they would like to remain anonymous.

4.0 Analysis and discussion

The results from the interviews and the literature searches have given me insight into the topics. The interviews with industry professionals have showed me their perspective on what is going on within the industry, and how they perceive the future of virtual reality, such as how the mobile virtual reality market will develop and how high quality virtual reality can be experienced by visiting facilities that rent virtual reality gear at a low cost. The interviews were consistent where the subject seems to agree on several aspects within the industry.

Though literature searches I have found information from market analysis companies such as Garner and Statista, and companies with influence within the industry such as Nvidia. Information such as the Gartner Hype Cycle have showed that Gartner perceives virtual reality as a technology that is maturing and on its way towards being a sustaining technology, where data from Statista regarding virtual reality sales confirm that the virtual reality industry is growing. The information from Nvidia shows how Nvidia have developed techniques to overcome challenges in virtual reality such as limitation of space and movement.

4.1 A maturing technology

As virtual reality continues to develop, it will reach a point where the technology and content is appealing enough to major consumers, that they are willing to spend their money on a device. The current prices of a devices today that can render virtual reality is significantly lower that the prices we had five years ago. The technological aspect has also improved through hardware development, increasing its computational capabilities.

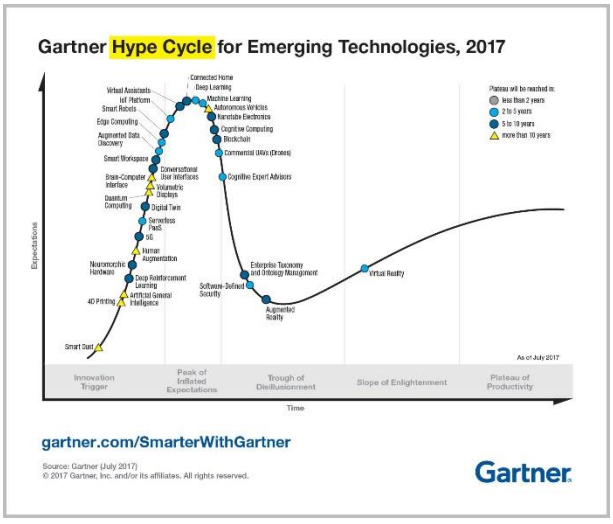

FIGURE 4-1 The Gartner Hype Cycle from 2017 shows virtual reality in the Slope of Enlightenment.

If we investigate the Gartner Hype Cycle for Emerging Technologies from 2017, we can see that Virtual Reality appears in the Slope of Enlightenment, where it is estimated to reach the Plateau of Productivity in 2 to 5 years.

As it develops, people will gain more experience in development using the technology.

However, if we look at the same cycle from 2018, Virtual Reality is nowhere to be found. One would expect to see Virtual Reality to move further into the Plateau of Productivity. But that did not happen. Shortly after the publication of the 2018 Hype Cycle, Gartner clarified the situation to German VR publication VRODO that *"The technology is rapidly approaching a much more mature stage, which moves it off the emerging technology class of innovation profiles"* (Gartner, 2018)

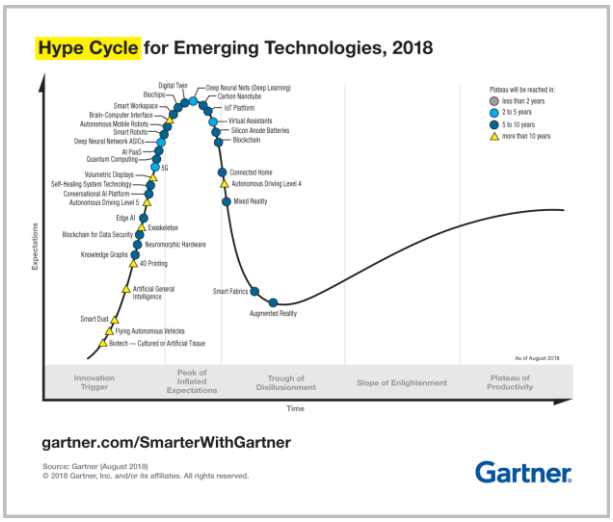

FIGURE 4-2 The Gartner Hype Cycle from 2018 where virtual reality is no longer present on the curve.

Virtual reality is really starting to gain traction. If we look at statistics from Statista, we can see that virtual reality video gaming revenue is increasing and is expected to reach 22.9 billion US dollars within the end of 2020.

The technology is showing a lot of signs that it is a valuble and growing industry.

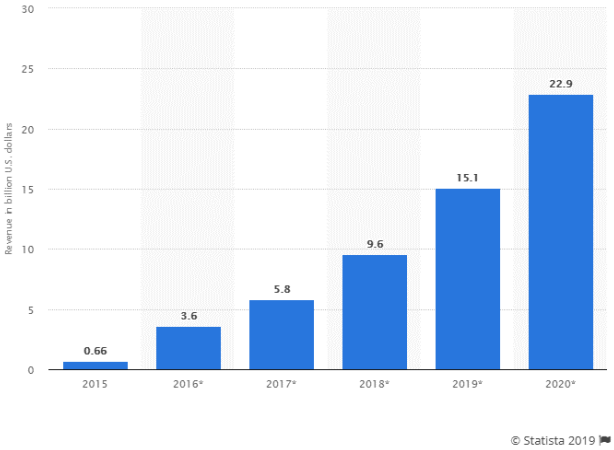

FIGURE 4-3 Statista's revenue graph showing growth in sales from 2015 to estimated sales in 2020

4.2 An introduction through smartphones

As our flagship smartphones become more and more capable of rendering 3D worlds, Smartphones could be a great introduction to show of what a virtual reality experience could offer as they are very easily accessible.
In an interview with Brad Plaxen, narrative designer and associate project manager for Defiant Studios, says

"Samsung VR and Google VR and things like that, I think they have two very specific purposes. But neither of which are going to radically shift the tectonic plates of the VR

industry. The first real usage I think of them as, is like a gateway drug. They're kind of like an introduction to the technology for people who've never tried it. But I don't think they are a legitimate platform for wide reaching massively successful virtual reality."

The smartphone virtual reality experience doesn't offer the same quality as a standalone or tethered experience does like the Oculus Rift and HTC Vive, but as an introduction, the experience could let the user know what they would be getting into and if it seems interesting enough for them to invest in a higher quality device without spending a fortune on equipment.

Brad continues to say *"So I think it's really great for introducing people to virtual reality who have never tried it, but as time goes on there will be fewer and fewer people who have never tried virtual reality. So the need for a technology to be an introduction gateway to it will become less and less because more and more people will have tried it."*

The Samsung Gear VR was released back in 2015, while Google released their Google Daydream in 2016. Oculus on the other hand has not developed a smartphone reliant device. Instead they are focusing on standalone devices with built-in displays that does not rely on a designated desktop computer to render the 3D world, such as the Oculus Go and the Oculus Quest. As of now neither Google nor Samsung seems to be working on a new virtual reality device.

Melissa Schoeller, Co-Founder of Presence Interactive says in an interview, *"Right now the mobile market is the most accessible way to get VR in the home, but unless suddenly someone figures out how to make consumers think of their cell phones as more than just casual game devices for the train, no one is going to use their mobile devices that way. I highly suspect that the way to get VR in people's homes is through more accessible standalone head-mounted-displays, similar to the Oculus Quest, rather than trying to leverage the power of mobile phones."*

What this could mean is that the smartphone VR market may become obsolete in time as it gets replaced by superior devices such as standalone Virtual Reality headsets. Headsets that would work in the same way as a standard video game console, where the buyer would get all necessary equipment in one box at a much lower price and ease of use than headsets that rely on dedicated computers.

As Sarah Tan, Gameplay Engineer at Against Gravity, says *"As for VR which use a mobile phone as the display, I think they'll die off in the next few years. Given a standalone and a mobile VR headset with the same specs, standalones beat mobile VR in every aspect, from price, tracking, heat management, performance, etc."*

4.3 Unrestricted movement in our virtual world

Solving the issue of movement within the space where the user is located could prove to be a hard task. There are a few methods that have come to light, one of them being Omni directional treadmills. But these devices are currently clunky, expensive and doesn't work that well. The current Omni directional treadmills of today have several issues that may not be solved within the next 5 to 10 years as the technological refinement that has to be considered has to be finetuned to a level that may not be possible with the current technology of today.

When asking Brad what he thought about these devices, he replied *"I've used one and they're awful. They're so bad."* When asking Melissa the same question, she replied, *"Yeah those are awful. They're awful and they might get better, in fact they probably will, but they're expensive and they take up a ton of space. Somebody who's already space limited in their home and doesn't have enough room for a room-scale Vive setup is not going to have enough room for an omni track."*

One place we may see an omni directional treadmill if they ever get to a satisfactory level are in location-based facilities, where a customer would rent an hourly experience.

However, the American technology company Nvidia in collaboration with Stony Brook University and Adobe, recently did research on how to solve this issue. The way they do it is by tricking the brain using a method called "Dynamic Saccadic Redirection".

FIGURE 4-4 Nvidia's Dynamic Saccadic Redirection technique that rotates the camera when a user performs a saccade. The user is not aware of the rotation and therefore believes they are still walking forward.

"Saccades are rapid, ballistic movements of the eyes that abruptly change the point of fixation."
(Purves, Augustine, Fitzpatrick, Hall, LaMantia, McNamara, Williams, 2004, p. 457)

At the exact moment we move our eyes, our visual system ignores the visual input we get from our eyes, and instead replaces the visuals with the next thing we see. The effect from this eye movement causes an illusion called the “Stopped Clock Illusion” that can be experienced daily, and most people have probably noticed it already.

By tracking the users eye movements, the rotation of the camera can be shifted as soon as user performs a saccade. The result ends up being that the user thinks they are walking forward in a large room, but in fact, they are walking in a circle in the smaller room they are physically in.

“We propose a redirected walking technique that can apply to small physical environments with static or dynamic obstacles. Via a head- and eyetracking VR headset, our method detects saccadic suppression and redirects the users during the resulting temporary blindness. Our dynamic path planning runs in real-time on a GPU, and thus can avoid static and dynamic obstacles, including walls, furniture, and other VR users sharing the same physical space” (Nvidia, 2018)

On the other hand, there are other ways to partially solve the issue of movement.

A way a developer could use the limitation of space to their advantage is to design the experience with the space in mind. With SteamVR’s Room Scale method, a user can assign the space they have at their disposal and from there on walk around and interact with everything within that zone. If a user walks to close to the border of the zone they have assigned, a wall will appear in front of the user, visually letting them know where their play area is.

Sarah says *“Developers can create adaptive experiences which dynamically scale the virtual play space bigger or smaller (see Job Simulator), design experiences which don't require much movement (see Superhot), etc. Most headsets with inside out tracking are also capable of remembering multiple physical playspaces, so consumers who can't afford a dedicated playspace can play in multiple locations at home or just move stuff out of the playspace when they want to hop into VR.”*

Developers could potentially use this feature to dynamically change the levels to fit the size of the room assigned by the user. That way the user could walk around in the virtual world and only be restricted to the design of the experience, not just reality.

On the other hand, Brad thinks that the physical movement in virtual reality is something that a player thinks they would like to do, but in reality does not. As he says in the interview, *"For Vive you have the whole room scale. So I think people thought if you have up to 10 feet by 10 feet, then people are going to want to run around and all that. But the reality of the situation which I don't think people knew three and a half years ago was that most people don't really want to run around, and they don't really have the space to do that. It's kind of exhausting. And so, I think a lot of the design has shifted towards thinking about what makes for the easiest experience. And I don't mean easiest in terms of difficulty, I mean in terms of access."*

Creating an experience that could dynamically change to a player's room size could prove to be hard, as a developer needs to make sure that their experience would be able to work in a room of any size. It could be better for a developer to focus on an experience that would work in any room size instead as we experience in most virtual reality games released today.

4.4 Creating a marketplace

For virtual reality to be attractive to a consumer there must be things to do. The more things there are to do, the more attractive the platform becomes. One of the things that will change is more content becoming available as developers are creating experiences for consumers. Similarly, to how video game consoles are sold today, virtual reality devices might become independent platforms, like the PlayStation 4, or the Xbox One. Where developers create experiences the same way video games are created for consoles.

Melissa says, *"If I'm spending four hundred dollars on a Vive, I don't want to have to spend another thousand dollars on a computer. But what Oculus is starting, is having these standalone headsets like the Oculus Quest. You need those standalone headsets and then you need that content that everybody's playing to get people to buy it. I know so many people who started playing Nintendo games and bought Nintendo devices because of Smash and Zelda. We need content that gets people excited about wanting to buy a headset so they can play the*

latest hit game. And neither of those things have quite happened yet, but I do think it's going to happen within the next five years."

When companies start making bigger and better experiences that could be compared to standard AAA games, virtual reality could gain a lot of value. But now, most of the experiences that have been developed, are either made by small indie-game companies, or they are short and small experiences that engage the player for a short while.

Once virtual reality gets some "Hit" games, it may increase the value of the devices, and its market by a huge amount.

4.5 Virtual hangout

One of the experiences highly anticipated to be developed for virtual reality is social platforms. A social platform where people from far and wide can meet up in a virtual world and experience things together could bring a lot more attention to the medium of virtual reality.

Brad says in an interview *"I think the number one biggest hurdle is VR needs to become a social platform. It needs to be a networked social platform with powerful multiplayer experiences that individuals can do with their friends or else it's never going to gain traction. Or not never but it's going to take a much longer time."*

Getting people to have fun while experiencing the content they are delivered may prompt them to start recommending the content to their friends and family, as getting more people to join the experience will let them have more people to share their experiences with, while simultaneously building a user base.

Brad continues to say *"the number one driving factor in sales, and this is true of almost every industry, is peer recommendation. You know when your friends and family are telling you that you should get it."*

Bringing social platforms into a virtual world could also create a social pressure where if people are not a part of the experience, they may experience fear of missing out. As Brad states later into the interview *"the second a product or a technology becomes social then*

suddenly if I want to do it with my friends, my friends need to have it. If you have two or three of your friends who are all interacting on a virtual reality platform together and you are not yet on that virtual reality platform. Not only are you going to feel like you're missing out, but your friends are probably going to be asking you, hey when are you going to get one, when are you going to get one? You need to get one so you can join us"

This social pressure and fear of missing out could pressure people into buying a device of their own. If their experience is entertaining enough, people will recommend others to get in on the fun.

4.6 Location based experiences

To experience virtual reality to an extent where the player would be fully immersed is both hard and expensive. The highest form for experiencing virtual reality will probably not be in your own home, but location-based facilities with more expensive gear such as a full body tracking and haptic feedback suits. These facilities would be able to rent the gear to their customers for a limited time, where the player can have a networked experience with or without their friends.

Melissa says *"even now, you can go to a warehouse where you put on a VR headset and a backpack, and play VR laser tag with a bunch of your friends. And that is only going to become more popular and more present, because you can charge people for it to recoup the costs of the high-end VR equipment."*

Location-based virtual reality facilities could charge per hour, where the amount of experiences can be endless, these facilities could theme the experiences and have an assortment for different games with different stories that the customer can experience. Theses experiences could also include haptic feedback gear which brings the customers into a new level of immersion, where they can not only see and hear the world they are in, but also feel it and interact with it in a way not possible with a home-based system.

Melissa says *"There's full on body suits with haptic feedback, and they're only going to get better. Right now they are so expensive, they are not something you're going to see in a person's home. But probably in the next few years when you go to one of those VR arcades you're going to get a fancy StarVR headset and you're going to get a fancy haptic feedback*

suit, and then you're going to go into a fully immersive zombie killing environment with your friends."

In the same way we go a visit a Go-kart track where the vehicles and equipment are expensive. Melissa believes that within the next five years, we will be able to go to a location-based facility and experience virtual reality with a higher quality and immersion as these facilities allow people to experience virtual reality without having to buy all the gear themselves and having a bigger space to interact with. Not many people have their own Go-kart but renting a Go-kart and a track at a facility for an hourly sum is an industry within itself and is very common for most people.

5.0 Conclusion

By looking into how virtual reality could change within next 5 to 10 years, we can get an understanding of where the technology is heading. Through interviews with industry professionals and literature searches I have investigated the status of virtual reality to see whether virtual reality would be a profitable and sustainable technology for industries to adopt or not, and how it could be adopted. What has been revealed is that virtual reality is a maturing technological medium.
Due to the vast amount of virtual reality application I have limited my work to focus on the entertainment purpose of virtual reality.

Today's way of gaining easy access to virtual reality, is by using a headset that supports a smartphone, the experience is not as high quality as a virtual reality experience using a dedicated computer and will probably be used as an introductory experience.

For people who want to experience a higher quality virtual reality experience, a standalone headset would be the way to go. This is because as Melissa mentioned in the interview, a virtual reality headset that also requires an expensive computer would be too expensive. A standalone virtual reality headset would offer a high-quality experience, right out of the box. Similarly, to how we use our video game consoles today. However, if someone wants to experience a full on virtual reality experience with devices such as haptic feedback suits and gloves, they could go visit a location-based facility that rents these devices for an hourly fee.

Virtual reality does have a problem when it comes to moving around in our own space, but there are several ways to deal with this problem. Some are expensive and will take many years to develop, such as an omni directional treadmill, and some are cheaper such as NVidias Dynamic Saccadic Redirection. There are also ways the developer could deal with the problem of space and movement by designing the experience in a dynamic way, where the experience would take the players room size into consideration, such as Steam's Room Scale.

Virtual reality also needs a marketplace where there are enough high-quality experiences to purchase. If the companies making these virtual reality headsets wants to attract more users, there needs to be value in the product. Having a lot of content where the player can pick and choose experiences that are interesting will add a lot of value to the technology. These

experiences could be developed by both 1st and 3rd party where things like exclusivity and AAA-Games could play a big role.

Multiplayer experiences with the ability to socialize could be a way virtual reality gains a lot of attention. Once something becomes social, it lets people share their experience. Virtual social medias are already available, such as Facebook Spaces. This digital socializing can make someone feel like they are missing out if all their friends are on the platform having fun while they are not part of the shared experience. The pressure of not being a part of the experience could push more people into buying a device of their own.

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Interview Consent Form

Research project title: *VR changes in the last 5 years, and changes in the next 5 to 10 years*

Research investigator: Espen Lindahl

Research Participants name: _____

The interview will take no more than 20 minutes. I don't anticipate that there are any risks associated with your participation, but you have the right to stop the interview or withdraw from the research at any time.

Thank you for agreeing to be interviewed as part of the above research project. Ethical procedures for academic research undertaken from Norwegian institutions require that interviewees explicitly agree to being interviewed and how the information contained in their interview will be used. This consent form is necessary for me to ensure that you understand the purpose of your involvement and that you agree to the conditions of your participation. Would you therefore read the accompanying information sheet and then sign this form to certify that you approve the following:

- the interview will be recorded and a transcript will be produced
- you will be sent the transcript and given the opportunity to correct any factual errors
- the transcript of the interview will be analyzed by Espen Kvamstrø Lindahl as research investigator
- access to the interview transcript will be limited to Espen Kvamstrø Lindahl and academic colleagues and researchers with whom he might collaborate as part of the research process
- any summary interview content, or direct quotations from the interview, that are made available through academic publication or other academic outlets will be anonymized so that you cannot be identified, and care will be taken to ensure that other information in the interview that could identify yourself is not revealed
- any variation of the conditions above will only occur with your further explicit approval

I also understand that my words may be quoted directly. With regards to being quoted, please initial next to any of the statements that you agree with:

	I wish to review the notes, transcripts, or other data collected during the research pertaining to my participation.
	I agree to be quoted directly with my name published.
	I agree to be quoted directly if my name is not published and a made-up name is used.
	I agree that the researchers may publish documents that contain quotations by me.

All or part of the content of your interview may be used;

- In academic papers, policy papers or news articles
- On our website and in other media that we may produce such as spoken presentations
- On other feedback events
- In an archive of the project as noted above

By signing this form, I agree that;

1. I am voluntarily taking part in this project. I understand that I don't have to take part, and I can stop the interview at any time;

2. The transcribed interview or extracts from it may be used as described above;

3. I have read the Information sheet;

4. I don't expect to receive any benefit or payment for my participation;

5. I can request a copy of the transcript of my interview and may make edits I feel necessary to ensure the effectiveness of any agreement made about confidentiality;

6. I have been able to ask any questions I might have, and I understand that I am free to contact the researcher with any questions I may have in the future.

_____ _____

Participants Signature Date

_____

Participants Contact E-mail

_____ _____

Researchers Signature Date

Contact Information:

If you have any further questions or concerns about this study, please contact:

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