ABSTRACT

A Rogerian Case Study Seeking the Future of VR:
Responding to Dr. Sutherland's Ultimate Display

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Throughout this thesis I will measure the progress of virtual reality (VR) development. I cover the history of the format starting with pre-film technology all the way through the commercial failure of the Virtual Boy. From here I address the development boom of the 2000s that resulted in the first generation of consumer VR and proceed to analyze the current market offerings from the three biggest companies currently investing in VR. These are analyzed through the theoretical foundations provided by Rogers and Kozmetsky, to establish a baseline from which to compare these different ways of interpreting consumer needs. This is synthesized into a Futures Cone projection that attempts to define what the future course of the industry looks like, with the understanding that these observations will undoubtedly change.

A Rogerian Case Study Seeking the Future of VR:
Responding to Dr. Sutherland's Ultimate Display

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DEDICATION

To Mom, Dad, and my grandparents. Thank you for cultivating a scholarly mind within me as I grew into who I am today.

CHAPTER ONE

An Introduction to “The Ultimate Display”

Background

Innovation is driven by the interaction between human creativity and curiosity. This is embodied by the relationship between science fiction and technological development. There are numerous examples of technologies, once seen in books or on screen, that have been translated into real life by an enterprising fan. Whimsical cosplayers trying to recreate props they saw their favorite characters wield are not very far from industrious inventors trying to reproduce technologies they have seen in their favorite shows. While many viewers may see the latter as an attempt to recreate nothing short of magic, these creators are powering the advancement of technology as a whole. It is the purpose of an innovator to think outside the box and to try to bring a new perspective to their field. Small moments and discoveries can shift the course of humankind dramatically. The concept of using the 3D illusion caused by using two images from slightly different points of view for entertainment has been around since the mid 1800’s. However, for the majority of their lifespan, 3D illusions and later virtual reality (VR) were only seen as gimmicks or toys. Even with this expectation coloring each advancement in technology related to it, VR has gained traction in the areas of training and simulation, hinting at its potential use as a tool. For the purpose of this study, a speech given in 1965 about computer displays will serve as the foundation from which to explore the future of virtual reality and where that untapped potential may lie.

In his speech to the International Federation for Information Processing Congress of 1965 titled “The Ultimate Display”, Ivan Sutherland paints a picture of modern technological development that seems almost prophetic. He describes the computational limits of the bleeding edge of technology of the day and reflects on the possibilities that those limits imply. He ends by describing the ultimate display that the speech is named after. It is a computer-controlled environment in which the user would be fully immersed, in other words: virtual reality (VR). Usually this type of speculative literature is limited to the New York Times Best Seller list, but “The Ultimate Display” demonstrates the ingenuity and open-mindedness that is needed to push technological innovation into a new era of user experience. In the spirit of that speech, the goal of this thesis is to investigate what the future of VR may hold by applying a Rogerian analysis of the diffusion of innovations in a society, to the trends that have defined the development of VR throughout its history. Synthesizing this information with insights gained from analyzing the market offerings put forth by the three biggest VR hardware production companies will help to generate a market forecast and establish the state of the market nearly sixty years after Sutherland’s presentation.

Echoing Sutherland’s description of the ultimate display, Sherman and Craig state “Many theorists consider the ultimate goal of VR to be a medium without a noticeable interface” (51). The distinguishing factor that separates VR from its other entertainment counterparts: reading, cinemas, and television, is its intent to immerse the viewer into the interactive world of their entertainment. VR blocks out the outside world in order to bring the audience into a seamless virtual experience in much the same way that a movie theater or a book would. Reading a novel creates a sort of mental immersion that can

make readers pass hours reading through their favorite story without hardly a change in position (Sherman and Craig 382). In a very similar way movie theaters seek to provide a cinematic experience with the fewest distractions possible. However, none of these options are as ubiquitous today as the television, even though it is built on a more social concept of entertainment than the isolation insinuated by the other two mediums. Television broadcasting is built on the national experience of sitting around the TV, and watching the "free" programing provided by the networks (Cook 384–85). "Video dropped into the middle of a new social revolution: the mass exodus to the suburbs, new realms of leisure, rising incomes, and a tremendous demand both for things and for entertainment that had been pent up by a war and depression" (Elliott 341). VR is now dropping into a world that is shrinking thanks to the proliferation of social media, making it easier than ever to be involved in social movements and the world that had been just out of reach up until now. This connection begs the question: How does the social climate in which VR is growing affect its visibility? It is no wonder that in this ever-shrinking world an entertainment platform built on this kind of social movement would take the economic lead. This is where VR can stand out from its peers. It is a system that allows for the facilitation of social environments that can make global communication as easy as breathing. "Once you've assembled your digital self, you'll be able to create, dance, work, shop, love, explore, play, and learn in thousands of virtual locations…" (Otto 1). With VR competing against several other forms of entertainment it brings up the question: What is VR?

Defining Virtual Reality

Some philosophers would define virtual reality to be anything that can be perceived that is not real (i.e. large paintings, books, Pompeian 360° frescos, etc.), or as Kant might argue everything is virtual because, "There is no access to the thing-in-itself" (Otto 7). However, as fascinating as this late-night coffee shop conversation would be, this is not particularly helpful to establish a working definition for VR that will help to navigate the future. Instead the definition can be distilled from the needs that VR should meet. In a research guide from 1993, Robert Carande states, "Virtual reality must provide a computer generated environment in which one or more characteristics of the user's physical presence are isomorphically represented within the environment" (xiv). This definition does well to cover a range of virtual worlds in which people interact. However, it does not consider the immersion and feedback that Sutherland brings up in his speech. "The ultimate display would, of course, be a room within which the computer can control the existence of matter" (Sutherland, "Ultimate Display" 2). The four elements of virtual reality as defined by Sherman and Craig create a definition that looks forward to the possibility of the ultimate display existing. " The key elements in experiencing virtual reality – or any reality for that matter – are a *virtual world, immersion, sensory feedback* (responding to user input), and *interactivity*" (6).

Having been referenced countless times by other scholars looking into the future of virtual reality (Burdea and Coiffet 4, 5, 21; Carande xi; Cook 883; Sherman and Craig 26, 28; Sutcliffe 9), Ivan Sutherland created "The Ultimate Display", not as a speculative work but one that carefully addresses the realistic possibilities present in its contemporary technology. This was done by applying a real world

understanding of the technological landscape of the time, to extrapolate a reasonable picture of the future possibilities of that technology. In his presentation, Dr. Sutherland discusses the broader implications of the technology being developed in his day, through a lens focused on the future ramifications of current discoveries. His precise and concise speech conveys a deep understanding of the viability of the technologies of the day. In order to evaluate the current state of the industry and attempt to look into the future, there are three elements to look at: history, technology, and the diffusion of ideas. This will help to establish a current state and future goal for the industry, in much the same way that Dr. Sutherland did in his speech.

CHAPTER TWO

Breaking Down "The Ultimate Display" and its Roots

Dr. Sullivan begins "The Ultimate Display" by addressing the predictive nature of human interaction with the outside world. "We sense an involvement with this physical world which gives us the ability to predict its properties well" ("Ultimate Display" 1). He uses this idea to specifically delineate the most useful characteristic of the computer display, its ability to simulate a reality that has not been explored yet. "It is a looking glass into a mathematical wonderland" ("Ultimate Display" 1). He then looks at the two major elements of a display, the input, and the output. The examples he gives of these show the limitations of the technology of the time, but also lead him to point out that, "We have much to learn about how to make good use of this new ability" ("Ultimate Display" 1). With the same air of optimism and forward thinking he goes on to make declarations about keyboard, mouse (light pen), touch, and voice inputs. All of which have become mainstays of current computer technology. This initial section is informed by his work on the program "Sketchpad", his dissertation project at MIT. "Sketchpad" is a system that "… contains input, output, and computation programs which enable it to interpret information drawn directly on a computer display. It has been used to draw electrical, mechanical, scientific, mathematical, and animated drawings; it is a general purpose system" (Sutherland, "Sketchpad" 9). Industry pundits Alan Blackwell and Kerry Rodden state in their preface to the 2003 republication of Sutherland's dissertation, "After 40 years, ideas introduced in "Sketchpad" still influence how every

computer user thinks about computing. It made fundamental contributions in the area of human-computer interaction, being one of the first graphical user interfaces" ("Sketchpad" 3). His interest in exploring the man machine interface pushed him to interact with many of the engineers behind similar programs. One of these people is Wesley Clark, who was in charge of computer applications in Group 51 of Lincoln Laboratory, and helped develop major elements of the TX-2 computer which would eventually run "Sketchpad". These interactions with engineers informed Dr. Sutherland's pursuit for understanding man machine interfaces, and by 1965 positioned him in the perfect place to deliver his speech, "The Ultimate Display".

He then goes on from what would be considered regular 2D computer displays into the territory of VR by stating, "If the task of the display is to serve as a looking-glass into the mathematical wonderland constructed in computer memory, it should serve as many senses as possible" ("Ultimate Display" 1). Even though there were no meaningful ways to create displays at the time for the other senses of smell, taste, and to a lesser extent sound, he describes what a kinesthetic display would entail. "The force required to move a joystick could be computer controlled…For example, the controls on the General Electric 'handyman' are nothing but joysticks with nearly as many degrees of freedom as the human arm. By use of such an input/output device, we can add a force display to our sight and sound capability" (sic) ("Ultimate Display" 1). Here he crosses disciplines and brings a new perspective for developers to look at. According to Sutherland's description of the application of these display technologies it seems that most researchers at the time where interested in representing, or working directly with reality, through computers. For example, before "Sketchpad" was developed no one had created a program that used a

pictorial interface, which could serve as an intermediator between the user and the raw data. Instead programmers limited themselves to what could be communicated to the computer with raw programing. Questioning the status quo is an important part of innovation and many key moments throughout the history of entertainment media have been defined by one person taking another's innovation in a new direction, in the way Sutherland did with "Sketchpad" through his innovation of the man machine interface. This leads into the most impactful statement from "The Ultimate Display":

> The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked. (Sutherland, "Ultimate Display" 2)

The History

This oft quoted line from Ivan Sutherland seems to echo from the future as the computer engineers of the late 1960's were already groping with problems that todays' programmers consider are beyond their reach and many people have relegated to the pages of science fiction. However, it is important to note that the idea of virtual reality has been kicking around in the minds of inventors for millennia. Painters of the classical period (around 40_{BC}) strove to immerse their rich patrons in cupid and cherub filled scenes of creation by painting frescos on the walls and ceilings of entire rooms in a lifelike yet dreamy style which can still be seen today in some archeological sites (Otto 6). This notion was later miniaturized in 1833 when Sir Charles Wheatstone created a device that would hold two pictures that were slightly offset, creating the optical illusion of stereoscopic vision (Hayes 1). The innovative battle that resulted in the creation of the

first motion picture camera resulted in the next ideological leap in the timeline, the Kinematoscope (Cook 5).

The first major technological hurdle on the path to modern day VR, was that of film development time. If the subject needed to stay still to properly take a picture of them, it would be impossible to record their motion in any meaningful way. “This required the drastic reduction in photographic exposure time from fifteen minutes to one one-thousandth of a second that was achieved between 1876 and1881 by the replacement of collodion wet plates with gelatin dry plates and by the introduction of ‘series photography’ by the Anglo-American photographer Eadweard Muybridge (1830-1904)” (Cook 3–4). This process used the chemical component of the reaction that resulted in the creation of the film industry. In much the same way as melting an ice cube is a change in form and not a chemical reaction, George Eastman simply changed its look and began mass production of the idea. Once Marey had created the film strip, George Eastman appropriated the technology. Instead of just a way to carry a series of photographs, Eastman’s idea was to capture motion and project the images back to large numbers of people (Cook 4–5). The race to lower exposure time was the first innovative competition that modern VR has to thank for allowing the medium to exist.

From here the next moment of vital importance to the history of Virtual Reality is the development of the Kinetoscope, and its confusingly named 3D focused sibling the Kinematoscope. Thomas Alva Edison meant the former to be a private viewing experience, “in which pictures made by the Kinetograph (the first motion picture camera) would illustrate the sound from the phonograph” (Cook 5). It is vital to understanding future events in VR history to realize that, “…Movies were intended to talk from their

inception so that in some sense the silent cinema represents a thirty-year aberration from the medium's natural tendency toward total representation of reality" (Cook 5). This precedent for technological development metaphorically tripping over itself would be repeated later on. One major note about the Kinematoscope and the Kinetoscope to keep in mind is that they were created about 40 years apart from each other and are equidistant in time from the creation of film. The Kinematoscope used paddles and pre-posed images to create a kind of stereoscopic stop motion scene for the viewer. The Kinetoscope, on the other hand, housed a strip of film that would loop in much the same way that modern day GIFs do. It did not have stereoscopic capabilities, but it did incorporate sound, bringing the technology one step closer to recreating life.

In the ever-expanding conquest of the senses, cinema has been the biggest driver for both the technology and the subject matter of 3D and virtual expression. With the opening of the first Kinetoscope parlor in the spring of 1894, the machine that is the Hollywood system began to churn out films for the American public to consume, and being an industry built on creativity, its constant evolution was inevitable (Cook 7). As impactful as the development of film as a form of mass entertainment was, it is curious to note that there was a subtle undercurrent of 3D technological development from its very beginning. For example, "*L'arrivée du train* made by Auguste and Louis Lumiére is officially the first 3-D motion picture made for public exhibition" (Hayes 3). The dual color anaglyphic system this was projected through functioned as a rudimentary, albeit quite effective, system to isolate the images for the left and right eye. This little piece of ingenuity harkens back to the optical toys developed by Wheatstone in the late 1800's and serves as a declaration of intent for the industry. It says, "we want immersion in our

entertainment", and immersion persists as a major element of movie making today. In the early 50's only a few special productions used stereoscopic 3D to immerse their viewers. However, a new system sought to bring the viewer closer to the story than stereoscopic 3D could, for a fraction of the price: Anamorphic Widescreen.

Cinemas turned to widescreen formats in the early 1950's because they provided an experience which a television owner would not be able to recreate faithfully in their living room. The importance of creating an "experience" cannot be understated because it is currently the selling point for most VR products. The media industry has spent half a century exploring wider and more immersive environments; working to carry this idea of immersion into the 21st century. The development and subsequent popularity of the Cinerama exemplify the importance of immersing the viewers in the viewing experience. Based off the Polyvision process invented by Fred Waller, "… as a battle simulator for gunnery training during World War II" (Cook 389). This system, "…was six times the standard size [of a normal film projection] and its curvilinear shape added the phenomenon of peripheral vision to the screen" (Cook 390). It achieved this by filming on three separate 35mm cameras and recording seven tracks of audio magnetically on a fourth strip of film. This was then played back by synchronizing all four systems and blending the edges of the three film strips on a strongly curved wall. This system was popular with audiences; however the cost to both shoot and exhibit was prohibitively high and led to the development of single camera and projector systems that would spawn a new wave of interest in the medium of film and would lead to the standardization of the widescreen formats for use in cinema.

The development of widescreen came at time when the number of movie going audience members rose, creating a new ideological development that would have lasting impacts on VR: the blockbuster. These movies are created with spectacle as the rule above all else, and formed the contemporary creative space that Hollywood invests in. Special effects which had been done practically up to that point grew in complexity and scale with the sole purpose of bringing in high numbers of viewers. These additions brought with them a major financial toll. With most technologies one would, of course, endeavor to cut costs in order to improve profit, so the film industry turned to the burgeoning world of computer graphics to solve their problems. "…CGI-induced production economies grew more complex in their ability to create lighting effects like day for night, to enhance lens optics, and to provide a variety of traditionally cost-intensive physical effects and stunts in a safe and cost-efficient manner" (Cook 882). Coincidentally, Sutherland's "Sketchpad" program spawned the creation of many of these 3D effects by introducing the idea of the digital wireframe, and in 1969 created the first digital workstation to create them (Cook 883). These new computer-generated images could create battlefields of thousands from just a handful of stunt men. This level of achieved impossibility speaks to the flexibility the artform has, and to the ingenuity of the people working within it.

The Sensorama developed by Morton Heilig in 1956 was inspired by the immersive wide screen of the Cinerama, and marks the next conceptual advance needed in the VR timeline. It is known for being one of the first personal viewing experiences that sought to include sight, sound, smell, vibration, and wind to immerse the viewer in a prerecorded experience (Sherman and Craig 25). This is the closest experience to the

description of the ultimate display that had been created up to this point, nine years before Sutherland penned his speech. Unfortunately, this came at a time when television began to take over the American household. “The old studio production system remained in operation throughout the 1950’s, but continued to crumble under the combined threats of political pressure, television, rising independent production, and, perhaps most serious, loss of the exhibition chains” (Cook 426–27). This meant that most of the marketable aspects of VR would be used as gimmicks to try to stem the loss of income from big productions, to the great detriment of their further implementation and research. Only used in one movie due to the lingering nature of smells, the introduction of Smell-O-Vision(1960), and it’s less well-known sibling Aroma-Rama(1959), to the film exhibition market is an infamous blip in the history of film as a failed attempt to incorporate an olfactory display (as per Sutherland’s words) into the cinematic space. “Like 3-D earlier in the decade, neither system survived its novelty period, although, when working properly, both could create an impressive olfactory illusion” (Cook 426). This is the stage onto which Sutherland entered with “Sketchpad” in 1964 and “The Ultimate Display” in 1965.

At the time, the ambitions to immerse the user in a virtual world were not relegated to exploitation film and carnival rides. A small flurry of technological development led to the first physical (as opposed to text based) interactions between users and computers in Ivan Sutherland’s landmark program for the TX2 computer, “Sketchpad”. “Sketchpad” allows the user to control a light pen (today’s mouse) to interact with shapes displayed on a CRT screen, effectively giving birth to the idea of the digital workstation and the graphic-user-interface (Sutherland, “Sketchpad” 3).

Sutherland's interest in human computer interfaces would then lead to his further development of the head mounted display (HMD) as described in his 1968 paper "A Head-mounted Three-Dimensional Display". In his research Dr. Sutherland and his associates created an HMD capable of providing a viewer with stereoscopic vision of several wireframe objects. They were having hardware difficulties making the system adjust the ever-changing view when loading solid shapes. However, the images they were able to provide were at 30 frames per second, limited by the draw speed of the mini cathode ray tubes they were using for displays. The most important development from this research and solution to those problems was the sequence of custom built machines (a matrix multiplier and clipping divider) that allowed for the system to redraw the image on the screen in response to changes in the users position once per frame, thirty times a second (Sutherland, "Head-Mounted Three Dimensional Display" 758). It did this by taking the positional data picked up by a physical arm or ultrasonic sensor and processing the image in relation to that, sending a new image from the new field of view in fractions of a second. Since the system only needed part of the reference image, this program worked to cut out the part of the image that was not required and alleviated the load on the system as a whole.

This marked VRs entry into the 70s with an air of discovery as several academic and military efforts to develop VR went forth to create a variety of HMDs and glove focused designs. Up to this point flight simulators had been designed with an individual vehicle model in mind and as each one was replaced it would be rendered obsolete. "If the simulation could be done in software on a general-purpose platform, then a change in airplane models would only require software upgrades. The advantage seems obvious"

(Burdea and Coiffet 6–7). This is the first example that fits the previously explored definition of virtual reality as an interactive digital space as opposed to the theatrical productions of the Sensorama or other cinematic offerings. In the same vein, NASA was looking to give its astronauts proper experiences in outer space, so they developed the Virtual Visual Environment Display (VIVED) (Burdea and Coiffet 7). This used optics developed by Eric Howlett called the LEEP (Large Expanse Enhanced Perspective) system , "… to deliver a wide field of view from a small display" (Sherman and Craig 28). These developments would result in creating a public image for VR, and with creation of the VPL DataGlove, VR entered the consumer market. Nintendo quickly followed up VPL's market offering with one of the first "mainstream" VR peripherals in the PowerGlove which sold nearly one million units in 1989. "The downfall of the PowerGlove was lack of sufficient games that used it, such that by 1993 its production had stopped" (Burdea and Coiffet 9). However it later became, "…a popular device for low-cost VR facilities and 'Garage' VR enthusiasts" due, in part, to the number of units that were in the marketplace (Sherman and Craig 31). This leap to consumer markets and the advancements in miniaturization they brought about, would inevitably lead to the exchange of information between scientists and researchers. A series of conferences in the early 1990s would mark a period focused on creating purpose-built systems a quarter of the size of previous efforts.

One such purpose-built system is the Nintendo Virtual Boy. It is a game console built with the purpose of bringing depth to the game market through games like Tetris 3D, but a series of poor decisions made in order to cut costs, specifically the decisions to make the headset stationary and monochrome, resulted in an extraordinarily poor player

experience (Zachara and Zagal 104). This, coupled with the threat of necessitating a health warning label regarding motion sickness and other negative physiological effects of being slouched over a table where the device stood, led to considerable consumer restraint when it came time to buy it. It was pulled from the shelves a mere three months after its release in the USA and was never released in Europe and Australia (Zachara and Zagal 101). The Virtual Boy is the first system in scope, form factor, and target audience that can compare to the systems developed in the 2010s, so it is an important market failure to measure them by. However, between the demise of the Virtual Boy and the rise of the Oculus Rift in 2013 there came a technological breakthrough that distinctly separates all prior developments from those present now. That development was the miniaturization of computer hardware due to the development of wireless cellphones.

The race for miniaturization in cell phones directly benefited the development of VR by providing some key hardware upgrades that up until this point relied on dedicated computers in the data pipeline to execute. Detailed in Sutherland's *A Head-mounted Three Dimensional Display* is the graphics processing pipeline that is necessary to implement head tracking in an HMD. Positional data is taken from the measuring device to a first computer which processes the information in relation to the 3D virtual space the viewer is inhabiting. This is then passed to a dedicated graphics processing unit that relates that to the 2D image that gets reproduced in the CRT screens for each eye (Sutherland, "Head-Mounted Three Dimensional Display" 758). This cascade of advancements actually helped to inspire Palmer Luckey, the creator of the Oculus Rift, to begin to make his own HMD. "Many of the key challenges in creating virtual reality, he

realized, had been solved by the makers of mobile phones and handheld games: powerful mobile processors, high-fidelity graphics software, and precision motion trackers were all available" (Kushner 36). Cheap access to advanced technology and access to the internet has led to the creation of many VR companies who are vying to be the company that makes VR a part of the everyday life of a media consumer.

The first wave of modern VR devices that came out between the summer of 2013 and mid 2017 were marked with a tone of adventure that embodies the technological advancements from this generation. The form and function of each new device matched the philosophy of each of their respective companies. Google Daydream (2016) was created as an attempt to get consumers to use their headsets while they were out and about. The HTC Vive (2016) was built around an entrepreneurial desire for precision, allowing for its implementation in large scale location-based VR projects as per their homepage. The Oculus Rift (2016) is the most consumer focused of these offerings, as their team built a system to be used in the home for many purposes such as designing in 3D virtual studios and chatting with people from around the globe in their disparate social offerings. Being the system with the most name recognition after being bought by Facebook in 2014, the Rift has been the platform of choice for many innovators in the medium. Sony is the final major player from this first wave of consumer VR as they have had a high level of success with their gaming focused PlayStation Virtual Reality (PSVR) system (2016). At first glance this looks like the most disadvantaged of the systems as it requires its potential users to have a PlayStation 4 in order to try it. However, this captive audience has not been a hinderance, and unit sales comparisons between the Oculus, HTC, and PlayStation set them as comparative equals (WebFX Team). This first wave of

devices is characterized by external sensors and a relatively complex setup requiring a dedicated space and an understanding of how the sensors relate to the system in order to troubleshoot technical issues on the fly. This has created a form of gatekeeping for the kind of consumer which would choose to delve into unexplored territory when it comes to confronting motion sickness and the possible requirement of custom-built hardware. All of which were issues that were represented in this wave of devices. However, the second wave of devices marked by the release of the Oculus Quest (2019) seeks to alleviate some of these issues.

Beginning in the summer of 2019, a second generation of devices, Oculus Quest and Vive Cosmos, are being released as a response to the issues of the first generation began to make waves. These devices are defined by an easier setup for the user and more flexibility when it comes to the space in which the devices can be used. Sporting internal sensors, these systems focus on flexibility as a selling point to accompany a higher screen resolution and lighter HMD design. Currently, the industry is left with a feeling of waning consumer interest in VR after the past few years of hype surrounding this “new” entertainment medium, and a level of curiosity about where the next innovation will come from to catapult VR into the next generation.

CHAPTER THREE

Theory and Method

Theoretical Background

Dr. Sutherland's look into the future of technology came from a position of deep understanding of the history and development of display technology thanks to his formative years designing "Sketchpad" and rubbing elbows with other innovators working in the field. In order to apply his point of view to the current state of the VR industry, this study rests on two theoretical perspectives. A qualitative research methodology functions as the root of this study with a structure consisting of a historical analysis, a study of the present state of the industry, and conclusions focused on the future of the industry. Within the study of the present state of the industry, two theories are used in tandem to achieve a well-rounded examination of the issues surrounding the VR industry. The Diffusion of Innovations theory, pioneered by Everett Rogers, functions as the primary lens through which the VR industry is analyzed. This is supplemented by the socioeconomic issues in creative and innovative management attributed to George Kozmetsy in *New Directions in Creative and Innovative Management: Bridging theory and Practice*. When combined, these two systems provide an orderly and concise way to identify the interactions between innovators and consumers which can drive the market. The observations gained through this analysis are developed into a series of conclusions based on the Futures Cone. The Futures Cone is a methodology used in futures studies, which organizes statements based on how realistic

each prediction might be while keeping in mind the possibility of movement between categories. This foundation serves to provide a structure that is more closely tied to the facts from previous research than sheer speculation.

Diffusion Theory

The main reason to use Roger's attributes of innovation as a theoretical foundation with which to forecast the VR industry is that it helps to categorize the various ways consumers interact with emerging technology and may give insight into how development is affected through these interactions. Rogers states that the "…five attributes of innovations are (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability" (E. M. Rogers 223). Each of these serve to address a separate concern relating to VR technology development and its future as a widely adopted technology.

"*Relative Advantage* is the degree to which innovation is perceived as being better than the idea it supersedes" (E. M. Rogers 229). Questions relating to this will be heavily focused on the reasons a consumer might find owning a VR headset beneficial and how the companies are addressing or interpreting that need. Rodgers mentions that there are various subtypes of relative advantage that may be interacting to produce the market need which is present today. Economic and social standing may be important to consumers ready to adopt any new technology regardless of the market's response to its release, but are there any incentives being given by companies or content producers to motivate the adoption of modern HMDs? The matter of VR being a replacement or a supplemental media product plays into this area of diffusion, the advantages and disadvantages of which greatly affect the way these companies sell their VR products.

"*Compatibility* is the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters". This is the element of previous familiarity and according to Rogers interacts, "…with (1) sociocultural values and beliefs, (2) previously introduced ideas, and/or (3) client needs for innovation" (240). With a nearly hundred-year history of stereoscopic toys before it, VR may be strong in this area. In asking about compatibility, instances where people had issues with being isolated from one's immediate surroundings or other external reasons for people to push away from trying out VR on principle would be of great interest as it would shed light on issues that would prevent a new user from encountering any of the other issues. The nature of VR being an isolating experience is a major element of VR's compatibility with today's society and is something that is actively being addressed by some companies. This may hold the key to finding VR's killer app because of social media's importance in today's culture.

"*Complexity* is the degree to which an innovation is perceived as relatively difficult to understand and use". More specifically, "The complexity … is negatively related to its rate of adoption" (E. M. Rogers 257). The high perceived technological barrier to entry that VR has according to news media, may be one of the biggest issues that the VR industry has had to tackle as many users that are not used to this kind of setup, "…may find the Rift's setup laborious" (Chen). Some of them even state that, "…many existing VR setups are still too hard to use" (Anderson 258). Most of the technological based questions would address this issue. Looking into how companies streamline the operating system or simplification of hardware installation would lead into

exploring just how a user is expected to go about implementing this kind of technology in their everyday life.

"*Trialability* is the degree to which an innovation may be experimented with on a limited basis"(E. M. Rogers 258). In the case of VR, products like Google Cardboard or 360° videos on Facebook are there to function as the first impression for many possible adopters. Identifying the public response to this area of VR technology would help to measure future attempts for using this as a gateway interaction. Looking into why other developers have chosen not to do this also would help serve the purpose of seeing if there is intentional support for the trialability of the technology in the development process when it is not the whole point of the product. Rogers notes that there is a positive trend between the amount of trialability a technology has and its rate of adoption, but issues of complexity may play a major role in just how trialable VR is to the general consumer (258).

"*Observability* is the degree to which the results of an innovation are visible to others" (E. M. Rogers 258). Rogers notes that technology that is more software focused than hardware focused is harder to observe due to the nature of programing being intangible (259). VR stands in a strange middle ground, because it is mostly constructed around the software-based experience, being immersed in a digitally mediated world, but it also has a major hardware element in the peripherals necessary to run such an experience. Questions regarding observability would be shaped around the use of social media and other visible aspects of marketing that may introduce the general public to VR without necessarily having to try out a device personally.

Creative and Innovative Management Theory

The Creative and Innovative Management Framework is a system pioneered by George Kozmetsky out of the IC² Institute at the University of Texas in Austin, which focuses on identifying the problems within a market in order to have a faster and more effective response to changes within it. "CIM is unique in its approach to creativity, innovation, and the creation of capital, and how all of these factors relate to management practices" (Carbonara, C. et al. 106). It is useful when applied to the VR industry alongside Diffusion of Innovations, because it adds another lens with which to interpret the significance of advancements in the industry so far. Technological, Economic, Legal/ Regulatory, and Socio-cultural context serve as overarching categories that most issues should fall under and help to tie this research together.

Technological issues comprise the majority of what has stood in the way of innovation in the field of VR since the very beginning. As such, major shifts in the industry are defined by breakthroughs like the development of film or the miniaturization of hardware for the cellphone. The current landscape of technological development has been defined by minute developments and integrations seeking to extract the absolute maximum potential from each element, such as those seen in the development of the cell phone. These breakthroughs are where companies will seek to establish their advantage over other companies, and as such may not even be information available to this study. However, with the variety of approaches to VR display and processing technology available on the market it would seem that there are still many ways in which technology will grow.

Since the topic being discussed here is one of a technological nature, the research is focused on issues with diffusion or how fast consumers will adopt the technology rather than the issues that needed to be resolved in order for the product to exist. These foundational innovations are important to the existence of VR, but are more so systemic and could easily distract from the present day issues facing the further evolution of the media.

Several points of view need to be taken into account in discussions of economic issues facing the VR industry as innovators, consumers and distributors all have to assess the values of the experience they are creating, buying, or selling. This means that technological, legal/ regulatory, and socio-cultural issues will have more of an effect on this category than economic issues would have on the others (with the possible exception of technological issues as the price for the creation of many of the hardware solutions to VR displays has been extremely high). Economic issues also directly contribute to discussions of diffusion as the value assessments of users directly effects the adoption rate of any of these technologies, much like we saw with the race to the bottom in the cellphone market. According to Rogers, economic factors greatly influence the rate of adoption, so major events like holiday sales, and more problematic ones like recessions can have an important effect on diffusion (230). Advertising campaigns from the different developers at events like E3 Gaming Expo, or other summer launch events that take advantage of the same surge in entertainment spending that summer blockbusters cause, has a notable effect on new product release dates. Seeing how these different factors contribute to the decision-making process for each developer will provide a temporal understanding of how products influence the consumer market.

Legal or Regulatory issues are based on problems so severe that a governing body has to intervene in order to protect both the consumer and the market from the disruption a poorly handled innovation-based issue and its effects could cause to the economy or the welfare of the population.

For example, interactions between the media industry and the government go back to the modesty code established to curb the racy tendency of early Hollywood films (Cook 237). This is one of the most impactful examples as it colored the entire film industry in ways that we still see today with ratings and in the discourse that surround disruptive content creations like HBO's Game of Thrones. This being said, there is a growing movement among internet users, reaching all the way to the United Nations, who demand for freedom from the regulation of media distributed through the internet (UNESCO). Legal/regulatory issues will continue to have an increasing impact on the VR market. There is precedent for intervention for the protection of the user in the disastrous case of the Virtual Boy, which had to have a health warning sticker attached (Zachara and Zagal 103). The current wave of VR technology is free of such scrutiny as small-time developers are still able to tinker and innovate as they please. These are the most problematic issues due to their permanence and the power they hold over our economy.

Socio-cultural issues are marked by the cultural landscape in which a product is presented and will oftentimes create entire movements within a population that will either support or ruin an innovation. These issues could range from conflicts with faith to a dissonance with the social ecosystem and even have such a subtlety to their influence on diffusion that it may let them go by unnoticed. The difference between European social

interactions on the street and the American equivalent of driving to meet with friends would be a good example of this. These demonstrate distinct points of view as to how social interactions are supposed to be carried out and how much effort is supposed to go into meeting up with friends. These socio-cultural elements play directly into the development of interactions in VR and other media platforms.

Sociocultural issues also cover issues of morality in a culture. A flagship moment that would represent this in the VR industry is the largely negative response from several populations to a "school shooting simulator" that would put the user in the shoes of an armed gunman carrying out a massacre or a policeman trying to stop said events (Hitt). This particular issue even had a similar precedent as the issue of violence in videogames came to a head before in 2009 with the release of *Call of Duty: Modern Warfare II*, in which the player controls an undercover soldier who is tasked with fitting into a terrorist organization. This game starts with an attack on an airport which the player cannot pass unless they "fit in" and shoot innocent people along with the terrorists. This caused a significant uproar despite options built into the game allowing players to skip the level in question (Shafer). The elements of simulation at play in these discussions make them a crescive matter in the world of VR development since there is a comparative high ground in training law enforcement personnel with VR simulations. This conflict between entertainment and useful training tool is just one of a myriad of moral questions that should be considered in order to consider how society and future VR development will impact each other.

Research Method

This project revolves around analyzing data from the present as well as the past in order to discern what the future may hold. In order to do this forecast, a historical understanding of the VR market and its roots is synthesized with an analysis of the present-day state of the industry, that lead into a series of "futures statements". The analysis of the present-day companies is carried out through researching answers to a series of questions that are guided by Rogers and Kozmetsky and seek to establish a level playing field between the 3 different approaches to the medium represented by Facebook, HTC, and Sony, the companies who represent the highest amount of net worth in the VR market. These questions were created by considering each of the 5 categories of diffusion and how they relate to the strengths or weaknesses represented by each company. The insight gained through this questioning is then applied to the structure of the futures cone in order to interpret the viability of the conclusions gained from said insight. These statements are categorized by their present interpreted relevance to the future of the VR market.

Futures Cone

The analysis is nestled into a modeled "futures cone" which serves as a model with which to temper findings into a reasonable series of conclusions based on narrative projections of the future based on the past development of similar technologies (Voros 11). This is done by looking five and ten years out while keeping in mind the inherent lack of certainty that accompanies long stretches of time in the tech industry. Voros states in *Big History and Anticipation* that these conclusions, "are all considered to be subjective judgments about ideas about the future that are based in the present

moment", and as such are meant to be seen as fluid interpretations that could move between the three prediction categories represented in this paper: preferable, probable, and possible, also referred to as the top, middle, and bottom of the cone of possibility (Voros 10). This system of encapsulation of ideas will facilitate further discussion by simplifying their categorization. Ideally, this approach can help to create a unified forum for discussion of these rather nebulous topics as VR becomes more present in the years to come. The benefits of looking both five and ten years out come from the structure this technique provides. This structure helps to limit speculation, and to stimulate effective foresight. If an amount of time significantly longer than ten years were to be implemented, it would open more speculative discussion as the tenuous connections between each topic would begin to complicate the participants understanding in an undue way. In order to avoid these issues, the five and ten year breakdown provides a period of time that falls within the understanding of those in the dialogue. Relating the two time periods to each other also helps to define what areas are not covered in this discussion, leaving clearly defined room for further research or further interpretation of this research.

CHAPTER FOUR

Analysis of the Present of Virtual Reality

To begin this analysis, it is important to identify the players and the aspects they are being analyzed by. The teams and products listed below are representative of around three quarters of the global market for VR headsets (Liu). This is a limited view of the industry, however for the purposes of seeing how the future of VR might be influenced by the market the companies that have garnered the most success should stand as a starting point. These companies have managed to push VR into the mainstream after nearly a century of small "startup" style innovation, so they will serve as a springboard to investigate possible future successes.

- Facebook: Oculus Rift Development Kit [DK1 (2013), DK2 (2014), Crescent Bay (Late 2014)], Oculus Rift CV (2016), Oculus Go (2018), Oculus Rift S (2019), Oculus Quest (2019)
- HTC: Vive Development Kit (2015), Vive (2016), Vive Tracker (2018), Vive Pro (2018), Vive Cosmos (in development, 2019)
- Sony: PlayStation VR (2016), PlayStation Camera (2013), PlayStation Move (controller, 2010)

Relative Advantage

In the area of relative advantage this study will be using four qualifiers that each of these companies has been addressing in their development. To sell more devices, each company first uses the development of more advanced hardware to give themselves the technical edge. They then leverage corporate status to create an extra level of confidence in their customer base. This then fuels the further development of a particular style of

content which targets a certain group, defining each companies' target market space. Finally, these companies partner with other developers to approach the challenge of defining content identity from many different angles. These partnerships also help to spread the financial load in order to lessen the dangers of heavy investment and reduce risk.

Hardware Development

The development of new hardware and using it as marketable leverage on consumers is an indispensable element of the tech industry, as more and more innovations make their way into the marketplace. This has created a cycle of upgrades that make most consumer electronics out today feel nearly disposable. For example, …"Apple built its reputation on smartphone innovations that kept existing users upgrading and new customers flocking to the company's devices, even as low-cost devices with similar features arrived from rivals such as Samsung and Huawei Technologies Co" (McMillan). The competitive advantages that these companies develop while in this competition will go on to create the building blocks for future innovation in much the same way as the new wave of VR was fueled by the remnants of the cellphone development race.

Facebook: Oculus. Oculus has come a long way from the development of the DK1 and along the way solved a lot of the issues with a home-based VR system. The DK1 only had tracking in the front of the HMD, so the range of motion was limited to what its singular, webcam like camera could detect. By comparison, the Rift S boasts built-in positioning sensors, removing the need for external sensors. This, combined with

an upgrade on the internal screen from 720p in the DK1 to 1440p in the Rift S, means that Oculus has been pushing to improve upon its original formula while still finding technological issues to solve.

HTC: VIVE. HTC has followed in Oculus' footsteps as a home-based VR platform in a very literal sense. The release of the development kits for the Vive came after the Oculus's own and seemed to address some of the issues they presented. The first of which was the improved ergonomics of having a solid headband in order to better distribute the weight of the HMD. The original Vive also incorporated a dual external sensor system and built in headphones in order to get the user out of their chair and into another level of immersion. These were both later adopted by the Crescent bay and Consumer versions of the Oculus and really show how these companies feed off each other. The newest version of the Vive, the Vive Pro, now includes cameras built into the headset allowing for better integration into location-based VR projects and increasing the scale of the room in which it can be used up to 22'11" with the latest version of its external sensors. The Vive Pro also boasts a much higher screen resolution than the Rift S with 1600x1440 per eye continuing to seemingly push the upper limits in terms of image quality (HTC Corporation, VIVE Pro).

Sony: PlayStation VR. Sony presents an interesting question with their PlayStation VR, as the hardware it brings is simpler than the Oculus or the Vive. It uses the PlayStation Camera to measure the six degrees of freedom it uses, coupled with lights on the headset and Move controllers (Pino, "PlayStation"). This rudimentary solution to the problems all VR systems are trying to solve seems to be aided by the self-contained

nature of a gaming console as the system's hardware is optimized to work well with the HMD. Sony brought this light tracking optimization as their identifying technical advantage and it seems to have paid off.

Corporate Weight

With the VR industry being as varied as it is there is a clash between large and small companies that could invoke the story of David and Goliath. "Large MNCs [Multinational Corporations] inspire awe in some and attract derision from others, and they receive the lion's share of attention during discussions about the impact of globalization on the business world" (Prashantham and Birkinshaw 6). The way larger corporations are leveraging this position on the market or not has influenced consumer reactions to new developments and having such a sizeable corporation behind VR technology has had a positive effect on market engagement.

Facebook: Oculus. The first major example that is present here is visible in the google analytics for the search term "Oculus Rift" which had its highest search rating in March of 2014 which is notably the day Facebook bought the company for two billion dollars. As a response to the intense backlash he received on internet forums the day of the sale, "He [Palmer Luckey] argued that the acquisition would provide the capital Oculus needed to hire more engineers and release the best possible product" (Dietrich-Egensteiner 5). This was not a futile effort as the number of headsets sold in 2019 is nearly equally split between Oculus, Vive, and PlayStation VR, each of which focus on marketing to a specific consumer group. Oculus had to grow quite a lot from its garage-based roots, in order to match its multinational corporation competitors.

HTC: Vive. Enterprise marketing is the name of the game when it comes to HTCs approach to selling their products. The steep price by comparison to the Rift or PSVR turned heads in initial reviews for their products. However, this makes sense since HTC would not see a percentage back from any profit gained by the final enterprising owner. In November of 2018, HTC announced a new platform for enterprise VR projects with dedicated hardware and databases for applications. Their own announcement regarding this release states that, "This launch reinforces Vive's increased commitment to bringing best-in-class design and software expertise—paired with the world's best VR hardware—to businesses of all sizes"
(Vive Team).

Sony: PlayStation VR. These previous companies used their massive amounts of resources to reach out to the widest audiences possible. Sony on the other hand decided to instead focus on creating an experience that they could sell to their loyal customer base. This focus on convincing their loyal customers to take a leap with them has borne fruit, as they have managed to keep on par and even exceed the marketing numbers from Facebook and HTC without extending the marketing for the PS4 more than they have any other console (Liu). The customer base in question is comprised of mostly gamers, which points to the issue of a generational gap in adopting new technologies.

Brand Identity

Creating a cohesive design concept for a product is one of the best ways to make it stand out amongst its competitors. This is the philosophy that Apple has used since its incorporation in 1977 and, according to Apple visionary Steve Jobs, is what makes their

products stand out in the varied field of consumer electronics. “We may have the best product, the highest quality, the most useful software etc.; if we present them in a slipshod manner, they will be perceived as slipshod; if we present them in a creative, professional manner, we will impute the desired qualities” (Allen). This concept of branding providing relative advantage to the consumer is one which few VR companies have tried to implement in this stage of the game.

Facebook: Oculus. The interaction between Oculus and its parent company Facebook is very much one that is more focused on the financial ties between them than as a branch of off Facebook’s main brand offering in its social media platform. This is noteworthy because there is still pushback from the earliest adopters and partners of Oculus, like Valve the development company behind Steam, who felt that the corporate giant’s acquisition of Oculus would remove all the creative control from Palmer Luckey. In the days following the news of the sale, Mr. Luckey went on an online forum he frequented, to state, “We did not sell out control to FB, we did it a long time ago when we had to raise money to keep going” (Dietrich-Egensteiner 5).

HTC: Vive. Vive’s brand identity is again focused on their corporate interests. This is visible in both their third-party operating system for their applications with Steam VR, and their utility-based design, allowing for enterprise modification for the purposes of their custom experience. This is unique approach also serves to emphasize that the target audience for the Vive is not the home market. This kind of neutral branding makes the Vive stand out as the most professional option out of the three big HMD’s.

Sony: PlayStation VR. PlayStation's brand has been built on "serious gamers" since their release of the PS2 in 2000 that brought about their now iconic black body and blue lighting look. The PSVR plays off this aesthetic by incorporating it onto a white bodied HMD that has a simplified exterior in order to emphasize its intention as a peripheral device to the PS4. The system does not have a standalone user interface, so it relies heavily on the system it is built from. This subservience in terms of design emphasizes Sony's intent on getting their customers to see the PSVR as a lower entertainment value commodity that could be hit or miss depending on the user.

Corporate Partnerships

Corporate partnerships provide an important amount of relative advantage due to the economic strength that comes from distributing the load of possible failures between a series of partners. This allows for ambitious innovations to germinate, something which a new technology, like VR, needs in order to reach the point in which it has gained a certain amount of notoriety. Hardware, software, and game development companies have partnered with bigger companies in order to tap into the freedom that comes from this kind of financial support to reasonable success.

Facebook: Oculus. The most notable example of this kind of partnership is the acquisition of Oculus by Facebook. This not only launched VR into the public sphere as many news outlets where drawn to the amounts of money that changed hands for this partnership, two billion dollars (Takahashi). This kind of partnership is a prime example of one in which the money helped to support the success of the device. It was clear from their record breaking Kickstarter campaign that the Rift would be reasonably successful,

however in order to carry out the mass manufacturing necessary to keep prices low, the oversite of Facebook was a useful aid. This also meant that now Facebook could partner with software production companies in order to provide content for the new medium, and these smaller companies could feel secure in their partnerships (Gilbert).

As of July 2019, Oculus and Sony have announced that they had an interest in working together in the future (Sutrich). This may be through collaborations with 3rd party game developers as they are showing interest in investing in future development in VR gaming.

HTC: Vive. Another interesting case of an initial creation being passed over to another bigger company in order to bring it to consumers comes in the form of the Vive. The original designers of the Vive were Valve, the company that owns the digital PC game distribution company Steam. Early on in the development of the Vive, Valve partnered with HTC in order to make sure it would have a fighting chance in the new VR market. The Vive began its life as the exclusive headset that could connect to the Steam Marketplace. As such, it could have been caught up in the issues Sony has had with the PSVR of having an extremely limited audience. The transfer of ownership to HTC allowed Valve to open its market up to the other PC controlled HMDs while still benefiting from their own invention. HTC has gone on to make its entire marketing plan around entrepreneurial partnerships by creating an entire business branch for the explicit purpose of managing these partnerships, and finding ways to have them all benefit from said partnerships (Vive Team). These partnerships include VR arcades which can connect to a special network that HTC provides, as well as the Taipei Medical University for educational purposes (HTC Corporation, HTC PRESS; HTC Corporation, HTC DEEPQ).

Sony: PlayStation VR. Sony has been very actively partnering with other large companies in order to keep promoting VR to the masses. Their focus on accessibility for the consumer has led to a number of partnerships that could be deeply impactful on the market in the future. In 2017 Sony partnered with Lenovo to help them design an HMD based off the designs for the PSVR (Moore). This is how the Lenovo Mirage came to be. The next notable partnership came from the gaming branch of PlayStation as there have been rumors about Sony partnering with Microsoft for a cloud solution to game distribution. This may indicate a shift in the competitiveness between the gaming giants, as the competition between them has set the tone for AAA video game development for the past 20 years (Jones). The most recent partnership with possible wide-ranging impact is one with Oculus. This partnership would have the VR giants working together with VR experience development studios to create cross platform games (Sutrich). This is notable and lucrative for both companies as they inhabit slightly different markets with Sony sitting in the console market and Oculus focusing on their PC based system.

Compatibility

The question of compatibility in the context Rogers writes it is mostly in regard to moral, religious, or philosophical issues. However the lifespans of the products that are being considered in this analysis have been relatively short by comparison to issues like the introduction of boiling water to isolated tribes in south America (E. M. Rogers 1–5). In this case the religious practices in the village dictated that boiled water was considered cursed, so the people had a high level of resistance to the idea of it actually being safer than un-boiled water. The case of VR is not necessarily as dire; however, it should be

noted that misconceptions and poor first impressions have created a broad cultural bias against VR, specifically the wild failure of the Virtual Boy.

Interpreted Application vs. Intended Application

The matter of users agreeing with the hardware developers on what the uses of that hardware should be is an interesting one. The development of VR came from a series of creators that appropriated previously developed hardware into a new form of media. This would directly contribute to sales and can serve the purpose of helping to identify issues with previous assumptions about the practical applications for VR.

Facebook: Oculus. On release, the Oculus Rift was poised to be the in-home standard for consumer VR. Being the product of a massive company with deeper media influences than HTC or PlayStation, it was sold to the masses as the next new thing. Advertisements on Facebook's news feed system incorporated 360° videos to get people interested and the devices were sold at all major electronics retail stores. Since the Rift was the first system to hit the scene when the Kickstarter campaign crushed records, it became what people thought about when they were talking about VR. The device itself is designed to fill that "normal" role quite perfectly. It has access to the most game libraries, and has a design that we have come to associate with broadly adopted consumer electronics. The system has a rather simple design when compared to the pock marked Vive and the neon futuristic PSVR. The Oculus Rift's marketing established it as the measure from which all other systems would be judged.

HTC: Vive. On release, the Vive was priced at $800 and was criticized heavily when compared to the Oculus. In comparisons between the Vive and the Rift reviewers

would generally laude the technical achievement present in the Vive but recommend the Rift due to the higher price, “not being worth it” (King). This point of view is very logical for consumers constantly trying to find the best value for the money. HTC did not, however, target the home audience alone with this product. This system is designed and heavily marketed to enterprise customers, meaning that it is made to provide a service that companies can monetize and turn a profit from. As HTC would never see the fruits of this from single headset purchases from the home market it makes sense that the price would be higher. They are selling the ability to profit from this device, something quite different from what consumers are expecting when they compare prices between systems.

Sony: PlayStation VR. On the other hand, the PSVR has been criticized for having a comparatively low quality in both construction and in motion tracking fidelity. This is again an issue of misrepresentation when it comes to reviews of the systems as the PSVR was never intended to compete with desktop-based VR systems. It is a console based peripheral. This means that its designers have optimized the accompanying hardware in order to make it simple for the customer to plug their chosen game in and play. This tradeoff between quality and complexity means that it is easier for a person who is new to VR to pick up a PSVR and play every VR experience available to the PlayStation without needing to invest in better and better hardware to run them. This keeps the monetary barrier to entry quite low without compromising as much on quality as an Oculus or Vive owner with a lower end PC.

Target Audience

The question of who VR is intended to be used by is one of particular interest as it is the guiding principal by which development is prioritized. These three companies have expressed a variety of approaches to this question throughout their development. This section builds on the identities that each company have created for their products and how these decisions impact them when it comes time to take them to market. This would include issues of alienating potential customers and going beyond the typical marketing strategies for traditional media in order to avoid such issues.

Facebook: Oculus. The interest of Facebook to develop the rift into the next social media powerhouse has been apparent since its acquisition of the tiny startup. While it may already be considered one of the most influential media companies of the 21st century, it is apparent that Facebook needs to maintain their level of influence in order to continue holding that position. In a 2019 report they stated that their average numbers of active users had dropped on a month by month basis (Al-Heeti). With the volatility of the social media space and the distinct possibility that Facebook will face a similar decline to that of Myspace and the like, it looks like they are turning to Oculus in order to expand their horizons. With new offerings like "Venues" and an update to the Oculus Home that allow VR users to interact with each other, Facebook seems to be betting on the importance of social interactions in VR (Rubin). In order to do this Facebook needs their systems to be widely marketable to everybody, regardless of demographic or level of technological literacy.

HTC: Vive. The Vive began its life in development under Valve and started out as a product to be sold to gamers, however, this is not the direction that HTC ended up taking when they partnered with Valve to begin production on the Valve. By expanding their maker to the enterprise market HTC has been able to create a justifiably more expensive product that has a relatively high learning curve its users must work around in order to take advantage of their advertised "Room Scale VR". Between the Gaming and enterprise market HTC has soundly claimed their target audience as the group of users that have both the income to buy the relatively high cost HMD and the knowledge of how to take advantage of this developer focused system. Their hands off approach to advertising, instead allowing the content creators to advertise their experiences and piggybacking off that interest to supply sales, also serves to highlight this particular tactic (Akopyan). Their interest in institutional projects such as their partnership with the Taipei Medical University also highlight this approach (HTC Corporation, HTC DEEPQ).

Sony: PlayStation VR. Ever the black sheep in the flock, PlayStation has made its name with a very straightforward target audience and demographic: PlayStation 4 owners. This being the case, they have still managed to become the company with the highest number of reported sales in the VR market. Oculus has no officially published numbers for sales. This is a conflicting series of statements. However, PlayStation's dedication to supporting their customers may be the key to their success. This is done in two ways, first, they invest heavily in having their possible adopters try the systems out, secondly, they have adapted their entry level bundle with the HMD to include the required Sony Move camera in order to really open up the chances that owners of the PS4

would be more interested in trying out the PSVR (Duran). This increases the chance that a member of their target audience will consider it a valuable purchase.

Fulfilling Needs

The final area of compatibility is that of fulfilling the users' needs. This has been a point of contention in previous iterations of the format as its importance in industrial and military simulation has affected consumers preconception about what to expect when they use it. What has become apparent is that VR can fill many roles. It is foundational when training pilots, provides viewing experiences that were previously unattainable (such as with VR cinema), and its use as a tool for communication have drawn the attention of many developers. This may no longer be a question about the purpose of VR, but one about which applications are out of the reach of our current technology and if the current systems might be able to attain them soon.

Facebook: Oculus. Social VR is the name of the game when it comes to Facebook's strategy for making the Oculus something which their consumers need (Rubin). Since the acquisition of Oculus, they have been working on ways to bring the social utility of VR to their customers. The biggest issue with Facebook's attempt to create an environment in which social VR can thrive is the lack of cross platform communication between Oculus systems. Spaces, the premium social VR platform for the Rift, is not available on the recently released Oculus Quest. Likewise, their other systems, the Go and Gear VR, do not have access to these systems and are isolated to their own software. Even though these issues may be resolved in future updates and releases, they presently demonstrate a surprising lack of cohesion in the way this ecosystem is being

constructed (Lang). Thankfully, third party systems that link all the different headsets, Vive and PSVR included, are fulfilling this need and have seen some levels of success (S. Rogers). The Oculus Rift S has room scale, inside out tracking (as opposed to the Rift's limiting eight foot by eight foot tracking area). This shifts the purpose of the system to go from the more stationary chair bound games to scalable experiences involving larger spaces. This shift is helping the Oculus be the everyman's HMD as they have access to the most experiences and can adapt to the user's needs.

HTC: Vive. On the other hand, the Vive and Vive Cosmos serve the function of being the "deluxe" market option thanks to its high price and initial presentation as the more professional option. This has helped it flourish in the enterprise VR market and appealed to users who were interested in the more premium experience. Some examples of this would be digital content creators on YouTube who could be seen as enterprise customers with private consumer interests. The Vive and Cosmos are built for room scale VR with several different applications. This means that these systems are built for experiences that are more expansive than those designed to be played while sitting (D'Argenio). Upon its release, the Vive differentiated itself from the rift through being a system focused on bigger experiences. Now the Rift S and Cosmos share a similar purpose with inside-out tracking. This shift in this tide may impact the development of future HTC products as they may pivot to focus more on their enterprise offerings than the consumer market that is currently enthralled with the Oculus.

Sony: PlayStation VR. The needs of PlayStation gamers with the PSVR can be boiled down to a fun and engaging system for a reasonable price. By being a console-

based system, it is already understood that there is an exchange between the quality of the images being produced by the system and the fact that it is a console, something inherently limited for the purpose of facilitating the gaming experience. This compromise is not just for the ease of use, which is addressed later in this piece, it is done in order to bring the cost down for the consumer. The PSVR package is the most affordable of the three compared here and when the base console is included is still less than a Vive package that will still need a computer strong enough to run it. This makes the PSVR very accessible for the target audience of PlayStation (Duran). This group has a limited income but an interest in the adoption of new technologies. However, this same group may not be able to choose between the three systems. The PSVR has a captive audience which is already primed to adopt the system, as long as it is within their reach financially. The PSVR also is known for its focus on gaming as the primary use of the system. This creates a well-defined and previously explored series of opportunities for creators in the PlayStation partnership to explore in order to create the best and most engaging gaming experiences.

Complexity

The issues of complexity in the usage of VR technology have been addressed differently by each of these companies and are one of the most marketable characteristics from each. The variety of applications for each of these market offerings mean that the solutions that each company have found solve their niche issues, while still leaving the greater issue of VR's complexity as a negative influence on its rate of adoption. The broad issues with complexity can currently be split into three categories. First, the initial setup of these systems is complicated at best and require an extra monetary investment at

the worst. Secondly, learning how to use the devices can be unintuitive to potential users due to the mass adoption of two-dimensional displays. Thinking in three dimensions is new. Finally, once these issues have been resolved, these devices are still not intuitive to use on a regular basis due to a lack of a universal digital language through which users can interact with the systems. This last issue harkens back to the issues Sutherland solved with "Sketchpad", interacting with a windowed user interface made computers accessible to the general public. A similar universal language for VR has yet to be developed and disseminated between all these companies.

Initial Startup Difficulty

The first major drawback to consider is the amount of work that must go into the installation of each of these devices. Each device requires a specialized location in which the sensors can operate without interference from external elements like the sun. These spaces must also allow the user to have a safe playing experience without being able to see when they might hit something. An important observation about these issues is that two of the three companies have sought to resolve them by implementing "inside out" tracking which replaces the external sensors that cause installation issues with cameras built into the HMD. These systems also will show the outside world to the user when they are in danger of hitting something. Unfortunately, this is a new addition to the market as of summer 2019, so it is difficult to gauge the long-term impact of these refinements on the market.

Facebook: Oculus. The issues with setup for the various Oculus systems can be categorized by the two categories: systems with outside in sensors and systems with

inside out sensors. The first of these includes the Rift CV1 and all the previous development kits, which require the user to set up a dedicated space which can be observed by a series of sensors. This is problematic for people with little available floor space as it would have them bumping into walls and other furniture in an attempt to operate within the bounds offered by the system. In order to avoid issues with a poor installation these systems also require the user to spend a moment after setting up the system in a new space to make sure the sensors can interpret the motion of the headset and controllers. These extra setup moments can be frustrating as the user might not know why the system is telling them something is wrong. Given this situation, the idea of inside-out tracking may serve to make the Oculus Quest and Rift S more approachable for new and enfranchised customers.

Inside-out tracking is both Oculus and HTC's answer to difficult setups. It uses onboard cameras in order to track the headset motion. This has the added benefit of allowing for passthrough programs that can show the outside world when the user steps out of the play-space. Facebook's proprietary program that enables this is called Guardian, which shows a 3-dimensional rendition of the outside world with black and white cameras that it uses for its sensors (Wilson). This system seems quite popular as Facebook recently announced at Oculus Connect 6 that the Oculus Quest would be receiving many flagship experiences thanks to the recent adaptation of these capabilities ported over from the Rift S (Oculus Blog).

HTC: Vive. The room-scale VR, which the original Vive and Vive Pro use, required two external sensors to cover a room area of 15 by 15 feet, double that of the Rift, which further cemented their reputation as the more professional of the popular

HMDs. However, this also came with calibration programs which further complicated its setup. These sensors have an issue where they would misinterpret other infrared sources that could be in the rooms where these were set up, further limiting the ease of use (Nunez).

This could be solved by the new Vive Cosmos which uses inside-out tracking to map a much more flexible play space. In reviews of the Cosmos some journalists have noted that this reliance on "inside-out" means that the optical tracking on the controllers is hampered by overlapping them, demonstrating one of the biggest issues with this type of tracking (Lee). However, at this point it is hard to say if this tradeoff of gameplay quality for improved ease of use is worth it. At this point in the adoption curve it may be more important to get the middle adopters started with an easier startup in order to fund later improvements on the gameplay.

Sony: PlayStation VR. The PSVR is still working with the setup woes of the original Rift and Vive as they only use one camera to track the motion of the user. However, it is reasonably easy to setup and allows someone who is wearing the HMD to set it up while looking through the camera. This simplification may be one of the compromises PlayStation made in order to adapt the hardware of the PSVR to the limited hardware of the PS4. Their follow up system, the PlayStation 5 will still support the original PSVR and there has not been any new announcement about updating the hardware of the PSVR for this system, so we may see Sony wait until other companies figure out inside out tracking and see how the market reacts to it before investing in creating a response. With their focus on creating an accessible product this strategy will allow them to perfect how their new system might react to VR and will help them figure

out just how easy they can make the setup for a new PSVR. This is probably done to follow the design philosophy of game consoles, easy plug-and-play gaming for any consumer.

Learning Curve

The next roadblock in matters of complexity is the learning curve. This idea can be as general as simply using the prepackaged software or as specific as being able to become immersed in the experience provided. Most issues with poorly designed software are resolved before a program makes it to the mass market due to the notoriety of the companies that they are partnering with. This helps focus the question for this section to asking about the audience response to experiences that are available for the home consumer and if those experiences are able to provide the amount of immersion the user base is looking for.

Facebook: Oculus. The man-machine interface for the Oculus has been polished as much as its pedigree would insinuate. With a user interface designed around pointing at your desired menu option with a laser pointer it functions as a logical interface that then links into its games and experiences with similar polish. Issues associated with these games usually come from the user expectation of being able to do more than they can actually do (Chen). However, in order to provide the level of freedom desired by the user it could take millions of dollars and hundreds of man hours from the developers to reach this point. These groups are quite limited at this time in the lifespan of VR, though in the future this might not be true. Issues with input difficulties are limited to the sensor boundaries. Thanks to using between two and three sensors the Rift Consumer Version

and its predecessors are able to account for the various possibilities presented by the user. However, the newer systems, the Rift S and the Quest, use inside out tracking.

HTC: Vive. According to several reviewers (Nunez; Wagner) the original Vive is an intuitive system to use. The experiences available for the system through Steam VR take advantage of the increased play space of the Vive in order to tap into the motor functions people are used to in everyday life. The controllers have impeccable tracking and their iconic shape translates into a wide range of uses in games. This connection strengthens the naturalistic style of immersion present in the experiences on the Vive. The biggest drawback to a user's immersion may be the particularly heavy HMD and link cable tethering it to its base computer. These are particularly prone to getting in the way when the user is involved in more athletic experiences, drawing them out of the moment. However it seems that this issue is somewhat mitigated as the user grows accustomed to working around the cable (Wagner).

Sony: PlayStation VR. Most of the issues between the system and the user come from the compromises PlayStation had to use in order to bring a relatively cheap console-based VR system. Once again, the first and possibly most noticeable issue comes from the limitation of having a single camera capturing the motion for the user. This can lead to issues of overlap with the controls and possibly the HMD itself that can cause hiccups in the gameplay, wrenching the user out of the experience (Pino, "PlayStation" 2). This crack in the immersion has made its way into the knuckle controllers for the Vive Cosmos and may be the next major technological hurdle for hardware developers to build around.

User Interface

A logical user interface is a crucial part of user experience. This becomes the main visual language that a user must become accustomed to in order to interact with VR experiences. This means that clunky half thought out systems should give way to polished "invisible" systems that do not put an undue strain on the user (Sherman and Craig 51). This is where big companies with established user experience (UX) teams have an upper hand. The importance of this UX is magnified due to issues with limited trialability necessitating a good first impression with a smooth understanding of the system. A good system must be simple enough to facilitate intuitive use with a short learning curve, and complete enough to allow developers the freedom necessary to explore the possibilities available in VR.

Facebook: Oculus. The user interface on the Oculus Rift is built around a virtual living space with a rather universal menu sitting in the middle of it. This makes switching between games a painless endeavor. Purchasing and installing new games is also possible from this screen (Pino, "Oculus" 2). The rest of the Oculus interface is operated by using a laser pointer to point at your selections and selecting it with the appropriate button on the remote.

This system may change with Facebook's introduction of built in hand tracking on the Oculus Quest and Rift S at the beginning of next year (Oculus Blog). The realization of this idea has been many years in the making and will require that a whole new interactive language be created in order to let users interact with their system in a logical way. At this time there is only a small smattering of examples, shown off at Oculus Connect 6, for how this will be implemented, but with the focus Facebook has put

on this element it may become the source of whatever the ubiquitous user interface for hands free VR will be.

HTC: Vive. The original HTC Vive uses Steam VR as its user interface, which is very similar to the "Big Screen" mode available in the Steam desktop application. This parent user interface (UI) includes both a social connection to Steam message boards and "Chaperone Mode" which serves as a prototype of later passthrough technology that has been included in the Cosmos. It also provides a direct line between Steam and the customer, so they have software with which to use their system.

The HTC Cosmos has shifted away from this system completely as it is their first system shipping with the "Vive Reality System" (Lee). The UI that comes packaged with this is called Lens. Within this UI their home screen program, called Origin, has a tutorial for people new to VR in which new users can learn about the still developing language of inputs that is used in VR. These would include things like pointing to an area the user wants to go to or the limitations of the passthrough system. This focus on first time users helps with the reputation HTC VR products have had of being unfriendly to new users.

Sony: PlayStation VR. Sony has decided to go the invisible route with the integration of the PSVR into the user interface of the PlayStation 4; making the headset work more as another kind of controller rather than a device with its own identity. To access VR games the user has to navigate on the monitor the PS4 is initially connected to, and that screen doubles the point of view of the HMD. This allows for friends in the same room to interact with the player without much issue. However, by relying on the main monitor to navigate out of game menus the user has to remove the headset in order to

switch between games, something which most other headsets go to great pains to avoid. In order to play games in VR this system uses controllers which have 8 buttons in a nonergonomic configuration which previous PlayStation users would find as a stumbling block as the 4 famous face buttons from the main controllers for the console are in a different configuration. All in all, this interface seems disjointed by comparison to the other market offerings and may see change as Sony develops new VR systems to accompany the PlayStation 5.

How does it All Work?

The final and possibly most impactful issue of complexity has to do with potential adopters being put off by a lack of understanding of how these devices work. The president of Viveport at HTC, likens it to the moment in *The Matrix* where Morpheus tells the protagonist that there is another reality outside of the one which he had known for his whole life (Akopyan). Virtual reality has been crafted into myth through various fantastical depictions in science fiction. This is where the need to have consumers try out the headsets comes from. Misconceptions about how personal and invasive the technology is, may lead people to never give it a chance. This issue crosses over with that of observability as VR is a technology that is not conducive to voyeur experiences in the same way that videogames are. The vice president of marketing for PlayStation, Mary Yee, said that getting consumers to try out VR is a major part of their marketing strategy (Duran). This is at odds with the trope of television stores creating displays with hundreds of different screens vying for the consumers' attention. When these issues of observability are resolved, this issue of a rather complicated technology intimidating potential adopters may no longer be an issue.

Trialability

Issues of trialability in VR stem from the high price for new devices, and the steep learning curve previously mentioned. As such, some companies have turned toward cheap to produce options, showroom demos, and providing the carnival like experiences of location-based VR. These options are supplemented by a focus on intuitive design by some companies so that they gain the attention of possible customers trying a friend's device. These solutions speak to the fractured nature of VR as a marketable product and is going to shape the identity of VR as it develops in the future. The three companies this study focuses on have taken on different identities in order to focus their efforts on more cohesive groups and in so doing, have a greater impact on those audiences.

First Time User Experiences

The importance of a user's first impression cannot be understated as it is of critical importance that a new device is not returned or relegated to a junk closet if these companies want to continue counting on income from their initial adopters. This is consistent with the tone of several reviewers cited by this paper, because they dedicate nearly a third of their review to their installation and first impression, glossing over what might keep them coming back in favor of what might have made them lose interest in the product (Nunez; Pino, "Oculus" 1–2; Pino, "HTC" 1–2). This is stated quite elegantly by the editor of *Human Factors* in 1990 in reference to computer hardware design, "When you consider the fact that there won't be a future without your customers, isn't it important to you that their first impression is a good one?" (Potosnak 83). This section focuses on how each of these companies address the first-time user and what special adaptations have been implemented in order to accommodate a positive first impression.

Facebook: Oculus. The Consumer version of the Rift came packaged with an initial experience for new players called Oculus First Contact which provides the user with a function introduction to the motor controls found in VR. The player can interact with a series of blocks and tools as they are guided by a virtual robot (Stein). This demo provides valuable experience to the new user that could help to stimulate a further interest in VR. It is important that this kind of program keep the barrier to entry as low as possible and allow people to learn and understand how to make VR work more than challenge them from the beginning. This keeps a possibly perceived skill barrier of entry from becoming an issue. This is further supported with a relatively universal UI that mimics those found on Xbox systems. This makes navigation a relatively straight forward process that builds on existing knowledge which a user probably already has (Pino, "Oculus" 2). By teaching new users the ins and outs of interacting with VR, and sticking to a well understood menu system, Oculus manages to create a first experience that avoids alienating potential adopters. This increases the chances of repeated interaction.

HTC: Vive. The original Vive had little more than an installation assistant program that would make sure all the lighthouse sensors were properly interpreting movement in the room. With the upcoming release of the Cosmos a new system called Origin has been developed to shepherd new users into a basic understanding of the internal language which the system uses to teleport the user around and interact with menus (Lee). This increases the system's approachability because it can serve to educate new users in a way that expects no previous knowledge on the part of the user. While the Cosmos does not come prepackaged with Steam VR, it does still provide access to content on that platform along with a sign on bonus of either a year or six months of

Viveport Infinity, HTC's VR experience streaming platform. This provides another reason for users to not abandon their system once it is set up, all the games they could possibly want to try in VR that HTC has access to, are right there. This ease of use is bound to give the Cosmos a leg up on their competition, high price aside.

Sony: PlayStation VR. When looking at first time experiences in VR, it is important to note that virtual reality has been used to refer to video games and role play experiences on 2D computer screens. This means that many self-identified gamers have been used to the ideas present in VR for a while. This came with training in how to do motion controls in the Nintendo Wii and similar systems like the PS3 (which implemented the Move controllers that are now the main controllers for the PSVR for games) which, when compared to current VR titles, seem eerily familiar. This Makes Sony's decision to not include a prepackaged "first experience" with the PSVR less surprising as a great majority of their users would be familiar with the concepts presented by VR motion controls due to the very nature of owning the required console to begin with. This is the first-generation system that is the closest to being "plug and play" thanks to its single motion tracking camera. As mentioned before, this creates a very swift first-time user experience as the time from setting up to playing a well-known title is much shorter than those found with the Oculus or Vive. Thanks to being a well-established game publisher, Sony has all the tools necessary to make the PSVR succeed when it comes to first impressions (Pino, "PlayStation" 1).

Demos

There have been attempts at getting, cheap to produce, cardboard HMDs that have the user's phone serve as the screen, however this has not been a widespread approach. The three companies highlighted in this study have instead opted for a balance between showroom demos and in store demos. These offer the best opportunity for a potential adopter to understand what VR is. This also means that developers can show off the potential future of VR in a controlled environment, building interest without opening themselves up to deeper scrutiny on their exact execution of the experience. Showroom demos are supplemented with in-store demos and interactions within the work environment. Between these three approaches these companies are able to spread knowledge about VR to the widest possible audience while at the same time tailoring those experiences to what that particular audience may want to know more about.

Facebook: Oculus. Oculus has used their yearly Oculus Connect show to do this exact method of slowly building interest in a project. A great example is their introduction of hand tracking on the Oculus Quest which will be released in spring of 2020, announced at their recent Oculus Connect 6 (Oculus Blog). Similarly they demonstrated the possibilities of "arena scale tracking" on the Oculus Quest at Oculus Connect 5, even though that software has not been implemented in any experience on the Quest yet *(Chan,* Oculus Quest VR *00:21:30-22:04)*. This all serves to spread public awareness of the capabilities of VR and let journalists speak to the experience, in a vicarious expression of letting the wide-ranging public try out these experiences. If this is not enough to spread the word, Facebook has provided systems for Best Buy and Microsoft stores to provide Demos of the Rift S and Oculus Quest in order to help

potential adopters try out VR (Heaney). This is fitting for a company with such a wide influence and is one more element that can help to further VR's presence in the public eye. Facebook is targeting the general consumer electronics market with these techniques, allowing other companies to focus on the gaming and industrial markets. By approaching the issue of trialability from several different angles, these companies are able to achieve a deeper interaction with the market.

HTC: Vive. "Our strategy is essentially to let others speak for us, let the developers show their content, let them show their experiences" (Akopyan). This quote from the president of Viveport, HTC's new VR game subscription service, may be oversimplifying HTC's role in the propagation of first-time experiences for people new to VR. Instead of focusing on the private home consumer market they have instead chosen to invest in their content creators and focus on delivering the highest quality material possible, allowing 3rd party companies show off these experiences in arcades and other out-of-the-home displays. This "real-life" interaction serves a different sector of the public that may not interact with electronics stores on a regular basis but may run into applications in their workspace. By targeting the public from this more hands-on angle, it opens VR up to the industrial and simulation markets, which have helped to keep VR relevant since the 1960s with the introduction of flight simulators.

Sony: PlayStation VR. Demos are the primary focus of the Sony team in charge of advertising the PSVR. The Vice-president of marketing for PlayStation, Mary Yee, said in an interview that …"Getting more interested gamers exposed to it would not only be good for us, but for the industry." (Duran). This article also references the importance

of letting potential buyers test out the system before buying it. This is the primary reason for having demos available in GameStop and Best Buy. Combined with their laser-focused audience of PlayStation owners, these techniques would at first seem to put them at a disadvantage as they require a significant initial investment. However, this strategy combined with lowering prices and their implementation of location-based VR experiences are how they have held on to their initial adopter wave and are seeing positive results as they now rival HTC and Facebook in headset sales.

Interacting with VR in the "Real World": Arcades, Training, and Location Based VR

A recurring detail throughout this research has been the challenge of expressing the value of using VR to potential customers. This affects marketing strategies and even design strategies intended to increase the observability of VR. However, this conversation usually turns to the idea of getting people to try on the headsets. The different companies use trials and trade shows to do this in a very direct and public manner, which is worth its own section of research. This refined approach to advertising the benefits of VR is the most visible way many customers may interact with the marketplace; however, more naturalistic methods should be addressed as well. Interactions "in the wild" per se, provide users with a more direct answer to the question of how VR can apply to their life. Seeing enterprise and education applications for VR may open up sectors of the industry that have not been fully tapped into yet. This also serves as a low-cost way for people to get to try their hand with various VR systems and to find out if they like the experience, or maybe inspire them to incorporate it into their home entertainment setup with the possible premise of applying it to their work environment as well, much like the personal computer in its early days.

Facebook: Oculus. The challenge of location-based VR is not one easily taken on. In late 2018 an article in Variety stated, "Up until recently, senior Oculus executives seemed to be dismissive of location-based entertainment even behind closed doors, stressing that the company was singularly focused on selling its headsets to consumers for in-home use" (Roettgers). This shift in tone, from one of close-minded focus to that of seeking out new possibilities, shows the importance imparted by these companies to getting these systems into potential adopters' hands. Even with the massive growth that Oculus experienced in the four years between being bought by Facebook and this article it was clear to the executive working with Oculus that more customers needed to have a hands-on experience with the system. This shift in policy has brought about a new line of business for Oculus as they have begun to work with enterprise partners in a capacity similar to HTC's system described later in this chapter. The action of dedicating resources to creating these partnerships can be seen as a sign of good faith that Oculus would support more experimental experiences in location-based VR such as The VOID, a location based VR company that seeks to explore group dynamics along with the possibilities for immersion available to location based VR (The VOID, LLC.).

HTC: Vive. Since the beginning of HTC's foray into the world of VR they have been focused on supporting their developers and enterprise partners through a series of programs that looked to support these small companies with both financial and technological needs. This has recently been doubled down on as HTC announced in June of 2019 that they were creating VIVE Enterprise Solutions, a new business branch that seeks to be a both hardware and solutions provider for both large corporations seeking to implement VR and smaller startups that show promise but need support from the parent

company (Fink). This emphasis on enterprise VR is also the biggest reason the Vive and Cosmos are the most expensive headsets in comparison to the various offerings from Oculus and the PSVR. These machines are meant to be implemented in a way that can provide income for the owner. This can be compared to the enterprise version of the Oculus Quest, which is retailing for $999 US plus a yearly $180 subscription to their enterprise service per device (Melnick). Looking at the history of VR, this strategy could bear fruit in the long run as the enterprise market around simulations and training has been keeping VR afloat since the 1960's and the introduction of programable flight simulators.

Sony: PlayStation VR. Due to the limitations built into the PSVR in order to make it easily accessible to the home console market, it is not the kind of device a company would use in order to create a location-based VR experience. However, the low cost of the systems and large game library accessible through their parent company Sony make them the perfect system for established arcades to add to their lineup. This is happening in Japan as Sony and PlayStation have partnered with several arcades in order to provide their customers with the hands on experience of playing in VR in an environment in which this kind of arcade already has a significant amount of success (Cooper). This was reportedly done in response to the slow response to their release by potential adopters (Mochizuki). Currently the PSVR has taken over the market having passed 4.2 million units sold as of March 2019, and according to their corporate blog seem to be focusing more on increasing the value of their game library to entice new consumers to take the leap into VR as opposed to loudly advertising their location based prospects (Grubb).

Observability

The issue of observability is one that can be seen in the formfactor of modern VR, it is a private experience where one is isolated from the world by the actual device. Spectators to those experiencing VR are not able to see how the user's eye is perceiving the 3-dimensional elements coupled with the 3D sound system and peripheral vision. It's not like the case of an arcade cabinet or a TV where some of the entertainment value comes from the vicarious experience of seeing others participate. In order to properly address this issue, this chapter is looking at how the industry as a whole is answering these issues instead of on a company by company basis except for when they show distinct approaches to these questions.

Big Media Moments vs Accessibility

An important difference in marketing approach between these three companies is in how they choose to relate to their customers through their advertising and how they gain mass appeal. These three companies represent two major ways of doing this, marketing with big splashy headlines, and increasing the accessibility to the product in a more individual manner. These methods seem to be related to the size of the company. Companies which have massive cultural influence have enough notoriety for announcements to make a splash in news media and in so doing, reach a high percentage of the population with no major investment on their part. However, this can come off as impersonal. The second method, increasing accessibility, is built on a more personal scale. By emphasizing the importance of each possible customer, a company can increase its outreach. VR companies can do this by interacting directly with their customers and providing more personalized feedback.

Facebook: Oculus. The most notable example of marketing with big headlines is the previously mentioned case of Facebook's purchase of Oculus in 2014. There is a noticeable uptick in the public's interest in VR in the days following this announcement, and the release of the Oculus Rift Consumer Version was met with a similar yet already toned-down reception (Google). In early 2019 Facebook again tried to capture consumer's attention with their marketing campaign for the Oculus Quest, an HMD which boasted internal room sensors and a much lighter design, similar to the Google Daydream. However its reception upon release during the summer months was subdued, contrary to the advertising campaigns expectations (Swant).

HTC: Vive. In the past few years HTC has pivoted away from the home consumer market with a notable scale back in their advertising resources (Hayden). This has been paired with a significant uptick in their investment in the corporate sphere. Most recently this has resulted in the creation of their business unit for corporate VR (HTC Corporation, HTC PRESS). By doing this HTC is demonstrating a clear focus in their strategy for making VR profitable. By promoting VR's accessibility in a market with a significant amount of financial resilience they are assuring the survival of the system. It is important to note that the corporate/industrial sphere is the historical root of VR and has a much longer track record of being successful than the home market. This shift has happened apart from the public sphere so there may still be some reliance on the consumer market.

Sony: PlayStation VR. Sony's marketing strategy is deeply rooted in making it easier for their customers to buy the PSVR. Actions like reducing the price of their HMD

or packaging the base console, one of the two prerequisites to operate the PSVR with the second prerequisite, the camera that functions as the motion sensor, or making sure demos are available in stores where the console is sold, function to bring ease to the consumer and show promising results as PlayStation continues to invest in their VR market offering (Duran). This tone is set to continue as they will continue to support the PSVR on their next flagship console, the PlayStation 5.

Built-in Observability

The issue of observability for VR is one which comes from its form factor as an isolated experience within the headset. However, the vicarious experience of VR is one which these companies have considered, and in so doing have implemented a series of ways to allow people outside the experience to take a little look into the virtual world. These are not groundbreaking implementations of these ideas as many gamers have grown accustomed to having the ability to participate in backseat gaming by watching someone else play on either a shared screen or streamed video. These details are important to point out due to being so mundane that they could be quite easily overlooked (Nunez; Pino, "Oculus" 1–4; Chen).

Facebook: Oculus. The challenge of demonstrating what VR users perceive in an experience might be solved by giving spectators a window with which they could look into the virtual world. Facebook showed off this exact idea at Oculus Connect 6 where they had a location-based experience that showed off the capabilities of the Oculus Quest. The spectator system took the form of a tablet with a camera facing away from the user which would take the real life footage of the player in the experience and overlay that

over the virtual environment as it would be seen from the point of view of the tablet (Chan, Oculus 11:25-14:05). This allowed people in line to watch the VR experience without the need of an HMD.

Interestingly, the Rift does not automatically mirror the HMD display to the main monitor it is connected to, limiting opportunities for social interaction. This is available with an application that comes with the Rift software; however, this creates a barrier of complexity that limits the social environment around the rift. This seems to have been resolved in the Oculus Quest which allows users to stream in game footage to nearby smart systems like Chromecast (Robertson). This shows that the need for built in solutions to observability is one which these developers are taking more and more into account.

HTC: Vive. The Vive seems like the least observable system of the three discussed here. Valve and HTC's solution to built-in observability comes in the form of a window that pops up when a user starts up an experience with SteamVR. This system allows for social interaction with other people in the same room and can help to alleviate the isolation felt in VR. This can help as a bridge to help indoctrinated users teach new users about the experience by letting both parties see the display (Pino, "HTC" 2). Steam messages do still come through the Vive and players can respond while still in VR however this is not a function of observability as it does not serve to represent the virtual world.

Sony: PlayStation VR. The PSVR has two options for ways users can interact with others either in the same room or across the world. One is Social Screen which is a

program that projects the image coming from the right eye of the user wearing the PSVR one the main screen that is connected to the system. This allows for interaction with others in the same room. The second offering that PlayStation provides is through the PlayStation Network. Share Play allows users to share the experience of a game by either allowing others to spectate remotely or even pass along the controls without the second user needing to actually own the game at all (Sony Interactive Entertainment Europe). These two options provide a subtle level of connection that allows very social users to maintain the social interactions they may desire in VR while not creating an environment that would push away users with less of an interest in this aspect of VR. This comes together to ensure that VR does not have to be a socially isolated experience (Pino, "PlayStation" 2).

Immersive Advertising

The trend of immersive advertising, defined as advertising that intends to interact with the viewer beyond the capabilities of typical 2D advertising, has surged with the contemporary rise of VR, and is a contributing factor to audience reception of VR. Research analytics for these new approaches show a demonstrable increase in audience interaction and click trough rates, and it seems that there is a positive relationship with the amount of the VR sphere that is being implemented. 2D being the least, and full VR interaction being the greatest, passing through 180° images and 360° videos along the way (Parikh). In the case of many consumers this is an introduction to the idea of VR and may be the precursor to a broad understanding of real-life VR that these companies are looking for. These applications could be considered VR-Lite due to a difference in how this project has defined VR versus augmented-reality (Johnson). These advertisements do

not add new information to the world around us but instead provide a momentary experience in another reality.

Facebook: Oculus. The creation of Facebook 360 has led to the propagation of a certain level of understanding for the utility of VR among the billions of users that are on their massive social media platform. Facebook 360's home page is headed with the statement, "[Facebook 360 is] A stunning and captivating way for publishers and content creators to share immersive stories, places and experiences with their fans" (Facebook, Inc.). This is a good example of how a side effect of lighter applications of VR might be able to provide a semblance of familiarity with VR. VR as a concept becomes something which every user of the platform becomes familiar with even without a direct awareness of this conditioning.

HTC: Vive. Vive has become the first company to introduce advertisements into their free offerings on Viveport, their virtual store for VR content. These made a splash in the news as part of the analytics that they track is how long you spend looking at the advertisement (Boyle). Their proposition seems to range from a full immersion in an advertisement to more subtle blank spaces like graphic t-shirt designs on a character model in an experience. This grandiose swing at the advertising market seems to have alarmed many reviewers who ask where the boundary is between appropriate advertising and intrusion on the users privacy (McCarthy). Vive being the first of the big companies to implement active support for advertisements within their software ecosystem bears noting as they are the company most focused on enterprise VR. Understanding user haptics that might be recorded during a session would be invaluable information for both

the enterprises using the systems as well as the greater corporations who are trying to tailor their content to better suit VR users. This is feedback which the advertising industry can use to better understand its audiences even in other 2D mediums as it could reveal subtle information about calls to action that had to be extrapolated before VR became an option (McCarthy; WebFX Team).

Sony: PlayStation VR. Unlike the Vive, the PSVR is advertising-free for the same reason it has set itself apart from the other two companies; it is a console peripheral. In the early days of console gaming this characteristic was less noticeable. However, one of the draws for gamers to the console market is that these devices provide an experience that is easily contained and does not require outside input in order to provide value to the player. By the same virtue that a new user can play any game from the PS4 lineup on the system immediately when they unbox the system, this same new user does not have to contend with advertisements popping up in their game. This is because, "PlayStation VR is fully focused on PlayStation-compatible video games. Those don't give a lot of opportunities for advertising if any at all" (WebFX Team). This does not leave PlayStation out of the market for VR advertising as their new campaign to advertise the PSVR makes use of carefully selected imagery in order to communicate to the viewer the sensations of VR (Duran). This is a clear attempt at resolving the issue of observability for VR.

Media Representation

Media representations of VR are the final aspect of observability that can help to educate the public on what VR "feels" like (Duran). However, this issue is not something

in which can be separated by company, because they have not made their way into mainstream media in a capacity higher than that of a product. Instead this section focuses on two varieties of science fiction VR representation: realistic or what we do currently have, and fictitious or something closer to the ultimate display which Sullivan wrote about. This is meant to help identify potential outside influences upon the public understanding of VR.

Idealized representations. These stories function as a way to channel the possibilities of VR. From utopian futures in which society has already solved most of the issues that would make such an innovation dangerous, to futures in which a dangerous virtual world is the only way to live in an otherwise hostile world; these representations worry less about the science behind the machines running these virtual worlds and focus more on why a virtual world is important. These examples can implement the simulation functions of their VR systems as a functional tool to augment their everyday lives like in the training programs in *The Matrix* (The Wachowski Brothers), or combat simulations in the *Star Trek* series (Roddenberry). These examples stand out as nearly word for word representations of the ultimate display described by Dr. Sutherland. Episodes of *Star Trek* (Roddenberry) which involve the simulations on the Holodeck going wrong, involve safety systems built into the system failing, allowing danger to come to the crew involved (TVTropes). This hints that the series may be asking just what the safe limits of VR might be and if there should be safety systems in place to ensure that technology does not cause harm. Most of the series premiered before the Virtual Boy caused its issues, so these questions may not have originally had direct application to any real-life technology. It may be beneficial to look back on these works as development continues, in order to

try to anticipate the very worst-case scenarios depicted in stories set in relatively utopian realities.

Realistic representations. This category of representation ranges from fictional stories like *Ready Player One* (Spielberg), to news stories covering the pop culture and tech world. Fictions which represent VR in a practical and grounded way fall into this category because of the nature of the reality they present. Viewers could feasibly come away from one of these experiences and understand how virtual reality that we currently have should work. The mystery behind the HMD is taken away through clever wording or cinematography. These are an important addition to the observability of VR thanks to this creative language guiding potential adopters through the experience. The main issue with this method of propagating observability is that by being artistic representations, these works have an inherent point of view which could clash with the viewers own perception. This could cause a viewer to disregard an innovation due to a breakdown in communication between the creator and viewer. This could of course happen with any creative work which could attempt to educate its audience. For example, there may be a difference in an audience's interest in trying VR after watching *The Matrix* (The Wachowski Brothers) as opposed to an audience who just saw *Ready Player One* (Spielberg).

CHAPTER FIVE

Conclusion

Futures Cone Projection

The Futures Cone projection used in this section will serve to avoid redundancy. The elements of the structure which are being used here will focus on the possible worst case, the more probable middle ground, and the optimistically preferable scenarios. It is important to remember that the elements brought up in these forecasts can shift between the three categories as time passes, ensuring their relevance to future readers as more developments shape the future of VR. The futures cone has been used to model several possible future outcomes (Voros 5–6).

Possible: Bottom of the Cone

The lowest level of adoption that could be visible in the future of VR is a complete scale back in the entertainment industry. Production companies would cut their losses or sell off assets and designs to private companies focused on industrial simulations. However, the simulation industry would continue to flourish as it provides a tangible value in the training of specialists like pilots and heavy equipment operators in the same way as it has since the 1960s.

In the next five years, a continuously shrinking industry would be buoyed by the professional simulation side of the industry as this kind of professional education has been the continuous through line for VR since the 1940s. Jobs in operating heavy machinery and piloting airplanes may continue to use these systems for the near future.

However, the entertainment industry would turn away from VR as a viable option within this time frame due to the high costs to produce both content and hardware. The increasing demands for higher quality content will increase the pressure on these companies to keep producing higher and higher quality content, creating an accelerated timetable to drop this investment and focus on other sources of income.

Following this timeline for the next decade would reveal VR as an artifact of a previous age. The previous heavy equipment training through simulation would be severely cut down as other technological systems take the reins and provide both a safer work environment and a better bottom line for companies. This trend has been growing since the beginning of factory automation, and these systems would continue to progress as the systems for automation get progressively better (Burdea and Coiffet 360). At this point VR for entertainment would return to being a garage kit driven hobby. Individuals might still use it for niche work like 3D sculpting or in order to assist with game design for other display systems, but these would be the exception.

Probable: Middle of the Cone

The most probable continuation from the path we are currently set on is that VR will slowly make its way into our media ecosystems. As systems become easier to setup and use companies will continue to invest creative resources into providing content that is designed to have a competitive value in relation to more traditional media display systems. However, this will be a slow growth more similar to the timeline for television game systems than the graphic development seen for PC games. Consumers will slowly continue to adopt VR in a very cautious way. This shift in adoption will feel contrary to the way's other media, like cellphones, are adopted. This slow adoption will allow for

companies to make more meticulous decisions in both hardware and software production but means that a major mistake could completely eliminate them from a competitive market.

The next five years there will be a shift in the VR industry from developing hardware solutions to creating next level interactive environments to attempt to keep viewers online for longer. This may come in the way of VR driven social media, like *VR Chat*, which has shown the public's interest in such face to face chat rooms. The viral response to *VR Chat* has since died down. However, the virtual worlds presented by other games like *Second Life* have been alluring since their creation at some level. A killer app from this genre of social media virtual spaces may be the next big thing to bring VR back into the social conscience. Meanwhile software developers will continue to develop better environments in order to focus on the user's gameplay experience. Studies into the enjoyment of VR games have described that enjoyment of VR games is directly influenced by the programs' representation of spatial presence (Shafer et al. 2). As games develop over this five-year period, this kind of feedback from the community of active VR users will shape the kinds of games that are made, creating a unified definition of what makes a good VR experience.

In the next ten years we could see the emergence of VR as a staple of communication through shared chat rooms for face to face communication through avatars. By this point a killer app for social VR media will have emerged, and a new generation of users will populate it. These users will have entered the market at around the time that most of the hype from the first release of the Oculus Rift will have died down, and as such will only be familiar with the easier to use systems, completely

avoiding the question of complexity that have plagued early systems. This new generation of users will use social VR media as a kind of pre-game chat room as the market for VR games will have crystallized a series of flagship games that make the most of the new creative tools available to game makers. This series of games will incorporate improved isometric representation of the player in the game with the social aspect that makes VR so intriguing. This can create group experiences that bring the whole video game culture closer together. The games that do this will have developed over many years. This is due in no small part to the amount of artistic innovation that must happen to fully implement the amount of creative options that are available to VR environment artists. It will take some time to figure out just how the Z axis influences game design and how to optimize these applications into a smooth gaming experience. Despite all of this, VR's standing with the public in the following decade will probably not change too much. It will still be a niche form of media consumption. However, it will be an important part of gaming culture.

Preferable: Top of the Cone

The ideal or top of the futures cone would be an eventual mass incorporation of VR into household media systems in a similar way to what happened with television. This mass adoption would be propelled by the social utilities available to VR in a similar way to what is seen in many science fiction depictions of the same. Seen with the technology we have available currently this could mean having VR setups throughout the house, however headset integration of motion sensors could be the push that is needed to make these systems widely adopted by the gaming crowd in the short term, and adopted by most people in the long term. These systems would be used for daily communication

on social media and would be useful for other media consumption, redefining the home cinema.

In five years, daily life would be defined by massive adoption of VR fueled by social pressures for adoption. In much the same way Facebook was adopted nearly 20 years ago, or television 50 before that, VR would become the next way to shrink the world as people would use it to meet with friends from far away and enjoy the presence that can be felt from VR's isometric representation of its users. This would be more easily accomplished once issues of complexity melt into the rather archaic past of VR's development. Plug and play as a selling point in today's technology markets serves as a preview of what this would look like. Business would be carried out through VR conferences instead of Skype and gaming would completely shift over to VR systems. Issues of motion sickness and poor motion representation would be left behind as more and more money is invested into recreating reality in VR by way of high frame rate and wide color gamut.

This obsession would continue to expand to a decade from now with the trend of creating locations in VR worlds represented physically in real locations on earth much like the extradimensional "Big Market" from *Valerian and the City of a Thousand Planets* in which people separated by dimensions interact through VR headsets (Besson). This everyday interaction with the virtual world would redefine how people interact and would see heavy pushback in terms of compatibility as several religious groups that already have issues with online interactions would see this as a massive conflict with their beliefs. This mass propagation of VR would be driven by the utility of creating a physical storefront that could be seen throughout the planet, creating a new avenue

through which to increase sales. By this point the question of government regulation would be broached as world governments would seek to be involved in online marketplaces. This view of the future would also mean that jobs that are currently shifting to the digital sphere like physical store front design and person to person marketing would become lucrative again. Headsets from this future will be defined by their ubiquity and portability as spaces designed to be seen in VR would ask customers to put them on before entering.

Discussion: The Ultimate Display II

The ultimate display would be a room in which a computer can control the existence of matter as perceived by a viewer. This experience would be one in which many people could be involved and would cater to the human need for social interaction while allowing the user to express ideas not possible in the material world. In order to do this, future generations of computer engineers and designers will need to find a design methodology that puts the user first as it is perception that drives the experience of Virtual Reality.

In order to provide enough of an isometric representation of the user in this system, input systems will need to be refined to the point of vanishing into the basic structure of the hardware, removing the need for the user to consider their proper function. BY taking the responsibility of proper system function away from the user a proper level of immersion might be achieved. This should be combined with high levels of fidelity with the virtual world in which the viewer is be immersed so as to increase levels of immersion and lessen the possibility that the user be pulled out of the experience by a fault in the experience.

These ideas may lead to a global society more connected than ever before as users would consider it normal and mundane to speak face to face with a friend on the other side of the world. There would be business opportunities that were once obsolete thanks to the World Wide Web that could once again flourish as a global community would walk the streets of a virtual overlay of the real world, and the ability to walk the streets of a far-off country and shop from real world store fronts from the comfort of their hometown. This will not be a replacement of the real world but an amplification of the real-world experience. In this way, Virtual Reality has the opportunity to enhance the human experience by expanding our sphere of influence in ways not achievable through physical means, and connecting us in ways that are unimaginable to this author.

Conclusion

This discussion on VR and "The Ultimate Display" has been a journey that revealed a topic that is much deeper than initially expected. VR technology is deeply rooted in human nature and the desire to recreate the imaginary worlds that inhabit every imagination. It represents fantasy that does not necessarily need to be fantastical in nature. This innate desire will keep VR from dying out completely no matter how disastrously the technology might fall. From these deep roots a complicated system of market forces keeps sculpting the definition of VR into something more and more real. This complicated system makes VR a deeply engaging topic for study as well as for those who are enriched through using these devices, and as the landmarks of the industry shift day by day it will be interesting to seek out that deeper understanding of the crossroads between human creativity and the real world.

Further Research: Face to Face Interviews

A qualitative naturalistic methodology serves as the best method to probe the industry for meaningful insight into the future motivations and inspirations for technological development due to the human quality brought forth by seeking out meaning in the deeper context of the interviewees answers. "The naturalistic paradigm affirms the mutual influence that researcher and respondents have on each other" (Erlandson 15), so by participating in the exchange of information both parties (interviewer and interviewee) will have been exposed to a broad pool of knowledge and experience that they will be drawing meaning from. The particular case of VR, being a technology built on user experience means that there is a possibility of extreme variation between each individual's interpretation of the future needs of the industry. This "…context provides great power for understanding and making predictions about social settings" (Erlandson 17). It is important to note that while both parties may operate in a similar space in regard to language and meaning, each has a distinct reality that they inhabit. "The process of inquiry for the naturalistic researcher becomes one of developing and verifying shared constructions that will enable the meaningful expansion of knowledge" (Erlandson 21).

In order to carry out this level of inquiry interviews with several members of the VR development community should be conducted with the intent of searching for more recommended interviewees as recommendations from previous participants. As previously stated, the structure for the questions will mostly revolve around the theoretical foundation defined by Rogers and Kozmetsky. Questions that serve to orient discussion in relation to the individual's position in the industry will be required as

infiltrating the businesses and getting enough insider knowledge to absorb such information outside of direct discourse is outside the scope of this project. These would fall under the category of knowledge questions as defined by Erlandson and can serve as both icebreakers and segues into new question topics.

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