CHAPTER 12

Looking for the Ultimate Display: A Brief History of Virtual Reality

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Throughout recorded history, we have created ways to bring imagined worlds and stories into our own reality in the forms of art, literature, and, more recently, digital media. Humans seem to value this process highly, so much so that the names of ancient masters of art still resonate through our schools. Each medium has intrinsic limitations to how the creator's vision of an alternate reality can be reflected, and it seems that humans continually search for a medium more realistic and more immersive than before. That is what this chapter is about: the developmental history of virtual reality (VR) technologies. From storytelling to modern VR devices, artists and inventors tried to capture their audiences by making them feel present in an alternate reality. Presence, as described later, can be measured in multiple ways, each relying on the sophistication of the underlying technology. As expected, inducing a subjective sense of presence has become more reliable as technology advances. We may be at a time in history where presence can be maintained constantly during the use of certain technologies, yet vast room for improvement remains. This idea will be explored first, in the next section.

THE ULTIMATE DISPLAY

The idea of VR and the pursuit to create may come from an inner motivation to obtain the *Ultimate Display*, as put forward by Ivan Sutherland (Biocca, Kim, & Levy, 1995). Such an invention would be a mode of media that is an *essential copy* and allows the user to transcend physical limits. In other words, it is something that stimulates our senses in such a way that we perceive the simulacrum as being real and seemingly grants freedom, or abilities, beyond the limits of the user's physical reality. For those familiar with *Star Trek*, the holodeck might be the Ultimate Display; the holodeck is a computer programmable room that uses light and force fields to recreate a full sensory experience of

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anything. The idea of such an experience is naturally appealing to humans, and perhaps that is why technology has attempted to move in that direction.

As part of the Ultimate Display, an essential copy can be thought of as a perfect rendition of an object that fools all senses into perceiving it as real. Physical transcendence in this case is the desire to be someone or something else beyond what you are in the physical world, going beyond what you are capable of in real life. Physical transcendence is a personal, self-only experience and is believed to be achieved by going past all your senses or to even change them altogether (Biocca et al., 1995). The ultimate display would provide the experience of a manufactured environment so perfect that, as Leone Battista Alberti says, it becomes a window to the imagined world.

In the quest toward the Ultimate Display, humans have captured aspects of it by physical means such as film, or by abstract means such as narrative literature (Biocca et al., 1995). On the other hand, perhaps the closest we have come to realizing it can be found in the dreaming experience. When dreaming, our senses are tricked into perceiving imagined worlds that are constructed from what appears to be essential copies. In dreams, we sometimes experience physical transcendence by embodying different bodies, by defying laws of physical reality, and sometimes even by having spiritual experiences within dreams (Hobson, Pace-Schott, & Stickgold, 2000; McNamara, McLaren, & Durso, 2007; Revensou, 2006). Unfortunately, for the majority of us, dreams cannot be controlled or experienced on demand. They are also an individual experience, so they leave a lot to be desired if they are contending for the title of Ultimate Display.

VR technology offers an experience approaching, ever so gradually, the Ultimate Display. With modern technology, VR equipment changes the perspective of the person wearing the headgear so that they see a virtual world. Principally, the development of technology has been aimed at improving the visual fidelity of the simulated worlds, trying to be so perfect that it creates an essential copy of an imagined world. If a user can be so present in the experience of a VR world that they believe it to be real, then the ability to move around the 3-D environment according to any alien physical laws the programmer chooses to simulate in real time, VR technology may be the closest we have been to realizing the Ultimate Display.

THE INGREDIENTS FOR PRESENCE

In dreams and in any type of communication media, *presence* is an important and common factor. Presence is a felt sense of authentic reality that would result from engagement with sophisticated media. Although the term presence is thought to be coined by the VR movement, it is not restricted to VR alone and has always been incorporated in how we perceive ourselves in the physical world. To be present is to be continually aware of one's surroundings as being outside of their self, whether physically or virtually. To perceive the external environment, a person has to be aware of the boundary that separates self from other. Some accounts of spiritual transcendence have even been reported where the person becomes so aware of their perceptual surroundings in relation to their consciousness that they have a sense of physically transcending themselves (Jonas-Simpson, 2010; Piqué i Collado, 2015). Inside a virtual world, the self–other dichotomy can be manipulated to simulate the bending or breaking of our universe's physical laws, thus transcendence following presence.

Presence is also best felt when the perceived imagery is viewed with the same complexity as you would perceive visual reality, which will be explored later in this chapter. Something that could be considered an essential copy would be viewed the same way because that object would emulate the way we normally perceive our real environments (Biocca et al., 1995). That is why it is important to consider presence when talking about the concept of an Ultimate Display; a sense of presence is likely to result from perceiving something that is an essential copy.

We can better manipulate presence in VR when we know exactly what it means to be present. Steuer (1992) used three categories to understand what contributes to feelings of presence: vividness, interactivity, and user characteristics. Technologies that produce experiences for the user that satisfy criteria within these domains (and adapt to user characteristics) will therefore induce a greater sense of presence and ultimately inch our media toward the ultimate display.

Vividity is a measure of the richness and complexity of visual elements in the virtual environment produced by the technology. Clarity and smooth eye movements provided by the technology would help the user experience the vividity of the virtual environment; these metrics are related primarily to the hardware that is being used, but occasionally also to the efficiency of the software programming. The cues generated by a virtual environment, whether perceptual or conceptual, are another important aspect of vividity. They provide a sense of cause and effect, and purpose, in the world. Perceptual cues are external sensory stimuli that evoke physiological reactions, such as perceiving a large spider, which may cause a panic reaction. Conceptual cues are information-based stimuli that would otherwise evoke physiological reactions, such as reading about the description of a large spider. Perceptual cues are especially important in VR because evoking an appropriate response to a virtual stimulus has been shown to increase the sense of presence. Feeling present in an environment can increase fear reactions to stimuli, but fear to the stimuli itself increases felt sense of presence, a bidirectional relationship (Peperkorn, Diemer, & Mühlberger, 2015; Yoon, Choi, & Oh, 2015). Researchers have also looked at how different regions of our brain respond to VR cues [using 3-D models on computers, not head-mounted displays (HMDs)]. Their results show that the visual processing centers of the brain were the most active, which suggests the primacy of imagery in the virtual environment for increasing presence. Indeed, with more cues or visual information needing to be processed, reports of feeling present increase (Clemente et al., 2014).

Interactivity, a measure of how much the user can cause an effect on the virtual environment, contributes to the sense of presence. A study by Huang and Yu-Ting (2013) found that increased interactivity with a virtual environment increased the feeling of flow for the user. Flow, which is the experience of prolonged focus on a task without being distracted, has also been linked to the feeling of presence. Significant flow seems to provide a significant sense of presence for the task at hand. Of note, flow has been shown to significantly increase when users feel as though they are physically touching an object in a virtual environment, such as using haptic feedback methods in medical simulation games or shooting games. This feeling can be produced even by simple methods, such as a vibrating controller when holding down the shoot button in a video game like *Call of Duty* (Jin, 2011). Free movement, another form of interaction, in a virtual environment has also been shown to have a positive and significant effect on felt presence (Clemente et al., 2014). Proprioception, the internal awareness of relative position we all have, and a significant contributor to presence, is one of the main targets in the development of VR media. Proprioception gives us a sense that we are fully present within an environment in a real and tangible way, and as we become accustomed to the interactive dynamics of a virtual environment, this sense grows. The induction of proprioceptive sensations would be a powerful way to trick the brain into thinking that it is present in a VR (Wright, 1987).

Another good way to understand and improve the felt sense of presence in VR is by understanding how a user's characteristics play a role. Users tend to be individually unique in many regards, such as personality traits, technology proficiency, and even cognitive styles, among others. These differences alter the way they perceive a different reality, especially in a computer-mediated environment like VR. A sense of presence within the virtual world occurs because of how our minds combine cues and features of the virtual environment to create mental representations, similar to how we create mental representations of our normal, physical reality. This is best felt in projection-based VR systems like the Oculus Rift (Chafkin, 2015; Revonsuo, 2006). A user's cognitive style, which is the way they analyze and mentally represent an environment, can be put into two categories: object visualization and spatial visualization.

Object visualization style types are most impacted by the vividity of a reality, as they will focus on visual features of objects. Spatial visualization style types tend to analyze the spatial layout between different objects to determine the environment's realism, therefore having expectations that the virtual space would have the same complexity and interrelationships as it does in reality. Thus, it is important to keep both styles in mind when creating a virtual environment, since if it corresponds to how we typically analyze real-world information, we will more likely feel like we are actually in that environment (Yoon et al., 2015).

The essential copy is something that perfectly fools the senses, but it is not a binary concept; the proximity of any particular media to the essential copy can be measured on a spectrum. Physical transcendence is freeing the mind of the constraints of the body. VR technologies have taken steps in an effort to completely fool the senses and take the mind where the body cannot go, from panoramic paintings to modern technologies. Because there were so many steps along the way to creating today's VR technology, it would be impossible to name them all here. Instead, we will touch on a few of the steps along the way to illustrate how VR technology has pushed boundaries to create alternate worlds that feel real. The quest toward the Ultimate Display is a staircase, leading ever upwards, built from art, technology, and the visionaries, to create worlds from imagination that transcend the rules of physical reality.

FIRST STEPS IN VIRTUAL REALITY

Storytelling is the internal process of creating a world and sharing it with others, which may be considered the first VR. It is the process of being guided into the imagination of another person who is facilitating the creative process. Yet, when one hears a story, a certain amount that the listener incorporates into their imagined world is unique to them, which is a reflection of the individual's life experiences. A storyteller may link together concepts and rough details of a virtual world for the listener, but many blank details are left to the listener's imagination. As technologies take the place of storytellers, less and less is left to the user to create. The mental bandwidth required to imagine the VR (i.e., imagining scenes, faces, objects, colors, etc.) is decreased, while sensory information is increased. Arguably, this shift frees up high-level cognitive faculties for other tasks such as reflective processing, meaning-making, or greater emotional involvement, processes that tend to occur while we interact with natural reality and, presumably, an Ultimate Display.

Panoramic paintings are an early example of VR technology that provided shared imagery. Panoramic painting became wildly popular in the late 1800s and early 1900s after they were invented by Robert Barker. Barker began construction, in 1792, of an entire building (a rotunda) dedicated to creating the illusion of immersing oneself into a different place. Imagine that, as you enter a building, you descend down some stairs followed by a narrow, long, and dark corridor. At the end is a spiral staircase that leads you to a platform. Atop this platform, all you see around you is a large 360 degree painting, and nothing more. The paintings were often 15 m high and 100 m long (Woests, 2009). The light source from above was hidden from sight by a shade or a roof, which was of a deliberate size so that the edge of the roof met the top of the painting to help the illusion that you were not just in a room.

The first of these rotundas was of a painted scene of Edinburg, Scotland. As popularity for this new form of entertainment grew, more such circular buildings were built in many of the world's great cities, featuring exotic landscapes, famous battles, and important cities. After some time, artists began to incorporate props in front of their images to give their work added depth, which created a more realistic experience for the viewer (Woeste, 2009). For their day, these panoramic paintings were a superior illusion. Panoramas took still imagery to a new level by placing the viewer into the center of the image, allowing for the viewer to feel present in the scene rather than simply observing it from afar. It was reported that Queen Charlotte said it made her feel seasick (Altick, 1978), which could be interpreted as a primordial form of "cybersickness," something that remains a problem yet to be solved by VR technology. In the 19th century, hundreds of panoramas were painted, but interest in panoramas declined due to the advent of cinematography, which recorded reality much quicker and in a process that was much more straightforward ("The Panorama in History", n.d.).

Panoramas were built in a time where film and television did not exist, photography was in its infancy, and travel at the speed we know it today was simply impossible. Panoramas were a first of their kind, and on such a grand scale, to induce a sense of traveling to another time and place without having to travel too far; thus, they included some degree of physical transcendence. Indeed, in terms of a VR technology, panoramas were relatively robust. Consider that they could often be quite vivid and complex, which itself enhances the quality of them as an essential copy. However, interactivity (i.e., one of the factors in inducing a sense of presence) is missing, aside from being able to turn in place and view a different scene.

Stereoscopic 3-D photos were another popular form of entertainment in the late 1800s and early 1900s. They were often provided in a device that presented slightly different images to each eye to create the illusion of depth (e.g., a View-Master toy). In 1838, Charles Wheatstone laid the foundation for how VR headsets would work, using the concept of stereoscopic images, which built upon the idea of binocular vision (or, more specifically, parallax). Of interest, the exploration of binocular illusions was explored as far back as ancient Greece, when the mathematician Euclid explained this principle (Gamber & Withers, 1996; "Stereoscope", n.d.).

The perception of depth makes the experience more vivid, though in a way that is mediated by the user's capacity for spatial visualization. Given that these images were the first major realization of a 3-D representation of reality, they can be considered a big step toward creating an essential copy.

After Queen Victoria took a fancy to the stereoscope at the Crystal Palace Exposition in 1851, stereo viewing was massively popular in Britain; there was at least one in every middle-class or upper-class home in the 19th century (Gamber & Withers, 1996). This was a 19th-century version of the first cheap, take-home, VR system. Imagine yourself, before airplanes could take you to any corner of the globe in a day, able to sit back in your favorite chair and see all the wonders of the world before your eyes. The new invention allowed for visual transportation (i.e., physical transcendence) to another place. Still, interactivity was missing.

The next step in taking immersion to the next level came from Morton Heilig, who is often regarded as the father of VR (Carlson, 2007). He had a vision for creating a multisensory theater experience, one that would be far more immersive than anything that has been seen or experienced before. He wanted to create a fully immersive, multisensory theater experience that encompassed 3-D images, stereo sound, wind, smells, and vibrations. "Open your eyes, listen, smell, and feel-sense the world in all its magnificent colors, depth, sounds, odors, and textures this is the cinema of the future!"

(Heilig, 1955). He ultimately created two versions of his vision: the Telesphere Mask and the Sensorama. According to Heilig's patent:

> *"The Telesphere Mask consisted of: A hollow casing, a pair of optical units, a pair of united television tubes, a pair of ear phones, and a pair of air discharge nozzles, all co-acting to cause the user to comfortably see the images, hear the sound effects and to be sensitive the air discharge of said nozzle."*
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> ***U.S. Patent No. 2955156 (1960).***

Despite the successful creation of the Telesphere Mask, Heilig deprioritized it so he could create something even more advanced, the Sensorama. The Sensorama simulator was patented in 1962, and Heilig had to invent a 3-D camera (a side-by-side dual film camera; Turi, 2014) and projector in order to see his vision come to life (Brockwell, 2016). He made five films dedicated to the Sensorama, which included a motorcycle ride through New York City, a bicycle ride, a ride of a dune buggy, a helicopter ride over Century City, and a dance by a belly dancer (Carlson, 2007). The experience of the motorcycle ride through New York included a seat that would vibrate as a motorbike would, air that would rush through the user's hair, and smells of the road and a passing bistro.

A gentleman by the name of Howard Rheingold tried the Sensorama in the 1980s, and he said that "the motorcycle driver was reckless, which made me very mildly uncomfortable, much to my delight" (Brockwell, 2016). Rheingold's discomfort is reflective of his immersion into the experience, perhaps feeling present with the VR. Arguably, the vividity of the scene was heretofore unsurpassed, and the experience was closer to an essential copy than anything before it. The Sensorama was another giant step toward the Ultimate Display, yet the missing ingredient to induce a strong sense of presence, interactivity, was still lacking.

Heilig saw the potential of his invention beyond entertainment. He envisioned his machine to be used as a training device for the armed forces, laborers, and students, where they could train without being subjected to the hazards of dangerous situations (U.S. Patent No. 3050870, 1962), or it could have been used by companies to showcase new products (Brockwell, 2016). However, despite the big plans Heilig had for his inventions, he was virtually ignored by financial investors and large corporations. Regardless, Heilig pressed on. In an interview of April 2016, Heilig's wife, Marianne, recounts the struggle of how they fought to keep the dream alive. They were able to install a coin-operated unit at Universal Studios, where it was rather successful. Eventually, the Heiligs moved the Sensorama to locations such as Time Square, the Santa Monica pier, and into various arcades.

Although the Sensorama was successful, quarters were not enough to support the expensive machines full of custom-built parts by Heilig himself, so when the machines broke down, that was it (Brockwell, 2016).

THE MODERN AGE OF VIRTUAL REALITY

Around the same time that Heilig was creating the cinema of the future in 1961, the engineers Charles Comeau and James Bryan at Philco Corporation developed an HMD called Headsight. This helmet incorporates a closed-circuit camera linked to a magnetic tracking system that would turn the camera in three dimensions: pitch, yaw, and roll (Rid, 2016). The image was created by using spherical mirrors, which projected a virtual 10-inch-high image that appeared to be 1.5 ft in front of the observer (Rid, 2016). The head gear was also intended to remotely view dangerous situations. One of the engineers placed a camera on top of the company building, and when he leaned over and looked down (from the safety of sitting in the lab), he said it felt "kind of creepy" (Rid, 2016). Headsight introduced interactivity into the realm of VR technology. However, the images were simply camera feeds, so the Headsight does not transport the viewer into another reality. It does, however, lay some of the foundation for interactive media. Therefore, the Headsight is another large leap toward the Ultimate Display, as is transcends the physical (e.g., placing the user's vision in a dangerous remote situation) and allows the user to control the visual experience.

In a speech given by Ivan Sutherland at the Proto Awards, he recalls seeing an experiment with a similar device, where a camera was mounted on rooftop, aimed at two people playing catch (Robertson, 2015). The observer, sitting in an office chair in another building, moved his head back and forth and was able to watch the game as the camera translated his head movements. At one point, one of the players threw the ball directly toward the camera, at which point, the observer, safe in another room, ducked out of the way. This is a strong example of presence. Upon seeing this, Sutherland was inspired to incorporate computers into HMDs.

Sutherland, in 1965, created the first HMD to incorporate computer technology to mediate a VR system, which came to be known as the "Sword of Damocles." The name arises from the Greek story of Damocles, which is a rather frightening and amusing comparison. In the story, a sword was suspended in the air by a hair, directly above the King's head, and at any moment, the hair could break, killing the king (Skurzynski, 1994; "Sutherland's Sword of Damocles" n.d.). Similarly, Sutherland's contraption consisted of a height-adjustable pole attached to the ceiling because the head gear was too heavy strap to someone's head. One can speculate that Sutherland may have mused that the device could fall and crush the user at any moment.

This was the first time that computers were used to display a real-world environment whose elements were augmented by a computer (Adams & Merklinghaus, 2014). The headgear itself was made of cathode ray tube monitors, two tracking systems (one mechanical, the other ultrasonic), eyeglass display optics, and a lot of computer programs and algorithms (Sutherland, 1968). Ultimately, Sutherland was able to project an ethereal cube (i.e., a transparent, 3-D wireframe cube) onto the semitransparent optic lenses to create the illusion that the cube was floating in the room (Sutherland, 1968). The graphics were primitive, the equivalent to the *Pong* videogame that came out in the 1970s. However, the 3-D cube would move and tilt, corresponding to the observer's head movements. Although the computer-generated graphics were primitive, it was groundbreaking. The technology to create an interactive 3-D image that changed and moved with the observer was the launchpad for future VR technology. By Sutherland's own admission, the Sword of Damocles was not especially immersive (Robertson, 2015), but the intention was not to create presence. Instead, this is an example of a technology that highlights advancements in interactivity and, perhaps, the quest for the essential copy. Though the represented cube lacked visual fidelity, it was an early demonstration of the digitalization of reality. Here, we have a digital object based on reality that exists entirely within software, obeying the laws of the program. Prior to this, no VR technology stood upon purely digital foundations, foundations that, arguably, could attain a level of vividity and interactivity unreachable by traditional mediums of art.

Twenty years later, Visual Programming Languages was one of the first companies to develop and sell VR products to consumers; it was founded by Jaron Lanier in 1984. Lanier is said to be a pioneer of, and coined the term, VR. This company developed the DataGlove, the EyePhone, and AudioSphere, devices that, when used together, create an immersive VR experience.

The DataGlove was wired with fiber optic cables on the back of the glove, which sent out tiny light beams as the wearer bent and moved their hands. A computer interpreted the beams of light and then generated an image on a small screen inside a helmet (i.e., the EyePhone) or onto a computer screen, where the user could watch a computer-generated image of their hand manipulate virtual objects in an entirely different place or environment (Sturman & Zeltzer, 1994). Two drawbacks limited the success of the DataGlove: it was too expensive for the average consumer (i.e., it cost thousands of dollars), and it was a one-size-fits-all glove (Burdea & Coiffet, 2003). The glove also lacked tactile feedback, which would likely reduce any felt sense of presence for being so inconsistent with expectations of reality.

The EyePhone used two small LCD television screens (stereoscopic), which were viewed through lenses to give the illusion of depth. The EyePhone allowed observers to enter into the computer-generated world; however, the graphics were typical of 3-D graphics c.1980s (e.g., 360 × 240 pixels), and only generated 5–6 fps, compared to the 30 fps generated by TV sets at the time (Sorene, 2014). Although the EyePhone lacked the vividity as we know it today, it was superior to anything that came before for inducing presence through VR technology.

The EyePhone made use of the DataGlove to navigate the z-axis in the virtual world. The user could fly through the virtual environment by using their index finger to control direction and forward motion. Holding their thumb close to their palm made them fly faster, and placing their thumb away from their hand (i.e., straight out) made them stop (Certeras, 1990). Allowing users to control their flight in a virtual environment was a milestone toward transcending the physical limits of our reality because it added interactivity into an otherwise impossible physical action. The combination of these devices fulfilled many requirements for inducing presence, but perhaps fell short on measures of vividity. Visual quality and complexity (as well as complexity in interactivity) still had far to go.

In 1991, Sega announced that they were working on VR headgear, which was meant to be an add-on to the Sega Genesis console. The headset was equipped with duel LCD screens in the visor, stereo headphones, and inertial sensors to track and react to head movements ("Sega VR", n.d.). Unlike previous headsets, and other headsets at the time, the Sega VR headset was lightweight and comfortable to wear for extended periods. The original design was meant to look like Geordi La Forge's visor from Star Trek: The Next Generation (Hill, 2014).

Although the headset was comfortable and sleek, the design never made it out of the prototype stage. Despite the sophisticated technology, the onscreen graphics were unable to keep up with the gamers' head movements, which caused a form of motion sickness, dubbed cybersickness. There were reports that up to 40% of testers became cybersick while being immersed in the virtual environments (Horwitz, 2004). Thomas Piantanida, a scientist at the Stanford Research Institute International's Virtual Perception Program, called the headsets graphical output the "barfogenic zone" (Barras, 2014). However, the official report states that the sense of immersion was so realistic that it could potentially cause injury to users who were moving around while wearing the headset, which created a health hazard. The headset made its final appearance in 1993 at a Consumer Electronic show. Clearly, intentions toward the Ultimate Display were there, but the quality of technology was not.

The next attempt at VR headsets came from Nintendo's Virtual Boy, released in 1995, which was another commercial flop. Hiroshi Yamauchi, the past president of Nintendo Co. Ltd., said:

> *"It has always been Nintendo's strategy to introduce new hardware systems only when technological breakthroughs allow us to offer innovative entertainment at a price that appeals to a worldwide audience. Virtual Boy delivers this and more. It will transport game players into a 'virtual utopia' with sights and sounds unlike anything they've ever experienced -- all at the price of a current home video game system."*
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> ***"Virtual Boy" (2004).***

However, The Virtual Boy did not perform as described, and the product quickly ceased production. In order to attempt a lightweight HMD, Nintendo had to forego conventional displays, as they were too power hungry and heavy. Instead, they used two oscillating mirror LED arrays, one for each eye. The oscillating mirrors, moving back and forth 50 times per second, used the reflection of the LED to sweep across the visual field. This created a bright, sharp image with high resolution for a low price. However, the display was only capable of displaying red graphics on a black background (Edwards, 2015).

The Virtual Boy also came with a short stand; the head-mounting straps were sold separately ("Virtual Boy", 2004), which made gameplay rather uncomfortable for the user, who had to lean into the headset at all times. Any feelings of physical transcendence would be undermined by a sore back and shoulders. Another problem with the Virtual Boy was that the eyestrain that came with using the headgear for extended periods of time caused headaches. This forced Nintendo to include a warning that said:

> *"This product MUST NOT be used by children under the age of (7) years. Artificial stereo vision displays may not be safe for children and may cause serious, permanent damage to their vision."*
>
> ***"Virtual Boy" (2004).***

A big step towards even greater interactivity in VR technology came in 2001 with the SAS3™ (or SAS cube™), which was the first PC-based cubic room. The SAS cube was named "The Cave," which was in reference to Plato's allegory of the cave wherein he challenges our ideas of perception, reality, and illusion. It was a room full of projectors and sensors driven by computers that react to people in the room. The advancements in PC graphic developed by the gaming industry meant that a cluster of relatively inexpensive PCs could be used instead of large supercomputers to yield the processing power required for effective vividity and interaction (Jacobson & Lewis, 2005). The SAS3 system used rear projectors to cast stereoscopic images onto four screens, one of which being the floor. The continuous visual images synchronized across all screens produced a virtual landscape. Users wear 3-D glasses equipped with motion tracking sensors, which track head movement (Fuchs, Moreau, & Guitton. 2011). The stereoscopic images made the environment look 3-D, and sensors let users interact with objects and navigate the space (Robertson, 2001).

In the quest for the Ultimate Display, the SAS3 appears to nearly attain it. However, the complexity and vividity of the images was not on par with reality, nor were there other sensory inputs, such as tactile feedback. Nonetheless, the experience is something like a panoramic painting with interactivity. The priority, at that point, became the quality of the sensory input.

CURRENT VIRTUAL REALITY DEVICES

Presently, VR devices still follow the basic mechanisms shown by NASA in 1987. They are no longer limited to research or instructional purposes, but are now commercially available for a reasonable price. Their use in our daily lives is multifold, and this includes therapeutic and entertainment purposes. If you consider the variety of movies, games, and social media, the use of VR has already been so embedded in our daily activities that it is altering our own reality.

Palmer Luckey is responsible for the creation of the Oculus Rift, once a relatively simple do-it-yourself kit and now the VR headset that combines realistic imagery with hand motion technology similar to the NASA headgear in 1987. The differences are extreme, however. Quality of image has improved significantly, and the sense of presence is an experience only felt by actually putting on the headset (Fenlon, 2015; Grayson, 2015; Rebato, 2015). Created at first to play video games, Luckey and his board members managed to get Facebook's Mark Zuckerberg to invest in the technology because of the consequences it could have in our lives. As Zuckerberg acknowledged openly, social networking sites connect people across the world in an intimate and real way. Social media brings news into focus, as well as entertainment and other information that is catered according to each individual. Like phones have revolutionized communication, technology such as Oculus Rift may have already created another revolution (Chafkin, 2015). Since the invention of the Oculus Rift, other companies, such as Samsung, Google, and Steam, have now come out with their own VR products offering similar experiences.

Type of content and platform is the largest difference among VR headsets. Companies like Google and Oculus try to connect a 360 degree experience to mobile phones (Google, 2015; Llmer, 2014). Google targets android phones with an app that connects to Google Cardboard. Google Cardboard, along with Cardboard Camera, the mobile application, creates user-made VR experiences by doing exactly what all VR headsets basically do: turn 2-D images, in this case panoramas, into 3-D images by using slightly different angles in each lens. The user can even add audio to these images to enhance the sensory experience of being in the moment the picture was taken. However, unlike the Oculus Rift, the user cannot move within the virtual environment freely, only look around 360 degrees with realistic depth perception. This is perhaps an even more advanced iteration of the panorama because, other than images, if Google Cardboard is used within YouTube videos, the experience is as though the user is in the center while everything is moving around them (Hollister, 2015). This is possible because of cameras specifically made to take videos in 360 degrees in real time.

Google Cardboard is one VR headset that is already available for purchase and use. Google Cardboard is very inexpensive (i.e., approximately $20) compared to any other VR headset, but that is primarily because it is literally made of cardboard (Google, 2015). Still, Google Cardboard has a broad reach among consumers, and more people are very likely to buy this headset than others. This is because the other headsets are significantly more expensive and come with other factors, such as specific compatibilities of PC being used, other required add-on products to improve the virtual experience, and motion sickness (Chafkin, 2015; Gamer, 2015)

The Samsung Gear VR headset is quite similar to Google Cardboard. It combines Oculus technology of depth perception and screen resolution with the Samsung Note phone's VR apps (Llmer, 2014). It is more immersive than Google Cardboard and gives excellent depth perception, but there is no motion tracking for Samsung Gear. It cannot be used for intensive gaming, but it is a very good way to experience landscapes and videos.

Valve, the company responsible for Steam, which is a widely used and popular gaming platform, also released their version of VR technology, namely the HTC Vive. Carlos Rebato (2015), a blogger from Gizmodo, believes that the HTC Vive is above any other virtual headset he has tried because of the heightened presence he experienced. According to his account, the Oculus Rift and Samsung Gear VR lag behind, comparatively. He describes the sense of presence and his body actually being there. This is because the HTC Vive has advanced positional tracking that uses sensors that are attached to the wall at a 90 degree angle. Most importantly, they have two controllers that have a touchpad and trigger and act as "virtual hands," and these controllers have trackers as well. Rebato calls it "the most impressive thing I've ever tried, bar none" (2015). The technology of HTC Vive is different from its contemporaries because users size the room they use the headset in so that the room becomes a mapped virtual space. Thus, the user can move around the room while the images on the display adjust to make the virtual environment follow closely with the user's movements. This, along with the hand use, creates a very immersive experience that makes users believe almost completely, if not fully, that they are actually present in that reality. The scaling size of objects compared to how they would appear in reality is accurate, which enhances the experience. Nathan Grayson (2015) of Kotaku tried the Vive just a few days later and was equally impressed by the sense of presence. The only issues both Rebato and Grayson had with HTC Vive is that the cords get tangled up and become a tripping hazard, and making VR items should be more tangible Rebato, 2015; Grayson, 2015).

So far, the headgears previously described create a 3-D VR environment from nothing material, a literal computer world. However, another type of headgear is becomingly increasingly popular in mainstream VR technology, and those are augmented reality devices. Augmented reality is different from VR because it superimposes virtual images onto the actual physical world. They do not create a new world, but add on to our surrounding reality. Although it is very new to the technology industry at the moment, what makes augmented reality so effective is the integration of already perceptually complex, real 3-D environments with virtual elements to create something believable. The experience constantly exposes the user to the boundary between real and unreal, and perhaps encourages an inclination in the user to simply accept everything as real.

The Microsoft HoloLens has been the most talked about augmented reality since its announcement in 2015 because the technology has been shown to already catch up to what many people have been calling "*Star Wars* holograms" (MacDonald, 2016; Orf, 2015). The HoloLens is a "self-contained" headgear (Microsoft, 2016) that uses spatial and object mapping of the surroundings and displays high-quality images and videos. The headgear produces audio appropriate to the distance of the object and action being produced. It also has the ability to interpret our hand movements and voice commands to control the objects displayed.

This augmented technology is not quite the Ultimate Display because it doesn't produce strong essential copies of things, and the images displayed are not realistic enough with the surroundings to be indistinguishable. Physical transcendence may be possible if the user considers themself to be another person in another world, but that would be much more difficult to do when the physical world is so clearly seen. However, as mentioned before, since the HoloLens uses the real world, the complexity of the environment is vivid and therefore likely to induce feelings of presence. The HoloLens is clearly meant to interact with the real environment in the most realistic way, and any of the cognitive styles, such as object and spatial visualization types, would satisfactorily feel presence in such an environment (Biocca et al., 1995; Steuer, 1992; Yoon et al., 2015). The Microsoft HoloLens is quite expensive, however ($3000), as it would be for how good the technology is for our time.

Recently, augmented reality has reached the regular consumer base, in the form of a game called *Pokémon GO*. Within a weekend of its release, Pokémon Go had already reached major heights of popularity and was continuing to do so more than any previous consumer-based mobile application or virtual technology (Chen, 2016; Cranz, 2016). It was a strong example of augmented reality, as it used the actual surroundings of the user as the environment in which the Pokémon, the creature to be captured by the user, existed. The game kicked off the recent surge of interest in VR in a very big way (Chen, 2016; Pokémon, 2016). At the time of this writing, talks to combine the Microsoft HoloLens with the Pokémon GO game were underway (Cranz, 2016).

Returning to VR, the Oculus Rift is what started the recent bloom of VR interest (Chafkin, 2015; Handrahan, 2015). It gave users an incredible sense of presence and left them wanting more. All the recent HMDs have focused on the vividity of the images produced, with the Vive being the best so far. With their focus on depth perception and spatial navigation within the virtual environment, but in relation to your head or body's physical movements, the current HMDs have almost realized Biocca's essential copy, at least from a visual perspective.

However, because of the many flaws, such as clunky headgear, glitches in the software, cords, and physical objects getting in the way of movement, it is not as easy to be completely fooled into believing what you are seeing (Grayson, 2015). Interactivity is high with the VR headgears alone, but accessory hardware is also being developed to provide new ways to interact. For example, the Virtuix Omni Treadmill is a relatively compact, touch-sensitive, omnidirectional treadmill that creates the illusion of physical movement in a virtual environment (Sofka, 2015; Virtuix, 2014). Users wanting a freer range of physical movement with no restrictions, like Vive, would definitely enjoy this experience a lot more. There are also other examples of creating a physical experience with the VR, using haptical methods, such as the Realm System, which uses physical resistance as part of its contraption to give the user the illusion of actual arm movements within the virtual world (Buckley, 2015).

Other methods have been used in combination with virtual headgears to increase the sense of being present in a VR. For example, the *Six Flags* theme park in New England is using VR headsets with the *Superman* roller coaster ride, displaying images as though you are flying beside this fictional character while on the ride (Harris, 2016). Universal studios also has a Shrek 4-D theater experience, where they show a 3-D film in conjunction with "4-D" effects, such as moving seats and mist, meant to increase the feeling that they, the audience, are actually there (Universal Studious Orlando, 2016).

CONCLUSION

Human beings continue to climb toward the perfect representation of reality, transposed into artful, convenient, or entertaining experiences. The achievement of this, perhaps known as the Ultimate Display, combines the perfect sensory reproduction of something real with the bending or breaking of physical laws of nature. The feeling of presence is something that naturally arises when media is powerful enough to trick the mind into belief. We now possess, with the aid of computers, a potent ability to induce this feeling. Presence is the effect caused by perceiving an essential copy. Physical transcendence follows from that. In the past, humans have glimpsed at pieces of these ideas and perhaps experienced fleeting moments of presence. However, traditional art tends to lack the quality of being able to trick the viewer into thinking it is something other than itself; paint will be paint, stone will be stone. Digital media is a dance of electromagnetic waves that can look like anything at all.

Our steps toward the Ultimate Display have not been linear, nor have they been consistent. However, if presence is the marker, then the advent of modern HMDs marks a new paradigm for VR, one where users must no longer fight to suspend disbelief at what they are seeing; instead, they must learn to suspend belief that the VR world is real. Though, perhaps in a sense, VR worlds are real enough and what we take to be natural reality is not as clearly bounded as it seems. Art, social media, imagination, and dreams are all realms of existence, and we are the architects and interlopers of these worlds. Faster and faster, vehicles to the virtual realities are arriving and bringing with them new paradigms of experience as they carry us upwards and onwards to the Ultimate Display.

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