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Virtual Reality: Where Have We Been? Where Are We Now? and Where Are We Going?

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Abstract

The rising popularity of virtual reality has seen a recent push in applications, such as, social media, educational tools, medical simulations, entertainment and training systems. With virtual reality the ability to engage users for specific purposes, provides opportunities to entertain, develop cognitive abilities and technical skills outside of the standard mediums (e.g., the television or the classroom) thereby optimizing exposure with realistic (live) opportunities. However, before these applications of virtual reality become more widespread, there are a number of open questions and issues that must be addressed including limitations, challenges, relationships between fidelity, multi-modal cue interaction, immersion, and knowledge transfer and retention. In this article, we begin with a brief overview of virtual reality methods, followed by a discussion of virtual reality and its applications (both historically, currently and in the future). We review virtual reality trends both from the early artistic days through to current day state of the art technological advancements. We explore emerging and futuristic breakthroughs - and their applications in virtual reality - showing how virtual reality will go way beyond anything we could envision. In fact, after reading this article, we hope the reader will agree, that virtual reality, is possibly one of the most powerful mediums of our time. While the earliest mechanistic virtual reality prototypes (e.g., Sensorama) allowed us to view stereoscopic 3D images accompanied by stereo sound, smells, as well as wind effect - set the foundation and direction for future pioneers - there have been spearheaded developments which have continually pushed the concept of virtual reality to new domains. As virtual reality evolves, many new and yet-to-be-imagined applications will arise, but we must have understanding and patience as we wait for science, research and technology to mature and improve. The article ends with a short overview of future directions based upon recent breakthroughs in research and what this will mean for virtual reality in the coming years.

Keywords: virtual reality; immersive; trends; techniques; timeline; technologies

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1 Introduction

Virtual Reality While virtual reality has been around for decades, it has only recently started to gain momentum due to advancements in science and technologies - leading to a multitude of breakthroughs in research and innovation that have had a major impact on how we view and use virtual reality (Sutherland, 1965). In fact, elements of virtual reality appeared as early as the 1860s while the term 'Virtual Reality' was first coined by the French playwright Antonin Artaud in his inspiring 1938 book 'The Theatre and Its Double' (Artaud, 1958). Originally the concept of imagination - stemming from sci-fi movies like the holodeck of 1987's 'Star Trek: The Next Generation' and 2009 'Avatar' films (Smith, 2014). Opens us up to new worlds and universes both real and imaginary (multi-verses). From flying through space and standing on the surface of Mars to swimming through body or interacting with molecules on an atomic level. As we discuss, on ongoing problem with virtual reality - is the 'interface' - VR does not just encompass the 'visual' aspect but all aspects of interaction - from audio and feeling to visual and smell - how to couple these senses efficiently with the human brain. The applications are limitless - from entertainment to training and simulation. Future - VR 'movies', online classrooms - with virtual reality we can go everywhere and do anything!

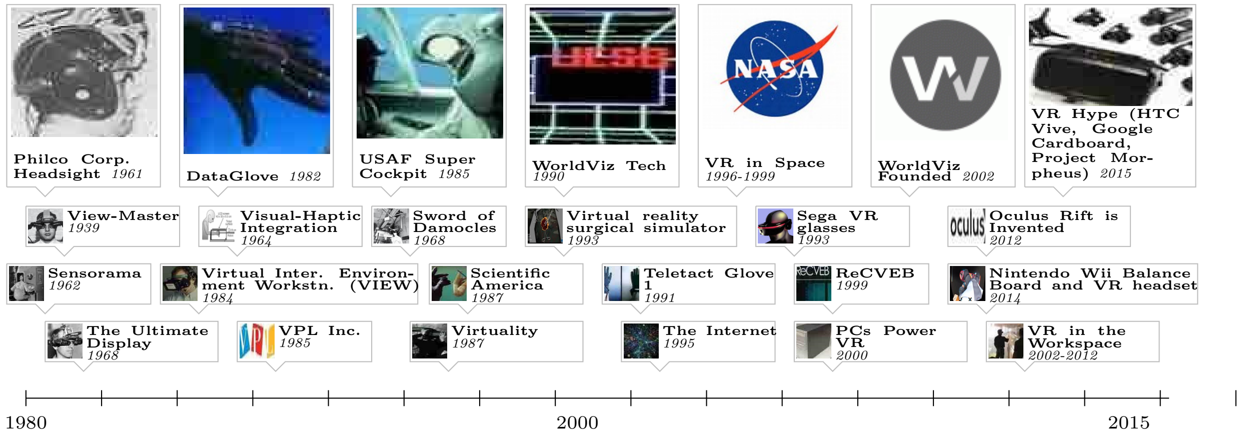

Figure 1: Timeline showing just a few of the important milestones in the area of VR over the past few decades - from the ground breaking work in the 60s and 70s on displays and immersion (Kohl, 1983) to more recent work by Kiili et al. (Kiili et al., 2015) on learning and assessment.

Benefits of Virtual Reality Images are richer than text; videos are even richer than images; virtual reality is the next level. Virtual reality has the potential to impact all of our senses (beyond simple visual and audio). This ability offers new ways of seeing/performing everything (e.g., from telephone calls (VR calls) to films). While television and movies convey real or imagined experiences, they are passive, then again, video games on the other hand are interactive but not realistic. Virtual reality brings a measure of conveyed experience, immersion and interactivity - in a full three-dimensional universe in which a person can move around and interact with (total submersion). The fact that virtual reality goes way beyond entertainment aspects is inspiring

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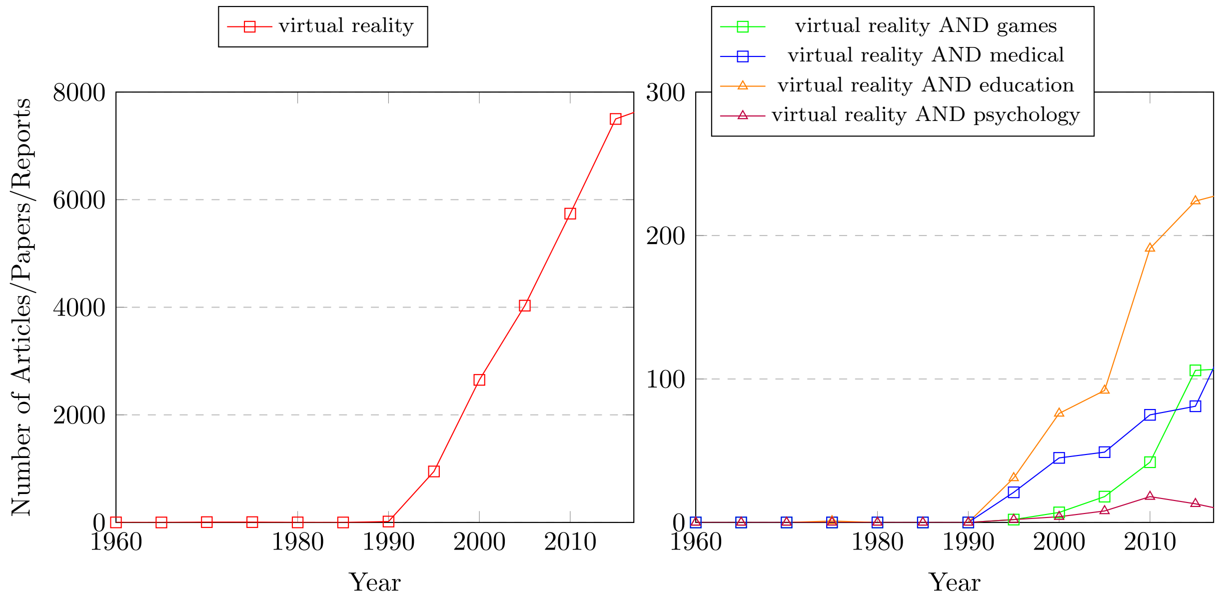

Figure 2: A coarse guide to the number of articles in the area of virtual reality. Plots show the number of new articles with the keywords in their title published over the past few decades (from Google Scholar 10/11/2017))].

and exciting, for example, the possibilities include: Psychological benefits (Plante et al., 2006), Cultural aspects (Garcia-Ruiz, 2018), Gait Rehabilitation (Sekhavat, 2018), Medicine Training (Ozad, 2018), Helping children with autism (Haddod, 2018) and even as diverse as measuring the impact of global leadership skills (Chirino-Klevans, 2018). We anticipate multiple indispensable virtual reality applications will appear over time and will be as important as systems such as the flight simulator which are now a core ingredient for pilot training (Satava, 1993). Something is too dangerous, expensive or distant in time, place or imagination to physically experience. The benefits and savings in time, cost equipment and safety are enormous.

Only the Beginning Virtual reality is still very much in its **infancy** and is only just becoming widely available to the general public. However, certain practical applications of the technology are already on the market. For instance, one can create virtual panoramic tours with **images** overlaid with text, which enable learners to explore the object of study from all sides (e.g., virtual tour of the Boeing 787 jet liner). The visual experience was not merely a collection of photographs, but a virtual environment that allowed the user to move about and examine the plane from both the inside and the outside. The virtual revolution offers infinite possibilities (and realities) that stretch to avatars, eternal life, new worlds (dawn of a new era) (Blascovich and Bailenson, 2011). A huge amount of virtual reality research virtual has been based around 'entertainment' with early work focusing on interactivity, 3D graphics, user interfaces and visual simulation (Ntokos, 2018; Zyda, 2005). Of course, the VR field is 'transitioning' with research from video games and training simulations bleeding out to a much larger audience - allowing the

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technological advancements to be leveraged to the wider community.

Contribution The key contributions of this article are: (1) review of the virtual reality timeline (from conception and science fiction to present day real-world applications); (2) trends, limitations and milestones that are steering the field of virtual reality; and (3) important areas that virtual reality is making an impact (e.g., communication (Biocca and Levy, 2013), medical (Rahm et al., 2016), training (Kozak et al., 1993) and psychology (North and North, 2017)).

Figure 3: **Classics** - (a) Sensorama (1956) - The Sensorama was a mechanical device able to show five short films while engaging multiple senses (sight, sound, smell and touch) (Jones and Dawkins, 2018). The Sensorama consisted of the following elements: A viewing screen within an enclosed booth which displayed stereoscopic images, Oscillating fans, Audio output (speakers), Devices which emitted smells. The viewer would sit on a rotating chair which enabled them to face this screen. They would be shown these stereoscopic images which gave the illusion of depth and the ability to view something from different angles. (b) Viewmaster (1939) (Kohl, 1983). (c) Sword of Damocles (1968) (Boas, 2013).

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2 Past to Present

2.1 Epochs

We broadly categorize the evolution of virtual reality into four ages ranging from the theoretical and initial inspiration to initial development and early prototypes on through to today's rejuvenation and finally tomorrows breakthroughs (see Figure 4 for a visual illustration of just some of the milestone events that have brought us to where we are today).

- Epoch 1 - Early Years (In the beginning ..)
- Epoch 2 - Infant Technology (As time went by ..)
- Epoch 3 - Current (Where we are now ..)
- Epoch 4 - Tomorrow (What next ..)

Epoch 1 - Early Years (Artistic/Imagination) In the beginning, virtual reality was dreamed up by pioneers through creativity, imagination and artistic initiative. Early examples of virtual reality include large 360 degree murals which enabled the observer to engage with the artwork on a simple level. Further artistic examples were formulated by the French playwright Antoni Artaud in his work 'Avant-Garde' who considered illusion and reality to be one and the same (1914-1939) (Artaud, 1958). He argued that a theatre audience should suspend their disbelief and consider the performance to be reality.

As time progressed these simple artistic principles were embellished by mechanistic systems with applications beyond simple entertainment. As early as the 1920's the development of the world's first flight simulator was presented by Edwin Link. This was designed as a training device for novice pilots. Also the View-Master (1939) which was stereoscope with rotating cardboard discs containing image pairs was popular first for 'virtual tourism' and then as a toy. There was also the famous 'Sensorama' by Morton Heilig one of the first VR machine - the first type of multimedia device in the form of an interactive theatre experience. While this early form of virtual reality was invented in 1957, was not patented until 1962 (see Figure 3).

The 'Headsight' at Philco Corporation (1961) was the first head mounted display (HMD) designed to be used by helicopter pilots who needed to be able to see their surroundings whilst flying at night. The Sword of Damocles (1968) was the first VR and augmented reality head-mounted display (HMD) system. While primitive both in terms of user interface and realism (e.g., HMD had to be suspended from the ceiling as it was to heavy to be worn) In 1968 Ivan Sutherland created the Ultimate Display: a head mounted display attached to a computer which enabled the wearer to see a virtual world. However, the sheer weight of this display meant that it had to be attached to a suspension device. The first interactive map appeared in the 1970's. Showed an interactive map of Aspen in Colorado by researchers at Massachusetts Institute of Technology (MIT). This was an innovative form of multimedia which enabled people to walk through the town of Aspen (see Figure 1).

Epoch 2 - Infant Technology Virtual Reality and Human Computer Interaction (HCI) has changed as technology has and continues to evolve. In the 1980's we saw the digital revolution

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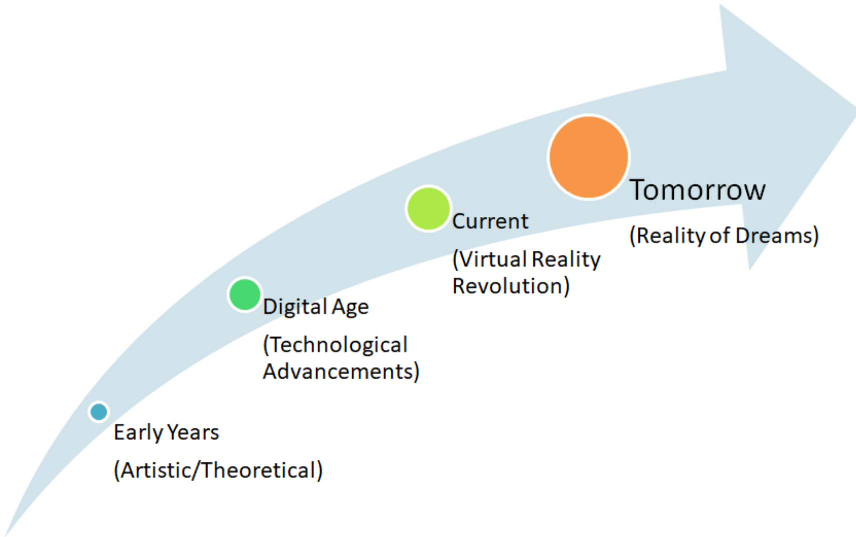

Figure 4: **Evolution of Virtual Reality** - From the beginning of creation to the viability and practical application through to future solutions of virtual reality (e.g., virtual worlds to haptic-interfaces).

(change from mechanical and analogue technologies to digital electronics). Virtual reality was able to piggy back on this advancement and was used by projects for NASA as well and helped researcher form new means of human-computer interaction. For example, a lot of this early work was carried out by Michael McGreevy (Fisher et al., 1986) - an authority in this field and several others who developed some of the original concepts and innovations of virtual reality systems that are still used today. A further boost to the virtual reality profile came in the form of Jaron Lanier who raised public awareness of this new form of technology. He along with Tom Zimmerman marketed a range of virtual reality gear in the 1990's.

In the 1990s, virtual reality continued to be popular medium - promising all sorts of amazing possibilities. However, the hype surrounding this technology had an adverse effect and ultimately led to its decreased popularity. As time progressed, people felt that virtual reality did not delivered on its early promises and as a result - public interest diminished. Even towards the downward spiral of public interest - a few interesting breakthroughs appears - for instance, the Forte VFX-1 headgear in 1995 and Virtual I-O I-Glasses in 1996 was one of the most advanced, complex and expensive consumer VR systems to be released (one of the earliest consumer VR headsets to hit the market).

Epoch 3 - Current Virtual reality has returned due to advancements in technologies, research (Figure 2) and consumer interest (see sales statistics in Figure 7). Researchers, technologists and anyone else working in the field of virtual reality is all too aware of the dangers of hype and as a result, have tended to downplay its capabilities in recent years. We have often see the term

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'virtual environment' and 'immersion' used considerably more instead of the term 'virtual reality' as a preference. However, there are numerous ways virtual reality can be used and the advantages of virtual reality cannot be ignored. As shown in Figure 2, there has been a large body of articles, reports and publications released in recent years discussing the benefits and applications of virtual reality in various fields. One such current project integrating the gustatory senses not just as an additional VR input, but as an integral element to the experience: using the fact that with head-mounted displays, user cannot see what they are eating and have to entrust a second user outside the VR experience to provide them with sufficient food and feeding him/her. The work demonstrated that eating can be an intriguing interaction technique to enrich virtual reality experiences while offering complementary benefits of social interactions around food (Arnold, 2017). Topics of emotional control (overlapping with physiological impact), as shown by Bernal and Maes (Bernal and Maes, 2017) who experimented with manipulating users' self-expression in VR space and as well as the perception of others in it, to evoke a desired emotional reaction - help the field of virtual reality expand from a medium of surface-level experience to one of deep, emotionally compelling human-to-human connection.

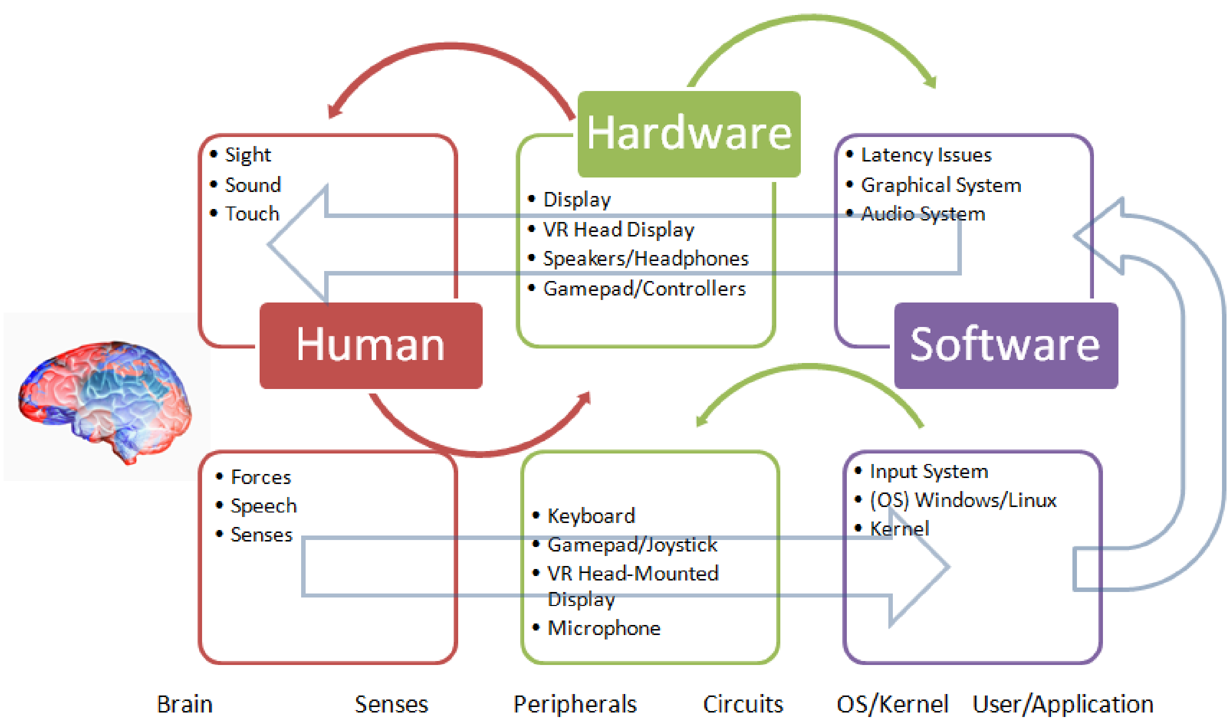

Figure 5: **Senses** - Interconnected 'feedback' loop between the real-world and our brain (illustrates the various interconnected layers and their closed relationship of dependencies).

Epoch 4 - Tomorrow Early scientific breakthroughs and research trends show inspiring possibilities (peek through the looking glass) - this combined with the creativity of imagination (e.g., science fiction) we are able to see what tomorrow might bring. For instance, as we discuss in later sections, the initial research with haptic-human interfaces for controlling prosthetic limbs has enormous potential in virtual reality (Sensinger et al., 2009) (see Figure 10 and Figure 11). Research into new shape-changing polymers (e.g., transformable-materials - shape-memory polymers and electrorheological fluids (Jacob and Mazursky, 2016)). 'Flexible' high-resolution displays (with transparency abilities for possible 'augmentation') (Chen et al., 2003). Increased computational power and network faster network speeds with the ongoing push towards quantum computing and fibre optics (Hanneke et al., 2009). This leads onto theoretical concepts, such as, holograms (hard and soft light) and the imagination of science-fiction (see Figure 6). Some concepts are in the early stages of development (actual prototypes in the laboratory) while in other cases the concepts are still very theoretical.

2.2 Science & Technology

Science & Technology (Virtual Future) The proliferation of scientific breakthroughs and technological advancements has given virtual reality a big push. These advancements have made virtual reality more accessible and portable (e.g., positional sensors, thin high-definition screens, increased computational power and bio-interfaces). One notable advancement is that of the VR headset - which has started a new turn in the virtual reality's evolutionary spiral. Lightweight, cheap and powerful. Virtual reality is now becoming more widespread as new experimental medium dawns. For instance, a few concepts that will change as virtual reality takes hold in the near future are:

- Change how we think and work (even learn)
- Connections (share thoughts & dreams)
- Addictions
- Reshaping social attitudes
- Virtual avatars (virtual/social presence)
- Real or virtual (fuzzy boundary)

Virtual Reality is Revolutionizing the World When people experience virtual reality for the first time, a common reaction is to start imagining all the different uses the technology might hold. In every industry, the potential is open-ended. The good thing is that scientists and professionals have been at the drawing board for years now, developing and implementing virtual reality in ways that can help them learn, create, imagine, train, diagnose in a variety of situations. For instance, virtual reality surgical simulator could offer the possibility of having the surgical resident of the future perfect a procedure without harming a patient, learning surgical anatomy and repeatedly practicing technique prior to performing surgery on the actual patient. This would translate into a very objective exam for certification using the exact same machines (Lange et al., 2000).

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Dangers and Warning The experience of virtual reality has its warnings - for instance, people may be prone to seizures, loss of awareness, convulsions, involuntary movements, dizziness, disorientation, nausea, light-headedness, drowsiness, or fatigue. For example, imagine walking around feeling dizzy and nauseous whenever you moved your head. This was a common occurrence in the early days of virtual reality (known as simulation sickness). Since the visual interface is through our eyes, long term expose leads to eye pain and discomfort, like eye-strain, eye twitching, or vision abnormalities (such as altered, blurred, or double vision). Finally, the psychological impact, influences our bodily functions, leading to excessive sweating increased salivation, impaired sense of balance, impaired hand-eye coordination, or other symptoms similar to motion sickness (et al., 1992).

Why has VR only started to appear now if it has been around since the 80s? For VR to succeed it needed commercial viability (see Figure 8). While the desire for immersion has always existed, VR has not been successful because of numerous reasons, such as:

1. Expensive
2. Lack of content
3. Hard to monetise

Of course times are changing. Interactivity would have remained wishful thinking if not for the development of **high-performance computers**. These machines provide the speed and memory for programmers and scientists to begin developing advanced visualization software programs. For instance, by the end of the 1980s, low-cost, high-resolution graphic workstations were linked to high-speed computers, which made visualization technology more accessible. All the basic elements of VR had existed since 1980, but it took high-performance computers, with their powerful image rendering capabilities, to make it work. Demand was rising for visualization environments to help scientists comprehend the vast amounts of data pouring out of their computers daily. As drivers for both computation and VR, high-performance computers no longer served as mere number crunchers, but became exciting vehicles for exploration and discovery. Ultimately this has fueled other areas of investigation (beyond simple computational problems), such as, interfaces (screens and gloves), haptics (feedback) and networking (connecting computers/people).

3 Science Fiction to Fact

There have been many novels and fictional depictions of the future that have been influential in early 21st century VR work. As shown in Figure 6, a timeline of inspirational science-fiction films and tv-series. Worth noting the importance of imagination and creativity - as stated by noble individuals, such as, William Arthur Ward who said ‘If you can imagine it, you can achieve it’, then there was, Walt Disney who said ‘If you can dream it, you can do it’ and finally, Albert Einstein who ultimately said ‘Imagination is more important than knowledge’.

As shown in Figure 2 and Figure 7, with constant growth in research, investment and public interest there is no double that Virtual Reality will be in the mainstream for many years to come with a multitude of exciting and noteworthy advancements.

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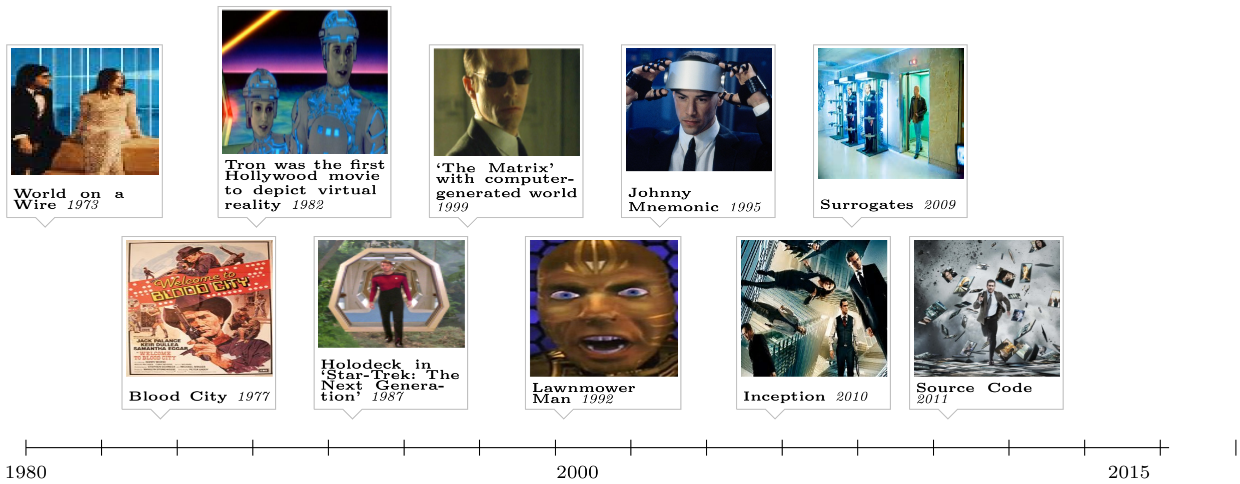

Figure 6: Sci-fi Timeline (sci-fi has inspired and steered virtual reality creativity behind the scenes - what was once thought impossible (only in movies) fuels our desires for what we expect in the real-world) (Burdea Grigore and Coiffet, 1994; Mazuryk and Gervautz, 1996; Wexelblat, 2014; Smith, 2013). For example, from mobile phones, virtual worlds, avatars, time-travel and holodecks.

4 Applications

Where is virtual reality making an impact? For example, a brief list of where virtual reality is making an impact is shown below in Table 4. Also it should be noted that a large number of the topics 'overlap' - for instance, medical training - overlaps with education, visualization and medical areas - which is a bonus as it promotes synergy and cross-disciplinary development/cooperation between subjects.

- Military (Bowman and McMahan, 2007)
- Education (Haddod, 2018; Ozad, 2018; Haddod, 2018)
- Healthcare (Sekhavat, 2018; Ozad, 2018; Santoso, 2018)
- Entertainment (Casas, 2018; Bates, 1992)
- Fashion (Bates, 1992; Bhatt, 2004)
- Heritage (Garcia-Ruiz, 2018)
- Business/Management (Chirino-Klevans, 2018)
- Engineering (Lindeman, 2018)
- Sport (Bideau et al., 2010)
- Media (Bates, 1992)
- Scientific Visualisation (Liwei, 2010)
- Telecommunications (Kerttula et al., 1997)
- Construction (Kanade et al., 1997)
- Film (Casas, 2018; Bates, 1992)
- Programming languages (Brutzman, 1998; VRML, 2016)
- Video Games (Ntokos, 2018; Nussli, 2018)
- Psychology (Botella et al., 2000)
- Dentistry (Luciano et al., 2009)
- Navigation (Yang et al., 2007; Liwei, 2010)

Table 1: Examples of just a few of the areas virtual reality is actively making an impact.

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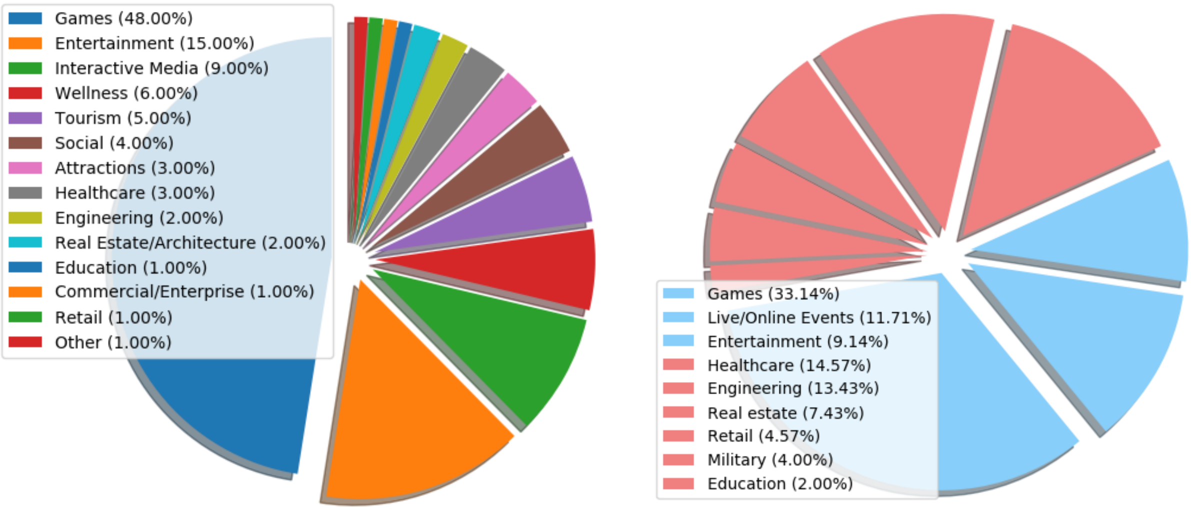

(a) 2018 (b) 2025-30

Figure 7: **Virtual Reality Worldwide Revenues** - (a) Currently in 2018 the Virtual Reality Software Revenue Share is worth a total of $4.8 Billion - areas that contribute towards towards sales range from training and education to social and engineering (notice that nearly 50% of revenues is from Games - core driving factor) (SuperData, 2018). (b) Predicted that by 2025 to 2030 Worldwide Revenues of Virtual Reality will reach between $30 to $35 Billion with the distribution gradually less dependent on games (but still a major factor) (Report, 2018; for Goldman Sachs, 2018). Pie chart (b) is split into two major areas - the consumer contribution (blue) and the enterprise and public sector (red).
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Virtual reality is offering new ways of interacting and seeing our world (and other worlds). What is more VR could eventually impact all of the senses as we improve the immersion through technological advancements (e.g., Haptics, Goggles, Gloves and CAVEs). Traditional computing mediums (monitors and keyboards) could change - with VR being the next computing platform.

World is Changing The Greek philosopher Plato used the word “Khora” to describe a place between reality and fantasy. The philosopher wrote this twenty-four hundred years ago. He envisioned what human beings thought of as real objects were merely poor imitations of ideal forms that could only be imagined. In recent years, this concept has evolved and is common place in our sci-fi genre (e.g., Star Trek’s Holodeck). Even though the concepts of virtual reality we envision of in our dreams is still far off - virtual reality is still common place in a number of places today (e.g., training simulations, video games and virtual classrooms). Virtual reality is changing how we see the world - for example, as a visualization tool, we can be at the heart of the action. Meteorologists (scientists who study weather and climate) are able to step into a hurricane to find out how the winds inside it behave-and come back out alive. Similarly, chemists and drug designers are able to examine the shape of complex molecules and build new ones, atom by atom (akin to constructing building). The practical aspects in business and science are far

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and wide - but the potential in entertainment and recreating are just as immeasurable. Viewers would be able to floats through mysterious, semitransparent landscape, like a diver underwater. Absorb surrounding and experiences beyond imagination.

5 Virtual Reality Modelling Language (VRML)

Human vision provides most of information passed to our brain and captures most of our attention (of the five human senses 70% is from visual input as shown in Figure 9) (Heilig, 1992). Hence, when we create 3D objects or develop VR programs, having a specific language to represent them is important (common language). Virtual Reality Modeling Language (VRML) is a standard language for the animation and 3D modeling of geometric shapes. It allows for 3D scenes to be viewed and manipulated over the Internet in an interactive environment. Using a special VRML browser, the user can connect to an online VRML site, choose a 3D environment to explore and move around the '3D world'. This includes the ability to zoom in and out, move around and of course interact with the virtual environment.

There are two major versions of VRML.

- First one is VRML 1.0. Worlds are static environments where we can navigate and click on objects to link to information. The first version of VRML allows for the creation of virtual worlds with limited interactive behavior. These worlds can contain objects which have hyperlinks to other worlds, HTML documents or other valid MIME types. When the user selects an object with a hyperlink, the appropriate MIME viewer is launched. When the user selects a link to a VRML document from within a correctly configured WWW browser, a VRML viewer is launched. Thus VRML viewers are the perfect companion applications to standard WWW browsers for navigating and visualizing the Web
- Second, VRML97 is the informal name of the International Standard (ISO/IEC 14772-1:1997). It is almost identical to VRML 2.0, but with many editorial improvements to the document and a few minor functional differences. (VRML97 is also the name of the VRML Technical Symposium that took place in February 1997 in Monterey, Canada). The extended standard provided extensions and enhancements to VRML 1.0: **enhanced static worlds; interaction; animation; scripting; prototyping**. VRML 2.0 takes VRML and extends it with **animation, behaviors, sensors and sounds**. There are also some new geometry primitives as well as support for collision detection. The VRML 2.0 scene graph has also been modified to support PC rendering systems more efficiently

The first release of the VRML 1.0 specification was created by Silicon Graphics, Inc. and based on the Open Inventor file format. The second release of VRML added 'significantly' more interactive capabilities. It was primarily designed by the Silicon Graphics VRML team with contributions from Sony Research, Mitra, and many others. VRML 2.0 was reviewed by the VRML moderated email discussion group and later adopted and endorsed by many companies and individuals (VRML, 2016).

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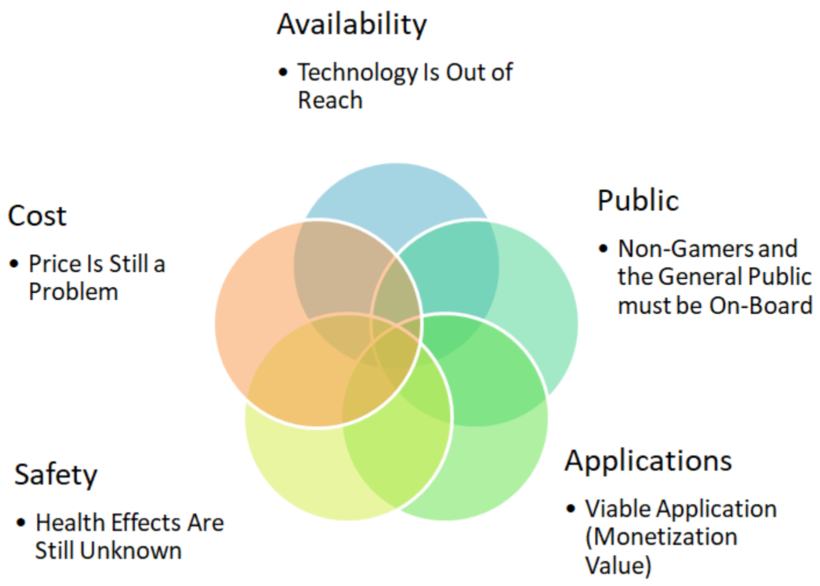

Figure 8: **Success Factors** - Broadly outlines five key driving factors to identify the success of virtual reality adoption.

6 Human Senses - Interface

Human Factors Each of the five human senses (see Figure 9 and Figure 5) (Heilig, 1992). These sensors play a crucial part in creating believable virtual reality environments. Incorrectly implemented, such as, misalignment of visual perception and correlation of sensory data (e.g., latency and synchronization) can lead to serious health and safety problems. For example, one common failure when providing inaccurate stimuli to the human senses it leads to **simulator sickness** which has been well documented in the literature. A particular number of studies have focused on the quantification and measuring of simulator sickness classfying the different meanings and measurable impacts (et al., 1992; Regan, 1995).

While the traditional concept of human senses is broadly categorized into five types - scientists have in some cases extended this to nine or more areas (e.g., up to twenty-one in some cases). The definition of a 'sense' is 'any system that consists of a group of sensory cell types that respond to a specific physical phenomenon and that corresponds to a particular group of regions within the brain where the signals are received and interpreted' (Meilgaard et al., 2006).

- Common: Sight, Taste, Touch, Smell, Sound
- Extended: Pressure, Time, Magnetoception, Hunger, Thirst, Chemoreceptors, Stretch, Receptors, Equilibrioception, Nociception, Tension Sensors and Proprioception

Of course, senses need to match not to mention each sensor can be broken down into smaller categories and types, like, for instance humans can recognize five main taste types: sweet, sour,

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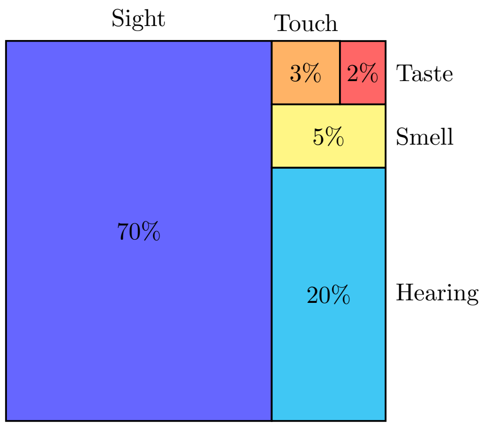

Figure 9: Breakdown of the five traditional human senses (Heilig, 1992) (emphasizing the importance of vision and sound - and why a large body of research has focused on these areas specifically).

salty, bitter, and umami (Medelius, 2009). In virtual 'cooking' worlds - we might want to try the foods or drink the flavored water - virtually 'taste' the experience. As technologies and interfaces evolve there will be a overlap between what is real and virtual. Researchers and industry are actively involved in improving different sensory experiences (Timmerer et al., 2014) and multiple sensorial multimodal media content (mulsemedia) (Ghinea et al., 2011, 2014), which includes olfaction (sense of smell) (Murray et al., 2014, 2016) and tactile (sense of touch) (Danieau et al., 2014) which will impact virtual reality.

Prosthetics to Monkey-Brains The research by scientists (Cole et al., 2009) for helping amputees to experience their lost limbs is applicable in other areas (e.g., interfacing between digital and real world). This principle of using 3-dimensional computer graphics and virtual reality headsets to help amputees with a lost limb get a 'restored' illusion has been demonstrated by researchers - and has shown extremely promising results for patients struggling to come to terms with amputation.

Interestingly, some of the early researchers approaches in advancing touch-sensitive prosthetics for people was been based upon experimented with rhesus monkeys, whose sensory systems closely resemble those of humans. They identified patterns of brain activity that occur when the animals manipulate objects and successfully triggered these patterns artificially through direct electrical stimulation of their brains. Given how complex the brain is, and how blunt current instrument electrical stimulation techniques are, there is still a long way to go - however, the initial research has shown extremely promising results (Tabot et al., 2013; Ornes, 2013).

The research with VR and amputees on its own is of crucial importance - for example, about 95% of amputees experience phantoms which often emerge immediately after amputation but sometimes after weeks or months (roughly two thirds of patients the phantom is extremely painful) (Cole et al., 2009; Ramachandran and Brang, 2016).

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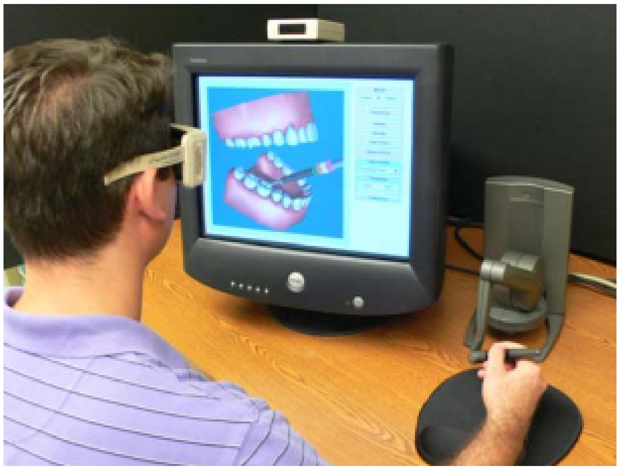
(b)



(a)

Figure 10: **(a) Muscle Sensors** - Prosthetic hand that can be controlled by muscle sensors (e.g., bionic-hand) (He et al., 2014). The illustration shows the result of an in-house 3D printer used to create low-cost prosthetic hands in combination with uncomplicated integrated circuits for reading muscle sensors. **(b) Dentistry** - Haptics-based virtual reality periodontal training simulations (Luciano et al., 2009). Allows trainees to practice performing, diagnosing and treatmenting of periodontal diseases by visualizing a three-dimensional virtual human mouth and feeling real tactile sensations while touching the surface of teeth, gingiva, and calculi with virtual dental instruments.

7 Problems to Overcome

Production Times With advancements in computational processing power has increased the technological and computing power. However, this does not necessarily translate into faster production time or smoother rendering when designing virtual environments. For one thing, programmers like to take advantage of more power by creating richer environments, which in turn take longer to render. Techniques used in traditional virtual environments (e.g., video games) are not always applicable to virtual reality solutions. For instance, users should be able to see the hairs on a person's head. While graphical tricks used in the past - like using flat 2D images to provide set dressing like grass (billboarding) - become obvious when viewed close up (as in VR worlds). Hence, developers have to be warey (or avoid) these shortcuts to make virtual reality worlds sufficiently detailed.

Cost Often overlooked within the bigger picture - is 'price' and, of course, accessibility to resources which are crucial factor for the long term success of virtual reality (see Figure 7). VR is constantly coming down in prices (making VR more accessible to the general public). As cellphones get annual releases - similarly virtual reality companies will likely improve models regularly (e.g., every year or two).

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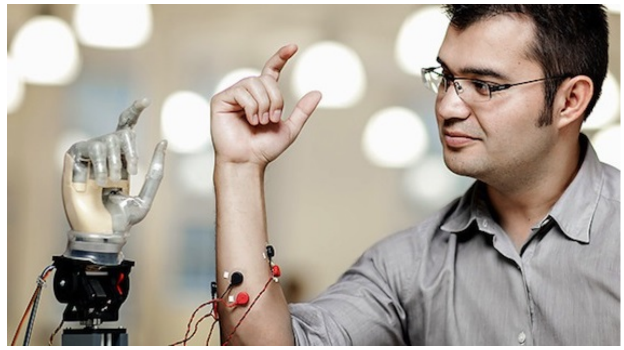
Virtual People Placing realistic 'virtual people' in the scene to interact with the user poses a formidable challenge. Render realistic virtual human that not only 'look realistic' but are able to purposefully interact with the environment and users - for instance, this may include speech recognition, the generation of meaningful sentences, facial expression, emotion, skin color and tone, and muscle and joint movements - is still beyond the capabilities of artificial intelligence and computer graphics (and especially challenging in real-time) (Slater and Sanchez-Vives, 2016).

Timing/Delays Especially with a large focus of VR research on 'remote' operation and communication. Sending and receiving data over large distances. For instance, from the other side of the country to the far reaches of the universe (Fong, 2017). This especially important for remote surgical procedures which are limited by variable transmission times for visual feedback (Guo et al., 2016). The delays are not just graphical - but also influence other senses (auditory to haptic resonating presences) (Wloka, 1995; Kühnapfel et al., 2000). Studies have shown the feasibility of remote virtual reality applications using conventional network infrastructures (depend on factors, such as, data volume, response time and number of users) (Suarez et al., 2017; Fong, 2017; Wada et al., 2016). The networking challenge of allowing dispersed people (across the world or galaxy) to seamlessly see, hear, and touch each other, as well as share real objects and equipment is one of the ultimate aims.

Human-Machine Interaction and Collaboration Natural (transparent) communication and synergy of interacting with the hardware is currently one of the biggest challenges (Quevedo et al., 2017). For instance touch poses an especially formidable challenge. While the option of gloves containing sensors can record the movements of a user's hand and provide tactile feedback the hardware is still somewhat simple (e.g., compared to the number of nerves and abilities of a real human hand). This is a factor today when training surgeons, when cutting through virtual tissue, should feel tiny different degrees of resistance to the motion of a scalpel at different places along the tissue. Improved coupling will allow the user to have greater immersion. For example, Quevedo et al. focused on the development of an immersive virtual reality automotive training system using different optimize materials, infrastructure, time resources to create an efficient system that was generated by the man-machine interaction oriented to develop skills in the area of automotive mechanical (Quevedo et al., 2017). Techniques have been developed for implanting thought-controlled robotic arms and their electrodes directly to the bones and nerves of amputees, a move which he is calling 'the future of artificial limbs' (mind-controlled artificial limbs fusing man and machine) (Sensinger et al., 2009). This research has applications in VR that make the interface a direct coupling (compared to controllers and having to physically move the body) (see Figure 11(b)).

Perceptual Requirements Classification of virtual reality perceptual issues is important. Human factors and perceptual problems from experimental studies have identified factors to help guide the design effective VR system. Also organizing these issues into ones related to the specific problem, environment, task, display, and individual user reduces the complexity of the design. This identifies issues associated with more recent platforms such as portable systems. Interestingly it allows developers and designers to approach and addressing these problems in addition to suggesting directions for future research (Azuma et al., 2001).

(a)



(b)

Figure 11: **Input/Output Sensors Control** - (a) Prosthetic hand that can be controlled by muscle sensors (bionic hand) (He et al., 2014). (b) Techniques developed in robotics for thought-controlled robotic arms and their electrodes directly to the bones and nerves of amputees (Sensinger et al., 2009).
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Designing Interdisciplinary VR Solutions As virtual reality solutions becomes more widespread, care must be taken to ensure that they are properly designed to meet their intended goals. With traditional development methods, designers and developers need to think differently, and are primarily concerned with creating an engaging experience that will keep the user entertained; to improve usability and engagement, they are free to modify the design throughout the entire development process. However, virtual reality designers/developers are not afforded this luxury but rather, must strictly adhere to the content/knowledge base while ensuring that their end product is not only fun and engaging, but is also an effective teaching tool. In addition to knowledge and expertise in virtual reality design and development, VR designers/developers must therefore also be knowledgeable in the specific content area and possess some knowledge in teaching methods and instructional design in particular. In other words, the development of effective VR solutions is not a trivial task and knowledge in VR design solely is not sufficient to develop an effective VR solution. VR development is an interdisciplinary process, bringing together experts from a variety of fields including user design and development and although designers are not expected to be experts in instructional design and the specific content area, possessing some knowledge in these areas will, at the very least, promote effective communication between the interdisciplinary team members.

Solutions are Coming With all the challenges and problems of Virtual Reality - it might seems hopeless. However, a large body of research is involved in efforts to solve such limitations. Of course, we are only in the early stages - but we are already starting to see the potential and possibilities. For instance, one area of novel research makes use of electrorheological fluids (Jacob and Mazursky, 2016), which alter their thickness when exposed to electric fields of different strengths (e.g., applications in haptic feedback). Virtual reality solutions would be able to use of this effect to send electrical signals to adjust a glove or garment's resistance to touch, providing touch feedback to the user. Virtual reality may not yet be as sophisticated as we had been lead to believe - but with advancements in science and technology we are now on the cusp of major breakthroughs which will change our world as we know it.

8 Conclusion

While there is still much progress to be made before the average user will be able to truly engage and appreciate VR. For instance, one bottleneck is the challenges in developing high quality virtual reality solutions quickly and easily. We are at the threshold of a new technical revolution, and as trends continue, we are certain to see breakthroughs in virtual reality over the coming years, make ski-fi a reality even the most forward-thinking futurologists. This is frontier territory, with no trend-setters and no rules set in stone.

Today, virtual reality is poised to change the way we interact with and control computers. Like the introduction of computers more than 50 years ago, its impacts are unknown. Will there be VR in every house, classroom, and office? Will immersing oneself in a computer-generated world be as commonplace as watching a movie? About the only thing that does seem certain about VR is that it will grow and develop. Nevertheless, as VR technologies matures, they will become better, cheaper, and more accessible. Furthermore, the networks that link computers will expand, making it possible for VR to weave its way into our daily lives. Clearly, the future of VR is limited only by our imaginations.

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