ENHANCING LIVES AND ENVIRONMENT WITH IMMERSIVE VIRTUAL REALITY

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Abstract

Virtual Reality (VR) started about 50 years ago in a form of what we recognized today as [stereo head-mounted display (HMD), head tracking, and computer graphics generated images] – although the hardware was completely different. The technology (VR) emerged again between early 80s and late 90s based on a different generation of hardware (e.g., CRT displays rather than vector refresh, electromagnetic tracking instead of mechanical). VR is the term used to describe a computer-generated environment that someone can explore and interact with. A user is immersed in the environment and the brain is basically tricked into thinking what someone is seeing in the virtual world is real. This attracted the attention of the public, and VR was hailed by many engineers, scientists, celebrities, and business people as the beginning of a new era, that would soon change the world for the better. Scientists, engineers, and people working in industry carried on with their research and applications using and exploring different forms of VR, not knowing that actually the topic had already passed away. The purpose of this article is to review a range of VR applications where there is some evidence for, or at least debate about it, and its utility. The recent appearance of low cost virtual reality (VR) technologies – like the Oculus Rift, the HTC Vive and the Sony PlayStation VR – and Mixed Reality Interfaces – like the Hololens – is attracting the attention of users and researchers suggesting it may be the next largest stepping stone in technological innovation.

Keywords: CAVE, Head-Mounted Display, Immersive, Virtual Reality, Virtual World

Introduction

The technology for immersive virtual reality (IVR) has been in existence for about 50 years, initially as a demonstrated laboratory-based idea (the ultimate display) (Sutherland 1965) and for the past 20 years as practical, affordable and useful systems. The vast majority of research and development in this area has been used in a way to simulate physical reality. Yet it is a medium that has the potential to go far beyond anything that has been experienced before in terms of transcending the bounds of physical reality, through transforming your sense of place and through non-invasive alterations of the sense of our own body. In other words, virtual reality has rarely been seen as a medium in its own right, as something that can create new forms of experience, but rather as a means of simulating existing experience (Brooks Jr 1999). As it has been mentioned before (Pausch et al. 1996), it is much like both cinema and television in their early days, which were used essentially as a medium for theatre. Our approach is to treat virtual reality as providing a fundamentally different type of experience, with its own unique conventions and possibilities, a medium in which people respond with their whole bodies, treating what they perceive as real.

Virtual Reality (VR) is a technology which allows user to interact with computer-generated 3D environment. This environment can be simulation of real world or of virtual world. It is essential that the person becomes part of this environment by interacting and manipulating it with series of actions.

During the past 25 years when VR was supposed to have "died" masses of research into both the development of the technology and its application in a vast array of areas has been continuing. Scott Fisher, one of the VR pioneers in a 1989 essay reported in Packer and Jordan (2002) set out a number of applications: telepresence, where VR provides an interface through which the participant operates in a distant place embodied in a robot located there; data visualization; applications in architectural visualization; medicine including surgical simulation; education and entertainment; remote collaboration. These were all applications that were being worked on at the time. In this article, we set out how VR has been used in these and in a variety of other applications, applications that have already shown results that may be of significant benefit for individuals and society. With VR available on a mass scale, the potential for these benefits to have significant impact is now all the greater. We have selected areas that we believe are particularly important for demonstrating how VR has been and might be used to improve the lives of people, and to help overcome some societal problems, or at the very least help in scientific understanding of problems and contribute toward solutions.

Currently standard virtual reality systems use either virtual reality headsets or multi-projected environments to generate realistic images, sounds and other sensations that simulate a user's physical presence in a virtual environment. A person using virtual reality equipment is able to look around the artificial world, move around in it, and interact with virtual features or items. The effect is commonly created by VR headsets consisting of a head-mounted display (HMD) with a small screen in front of the eyes, but can also be created through specially designed rooms with multiple large screens. Virtual reality typically incorporates auditory and video feedback, but may also allow other types of sensory and force feedback through haptic technology.

Immersion and Presence

Consciousness of our immediate surroundings necessarily depends on the data picked up by our sensory systems – vision, sound, touch, force, taste, and smell. This is not to say that we simply reproduce the sensory inputs in our brains – far from it, perception is an active process that combines bottom-up processing of the sensory inputs with top-down processing (including prior experience, expectations, and beliefs) based on our previously existing model of the world. After a few seconds of walking into a room we think that we "know" it. In reality, eye scanning data show that we have foveated on a very small number of key points in the room, and then our eye scan paths tend to follow repeated patterns between them (Noton and Stark, 1971). The key points are determined by our prior model of what a room is. We have "seen" a small proportion of what there is to see; yet, our perceptual system has inferred a full model of the room in which we are located. In fact it has been argued that our model of the scene around us tends to drive our eye movements rather than eye movements leading to our perceptual model of the scene (Chernyak & Stark, 2001). It was argued by Stark (1995) that this is the reason why VR works, even in spite of relatively simplistic or even poor rendering of the surroundings. VR offers enough cues for our perceptual system to hypothesize "this is a room" and then based on an existing internal model infer a model of this particular room using a perceptual fill-in mechanism. Recall the quote from Sutherland above how people accommodated to and remarked on the realism of the wire frame rendered scene displayed in the "Sword of Damocles" HMD.

The technical goal of VR is to replace real sense perceptions by the computer-generated ones derived from a mathematical database describing a 3D scene, animations of objects within the scene – represented as transformations over sets of mathematical objects – including changes caused by the intervention of the participant. If sensory perceptions are indeed effectively substituted then the brain has no alternative but to infer its perceptual model from its actual stream of sensory data – i.e., the VR. Hence, consciousness is transformed to consciousness of the virtual scenario rather than the real one – in spite of the participant's sure knowledge that this is not real.

Effective substitution of real sensory data is an ideal. In practice, it depends on several factors, not least of which is – which sensory systems are included? Typically, vision, and often auditory, more rarely touch, more rarely force feedback, more rarely still smell, and almost unknown taste. If we consider the typical VR system, it is primarily centered around vision, may have sound, and may have some element of tactile feedback. However, even vision alone is often enough for numerous applications, since anyway for many people it is perceptually dominant. So, participants in a VR typically encounter a situation where their visual system places them on say a roller coaster, but all other sense perceptions are from the surrounding physical environment. Nevertheless, they may scream and react as if they are on the roller coaster even while talking to a friend in reality standing nearby.

By an *immersive* VR system we mean one that delivers the ability to perceive through natural sensorimotor contingencies. This is entirely determined by the technology. Whether you can turn around 360°, all the while seeing a very low-latency continuous update of your visual field in correspondence with your gaze direction, is completely a function of the extent to which the system can do this. We can classify systems in this way as being more or less immersive. We say that system A is more immersive than system B if A can be used to simulate the perception afforded by B but not *vice versa*. Hence, in this sense an HMD is "more immersive" than a Cave, since there is something that can be represented in an HMD that cannot be represented in a Cave (even a six-sided Cave): the virtual representation of the participant's body. In a Cave when you look down toward yourself you will see your real body. In an HMD with head tracking you can see a virtual body substituting your own (if this has been programed). Moreover, the virtual body can be designed to look like the real one, or not, and certainly with body tracking can be programed to move with real body movements and so on. So, in this way an HMD-based system can (in an ideal sense) be set up to simulate a Cave, but not *vice versa*.

Immersive systems can be characterized by the sensorimotor contingencies (SCs) that they support. SCs refer to the actions that we know to carry out in order to perceive, for example, moving your head and eyes to change gaze direction, or bending down and shifting head and gaze direction in order to see underneath something (O'Regan & Noë 2001*a*,*b*; Noë 2004). The SCs supported by a system define a set of valid actions that are meaningful in terms of perception within the virtual environment depicted. For example, turn your head or bend forward and the rendered visual images ideally change the same as they would if you were in an equivalent physical environment. If head tracking was not enabled, then turning your head would have no effect, and therefore such an action could not be useful for perception. I define the set of *valid sensorimotor actions* with respect to a given IVR system to be those actions that consistently result in changes to images (in all sensory modalities) so that perception may be changed meaningfully. I define the set of *valid effectual actions* as those actions that the participant can take in order to effect changes in the environment. I call the union of these two sets the set of *valid actions*—the actions that a participant can take that can result in changes in perception or changes to the environment.

For example, consider an environment displayed visually through a head-tracked HMD. A participant in such an environment can usually quickly learn the effect of head movements on visual perception—the SCs. Such head movements will be valid sensorimotor actions. However, suppose the participant reaches out to touch a virtual object, but feels nothing because there is no haptics in this system. Here, the reaching out to touch something is not a valid sensorimotor action for this IVR. Now imagine an environment displayed visually on a large back-projected screen—again with head tracking. However, now when the participant looks far enough to one side visual elements from the surrounding real world would intrude into the field of view. Actions that result in perception from outside the virtual environment are also not valid sensorimotor actions. Suppose in either system the participant wears a tracked data glove, which is represented as a hand within the virtual environment. When this virtual hand intersects an object and the participant makes a grasping gesture, then the object might be selected and moved to another place. This would be an example of a valid effectual action. Without the data glove, the moving and grasping action would have no effect, and therefore would not be a valid effectual action. With today's generally available technology, participants will not experience a virtual reality system with generalized haptics, so that this dimension of SC will always fail if tested—for example, if a participant in a virtual reality touches some arbitrary virtual object they would feel nothing. The whole aspect of physicality is typically missing from virtual environment experiences—collisions do not typically result in haptic or even auditory sensations.

Specifically, immersion concerns the amount of senses stimulated, interactions, and the reality's similarity of the stimuli used to simulate environments. This feature can depend on the properties of the technological system used to isolate user from reality (Slater, 2009).

Higher or lower degrees of immersion can depend by three types of VR systems provided to the user:

- Non-immersive systems are the simplest and cheapest type of VR applications that use desktops to reproduce images of the world.
- Immersive systems provide a complete simulated experience due to the support of several sensory outputs devices such as head mounted displays (HMDs) for enhancing the stereoscopic view of the environment through the movement of the user's head, as well as audio and haptic devices.
- Semi-immersive systems such as Fish Tank VR are between the two above. They provide a stereo image of a three dimensional (3D) scene viewed on a monitor using a perspective projection coupled to the head position of the observer (Ware et al., 1993). Higher technological immersive systems have showed a closest experience to reality, giving to the user the illusion of technological non-mediation and feeling him or her of "being in" or present in the virtual environment (Lombard & Ditton, 1997). Furthermore, higher immersive systems, than the other two systems, can give the possibility to add several sensory outputs allowing that the interaction and actions were perceived as real (Loomis et al., 1999; Heeter, 2000; Biocca et al., 2001).

Finally, the user's VR experience could be disclosed by measuring presence, realism, and reality's levels. Presence is a complex psychological feeling of "being there" in VR that involves the sensation and perception of physical presence, as well as the possibility to interact and react as if the user was in the real world (Heeter, 1992). Similarly, the realism's level corresponds to the degree of expectation that the user has about of the stimuli and experience (Baños et al., 2000, 2009). If the presented stimuli are similar to reality, VR user's expectation will be congruent with reality expectation, enhancing VR experience. In the same way, higher is the degree of reality in interaction with the virtual stimuli, higher would be the level of realism of the user's behaviors (Baños et al., 2000, 2009).

Virtual Reality Technologies

Technologically, the devices used in the virtual environments play an important role in the creation of successful virtual experiences. According to the literature, can be distinguished input and output devices (Burdea et al., 1996; Burdea & Coiffet, 2003). Input devices provide users the sense of immersion and determine the way a user communicates with the computer. It helps users to navigate and interact within a VR environment to make it intuitive and natural as possible. Unfortunately, the current state of technology is not advanced enough to support this yet. Most commonly used input devices are joysticks, force Balls/Tracking balls, controller wands, data gloves, trackpads, On-device control buttons, motion trackers, bodysuits, treadmills and motion platforms.

Figure 1: Vive (HTC) and Oculus Rift Source: http://web.tecnico.ulisboa.pt/ist188480/cmul/devices

On the contrary, the output devices allow the user to see, hear, smell, or touch everything that happens in the virtual environment. As mentioned above, among the visual devices can be found a wide range of possibilities, from the simplest or least immersive (monitor of a computer) to the most immersive one such as VR glasses or helmets or HMD or CAVE systems.
Furthermore, auditory, speakers, as well as haptic output devices are able to stimulate body senses providing a more real virtual experience. For example, haptic devices can stimulate the touch feeling and force models in the user.

Apart from input, output hardware and its coordination, the underlying software is also equally important. It is responsible for the managing of I/O devices, analyzing incoming data and generating proper feedback. The Virtual Reality Modelling Language (VRML), first introduced in 1994, was intended for the development of "virtual worlds" without dependency on headsets. The Web3D consortium was subsequently founded in 1997 for the development of industry standards for web-based 3D graphics. The consortiums subsequently developed X3D from the VRML framework as an archival, open-source standard for web-based distribution of VR content. The whole application is time-critical and software must manage it: input data must be handled timely and the system response that is sent to the output displays must be prompt in order not to destroy the feeling of immersion. The developer can start with basic software development kit (SDK) from a VR headset vendor and build their own VWG from scratch. SDK usually provide the basic drivers, an interface to access tracking data and call graphical rendering libraries. There are some ready-made VWG for particular VR experiences and has options to add high-level scripts.

Virtual Reality Applications

With the advancement in display, sensing and computer technology, it gives the user a new VR experiences which are more realistic and immersive for different VR applications. VR can lead to new and exciting discoveries in different fields. There are wide range of applications for VR which includes:

a. VR in Military

The military in the UK and the US have both adopted the use of virtual reality in their training as it allows them to undertake a huge range of simulations. VR is used in all branches of service: the army, navy, air force, marines and coast guard. In a world where technology is adopted from an early age and children are accustomed to video games and computers, VR proves an effect method of training. VR can transport a trainee into a number of different situations, places and environments for a range of training purposes. The military uses it for flight simulations, battlefield simulations, medic training, vehicle simulation and virtual boot camp, among other things. VR is a completely immersive, visual and sound-based experience, which can safely replicate dangerous training situations to prepare and train soldiers, without putting them at risk until they are ready for combat. Likewise, it can also be used to teach soldiers some softer skills, including communication with local civilians or international counterparts when out in the field. Another of its uses includes treating Post-Traumatic Stress Disorder (PTSD) for soldiers who have returned from combat and need help adjusting to normal life situations; this is known as Virtual Reality Exposure Therapy (VRET). A key benefit for using virtual reality technology in the military is the reduction in costs for training.

b. VR in Sports

VR is revolutionizing the sports industry for players, coaches and viewers. Virtual reality can be used by coaches and players to train more efficiently across a range of sports, as they are able to watch and experience certain situations repeatedly and can improve each time. Essentially, it’s used as a training aid to help measure athletic performance and analyze technique. Some say it can also be used to improve athletes' cognitive abilities when injured, as it allows them to experience gameplay scenarios virtually. Similarly, VR has also been used to enhance the viewer’s experience of a sporting event. Broadcasters are now streaming live games in virtual reality and preparing to one day sell virtual tickets to live games so that anyone from anywhere in the world can ‘attend’ any sports event. Potentially, this could also allow for those who cannot afford to spend money on attending live sports events to feel included as they can enjoy the same experience remotely, either for free or at a lesser cost.

c. VR in Education

VR uses for education don’t stop at the military or medical field, but extend to schools with virtual reality also adopted in education for teaching and learning situations. Students are able to interact with each other and within a three-dimensional environment. They can also be taken on virtual field trips, for example, to museums, taking tours of the solar system and going back in time to different eras. Virtual reality can be particularly beneficial for students with special needs, such as autism. Research has found that VR can be a motivating platform to safely practice social skills for children, including those with Autism Spectrum Disorders (ASD). Technology company, Floreo, has developed virtual reality scenarios that allow children to learn and practice skills such as pointing, making eye contact and building social connections. Parents can also follow along and interact by using a linked tablet.

Figure 2: *Engage application with students learning collaboratively inside a lecture room.*
Source: https://virtualspeech.com/blog/vr-applications

d. VR in Recreation

Many real-life hobbies are available in VR, and the immersive experience makes them all the more enjoyable and accessible. If you're a fan of cultural activities, you can visit museums such as the Natural History Museum in London or, if you're more of a thrill-seeker, there's even a VR theme park opening in China. One of the more unique ways VR is being used is by Galatea, who provides a writing and narrative design management tool for immersive storytelling.

Figure 3: *VR theme park in China from SLQJ.* Source: Source: https://virtualspeech.com/blog/vr-applications

e. VR in Medical Training

Due to its interactive nature, medical and dental students have begun using VR to practice surgeries and procedures, allowing for a consequence free learning environment; the risk of inflicting harm or making a mistake while practicing on real patients is eliminated. Virtual patients are used to allow students to develop skills which can later be applied in the real world. Using VR technology in the medical industry is an effective way to not only improve the quality of students in training but it also presents a great opportunity to optimise costs, especially since health services are continuously under pressure with tight budgets.

f. VR in Automotive industry

VR allows engineers and designers to experiment easily with the look and build of a vehicle before commissioning expensive prototypes. Brands such as BMW and Jaguar Land Rover already use VR to hold early design and engineering reviews to check the visual design and object obscuration of the vehicle - all before any money has been spent on physically manufacturing the parts. VR is saving the automotive industry millions by reducing the number of prototypes built per vehicle line.

g. VR in Tourism

Imagine being able to try your holiday before you buy it. That's exactly what the future could hold. The industry is taking the first steps to enabling you to go on guided virtual tours of hotels, restaurants and tourist landmarks. Thomas Cook launched their 'Try Before You Fly' VR experience in 2015, where potential holidaymakers visit stores in various countries to experience the holiday in VR before booking it. There was 190% uplift in New York excursions bookings after people tried the 5 minute version of the holiday in VR. Google Expeditions is another way tourism can become more accessible. Users can travel the world from the comfort of their own home, allowing people of all ages and backgrounds to explore coral reefs or the surface of Mars.

h. VR in News and journalism

You can now watch news stories and documentaries in VR. The New York Times has already entered this space, and it's only a matter of time before other media outlets join them. In the NYTVR app, you can experience stories rather than just listen to them, as if you were standing opposite the journalist where the story is happening. VR is likely to influence your workplace, hobbies and social life in the future - and that's sooner than you may think. The possibilities of VR are endless; the only things we can't replace in VR are eating and sleeping… for now.

There are also many more application area of Virtual Reality such as; Marketing, Charity, Social, Well-being, Events and Conferences, Arts and Designs, Gambling, Real Estate etc.

Concerns and Challenges

Health and safety

There are many health and safety considerations of virtual reality. A number of unwanted symptoms have been caused by prolonged use of virtual reality, and these may have slowed proliferation of the technology. Most virtual reality systems come with consumer warnings, including: seizures; developmental issues in children; trip-and-fall and collision warnings; discomfort; repetitive stress injury; and interference with medical devices. Some users may experience twitches, seizures or blackouts while using VR headsets, even if they do not have a history of epilepsy and have never had blackouts or seizures before. One in 4,000 people, or .025%, may experience these symptoms. Since these symptoms are more common among people under the age of 20, children are advised against using VR headsets. Other problems may occur in physical interactions with one's environment. While wearing VR headsets, people quickly lose awareness of their real-world surroundings and may injure themselves by tripping over, or colliding with real-world objects.

VR headsets may regularly cause eye fatigue, as does all screened technology, because people tend to blink less when watching screens, causing their eyes to become more dried out. There have been some concerns about VR headsets contributing to myopia, but although VR headsets sit close to the eyes, they may not necessarily contribute to nearsightedness if the focal length of the image being displayed is sufficiently far away.

Virtual reality sickness (also known as cybersickness) occurs when a person's exposure to a virtual environment causes symptoms that are similar to motion sickness symptoms. Women are significantly more affected than men by headset-induced symptoms, at rates of around 77% and 33% respectively. The most common symptoms are general discomfort, headache, stomach awareness, nausea, vomiting, pallor, sweating, fatigue, drowsiness, disorientation, and apathy. For example, Nintendo's Virtual Boy received much criticism for its negative physical effects, including "dizziness, nausea, and headaches". These motion sickness symptoms are caused by a disconnect between what is being seen and what the rest of the body perceives. When the vestibular system, the body's internal balancing system, does not experience the motion that it expects from visual input through the eyes, the user may experience VR sickness. This can also happen if the VR system does not have a high enough frame rate, or if there is a lag between the body's movement and the onscreen visual reaction to it.[Because approximately 25–40% of people experience some kind of VR sickness when using VR machines, companies are actively looking for ways to reduce VR sickness.

Children in virtual reality

The relationship between virtual reality and its underage users is controversial and unexplored. In the meantime, children are becoming increasingly aware of VR, with the number in the USA having never heard of it dropping by half from Autumn 2016 (40%) to Spring 2017 (19%).

Valeriy Kondruk, CEO of VR travel platform Ascape, says the app downloads in March 2020 increased by 60% compared to December 2019 and doubled in comparison with January 2020. According to Kondruk, normally, the busiest month for VR companies is December, which is associated with winter holidays and people spending more time at home.

In early 2016, virtual reality headsets became commercially available with offers from, for example, Facebook (Oculus), HTC and Valve (Vive) Microsoft (HoloLens), and Sony (Morpheus). At the time and to this day, these brands have different age instructions for users, e.g. 12+ or 14+, this indicates a completely self-regulatory policy.

Studies show that young children, compared to adults, may respond cognitively and behaviorally to immersive VR in ways that differ from adults. VR places users directly into the media content, potentially making the experience very vivid and real for children. For example, children of 6–18 years of age reported higher levels of presence and "realness" of a virtual environment compared with adults 19–65 years of age.

Studies on VR consumer behavior or its effect on children and a code of ethical conduct involving underage users are especially needed, given the availability of VR porn and violent content. Related research on violence in video games suggests that exposure to media violence may affect attitudes, behavior, and even self-concept. Self-concept is a key indicator of core attitudes and coping abilities, particularly in adolescents. Early studies conducted on observing versus participating in violent VR games suggest that physiological arousal and aggressive thoughts, but not hostile feelings, are higher for participants than for observers of the virtual reality game.

Privacy

The persistent tracking required by all VR systems makes the technology particularly useful for, and vulnerable to, mass surveillance. The expansion of VR will increase the potential and reduce the costs for information gathering of personal actions, movements and responses.

Conceptual and philosophical concerns

In addition, there are conceptual and philosophical considerations and implications associated with the use of virtual reality. What the phrase "virtual reality" means or refers to can be ambiguous. Mychilo S. Cline argued in 2005 that through virtual reality, techniques will be developed to influence human behavior, interpersonal communication, and cognition.

Conclusion

We have previously defined presence in virtual reality as the extent to which people respond realistically within a virtual environment, where response is taken at every level from low-level physiological to high-level emotional and behavioural responses (Sanchez-Vives & Slater 2005). Although we stand by this approach, we find the terminology problematic. The word 'presence' has come to have multiple meanings, and it is difficult to have any useful scientific discussion about it given this confusion.

In physical reality and first-order virtual reality, there is something very simple that you can do to physically establish your presence. Look down, and you will see your body, or see parts of it continuously in peripheral vision. For example, wearing an HMD a virtual body can be portrayed collocated with your real physical body, so that when you do the same movements that you would do in physical reality to look at your body, instead you would see your virtual body. Using normal actions you know how to change your sensory stimulation as a function of your actions, and one action that is not special compared to other actions is to look down and see yourself.

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