CHAPTER 3

Virtual Reality Technologies

Steffi Davey and Paul Hancock

3.1 Introduction

The concept of virtual reality (VR) has been around for longer than most would expect, dating back to the 1950s. However, this initial introduction to VR is quite removed from what we would refer to as VR today. Also, there is a wide spectrum of what people envisage when asked about VR. Therefore, it is important to start with a definition of the concept. Although there have been many conceptualisations, most involve interaction within an 'immersive' computer-generated environment, including platforms such as semi-immersive caves.

For the purposes of this chapter, VR will be referred to by the following definition:

> VR is an interactive, participatory environment that could sustain many remote users sharing a virtual place. VR is characterized by the illusion of participation in a synthetic environment rather than the external observation of such an environment. It relies on three-dimensional, stereoscopic, head-tracked displays, hand/body tracking, and binaural sound. VR is an immersive, multisensory experience. (Earnshaw, 2014)

S. Davey (✉) · P. Hancock
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: steffi.davey@shu.ac.uk

B. Akhgar (ed.), *Serious Games for Enhancing Law Enforcement Agencies*, Security Informatics and Law Enforcement,
https://doi.org/10.1007/978-3-030-29926-2_3

The 1960s saw the introduction of the first head-mounted displays (HMDs). Probably the most famous of these was the *Sword of Damocles* invented by Ivan Sunderland. Yet, it took until the twentieth century for VR technologies to experience a real surge in popularity, even if VR was used to a certain extent in research and the military. An increase in interest arose with the introduction of the Oculus Rift (often misconstrued to be the first VR headset). Since then the excitement around VR has remained relatively consistent (Blach, 2008).

There are two key benefits of using VR: Firstly, VR offers a cost-effective option to experience something that would otherwise be very costly and/or time intensive to execute in reality (e.g. traveling to the International Space Station); secondly, it enables users to experience things that would otherwise be impossible (e.g. traveling in a capsule through a human body).

This chapter discusses some of the popular technologies available for VR development in the context of serious games. It will then go on to explore current applications of virtual reality in both research and industry and considerations for serious game-based virtual reality developments. It will further discuss pertinent challenges around VR including ethical implications.

3.2 An Overview of VR Technologies

There are a number of VR technologies available in the market, although they fall into two main categories. The first are solutions in which users sit or stand whilst they are wearing the device, which means they are only able to move their head whilst using the headset. The second group are devices with which users can move around and have their movements tracked via cameras, so that these movements can be translated into the virtual environment. The following section will discuss features of the different types of products, including a range of VR headsets along with accessories that may enhance users' experiences in VR.

3.2.1 Seated or Standing VR Headsets

Seated or standing headsets are devices that contain a small screen, displaying an image for each eye and often include headphones. The headsets are typically tethered to a PC either by cables or via a wireless connection. Some of the more high-end headsets will use infrared cameras to track the position of the headset, these are usually positioned in front of the user (commonly mounted on a monitor). This setup largely limits tracking to head movements as opposed to whole body movements. As a result, the

Fig. 3.1 Example of a seated or standing VR headset. (Picture credits: https://commons.wikimedia.org/wiki/File:Oculus-Rift-CV1-Headset-Front.jpg)

user will typically stand still or sit whilst wearing the headset – hence, the term seated or standing VR. One of the first headsets of this type to have a significant impact on the advancement of VR technology was the Oculus Rift (see Fig. 3.1). Seated or standing VR headsets are ideal for use in locations where there is insufficient space to allow for the user to move around.

3.2.2 Room-Scale VR Headsets

In contrast to seated or standing headsets, room-scale headsets allow for a user's movements to be mapped to movements within the virtual environment. This setup enables the user to move more naturally in VR leading to a more realistic experience. Often two or more infrared cameras are used to track the player's position. This positional tracking enables users to have complete control over what they see in VR. They are further able to crouch down, lean around corners and get as close as they like to the objects in the virtual environment. The use of two cameras instead of one ensures that the tracking remains reliable. Tracking of body movements requires a larger, dedicated area compared to the seated or standing setup.

Room-scale systems are ideal for the development of serious games platforms in which learning outcomes are better served if users can move around, even if movement is limited to the allocated playing area (e.g. skill development and environmentally based learning; see, for instance, Chaps. 6 and 10). Limitations to the physical space can be overcome by including functionalities such as teleportation to move within the game. This is an area of extensive research[1,2] investigating ways to make the most of

[1] https://ieeexplore.ieee.org/document/7460053
[2] http://shura.shu.ac.uk/18594/

restricted playing areas (e.g. how to design games in a way that will encourage users to turn naturally before reaching the edge of the physical playing area).

Whilst range of movement adds to immersion, room-scale VR headsets are typically tethered to a PC by a wire. This wire can be a trip hazard and can detract from the sense of immersion with negative impact on the user's game play. As an alternative, wireless adapters are available for some headsets such as the HTC Vive. The downside of headsets without cables is that the headsets have to use battery power, which will need recharging during long sessions.

Room-scale headsets generally come with handheld controllers, which allows the users' hand movements to be tracked accurately. Further, buttons on the handset allow the user to interact with the game applications. For instance, pressing a button may be linked to firing a gun or the teleportation to another location, which can lead to confusion and detract from the user experience. In the future we can expect to see the advent of VR gloves and hand tracking which will open up the window for much more intuitive interactions within VR. Some headsets also include front cameras, so that the user can see the outside world opening the possibility for augmented reality (see Chap. 4). The HTC Vive Pro, for example, includes two cameras on the front enabling stereoscopic 3D views (see Fig. 3.2).

Fig. 3.2 Example of a room-scale VR system. (Picture credits: https://www.flickr.com/photos/bagogames/25845851080)

3.2.3 Mobile VR

Mobile VR platforms offer an inexpensive VR solution, as they make use of the hardware already built into mobile devices. In mobile VR setups, a mobile phone can be clipped into the front of the headset, so that the phone screen sits in front of the user's eyes (cp. Fig. 3.3). The screen on the phone is split to create a stereoscopic display. These headsets typically have a single button the user presses to interact with the application. Some devices come with a handheld controller, which can be used to navigate the virtual world and offer increased user interaction.

An example for an even cheaper mobile VR solution is Google Cardboard (see Fig. 3.4). This setup is perfect for trying out VR applications without the need to acquire sophisticated and expensive equipment. As the name suggests, the device is largely constructed from cardboard and contains lenses for each eye. Head movements are tracked using the gyroscope of the smartphone. The low cost of such devices and their easy assembly makes them ideal for applications that are intended for a large number of users for short periods of time and where users are not expected to move whilst using the application. As there are no cameras for the tracking of users' movements, they do not work well if the user tries to walk around. These devices also provide an efficient solution during the

Fig. 3.3 Example of a mobile VR. (Picture credits: https://www.samsung.com/global/galaxy/gear-vr/)

Fig. 3.4 Google Cardboard. (Picture credits: https://vr.google.com/intl/en_uk/cardboard/)

prototype phase before a final headset has been chosen for deployment. Conversely, the low quality of the lenses and the lack of features to provide comfort make it unsuitable for applications that require the user to wear the device for long sessions.

3.2.4 VR Accessories

To enhance the sense of immersion, numerous hardware devices can be added to the basic setups described above. This includes items such as haptic vests and full body rigs, which introduce somatic senses (i.e. body sensations of touch and pressure) into the virtual world (cp. right side of Fig. 3.5). Another innovation in this field is the omnidirectional treadmill (see left side of Fig. 3.5 for an example), which detects the user's steps and will move the user in VR in accordance with their movement on the treadmill. Treadmills can help with locomotion issues that can induce sickness during VR-based games (see discussion below).

Fig. 3.5 Examples of VR accessories. (Picture credits: https://commons.wikimedia.org/wiki/File:Virtuix_Omni_product_view,_profile.jpg, https://commons.wikimedia.org/wiki/File:NullSpace_VR_Mk_2.jpg)

3.2.5 Considerations for Choosing VR Technologies

Finding the balance of value for money is an important consideration when deciding which VR hardware should be used for the intended serious game product. This often means considering financial budgets next to the question of how comprehensive and interactive the serious game needs to be; that is, how important is it for the user to feel a sense of immersion and how much interaction (with virtual objects, people or an environment) is required to achieve the desired learning outcomes?

Generally, for maximum impact or to evoke emotions or a sense of awe, the higher-end hardware offered by camera-tracked headsets is preferable. Additional hardware, such as a treadmills or haptic vests, can be used to increase the sense of immersion. Further, it is important to consider whether the user should be able to walk around or can also stand still or sit whilst using the application. If movement is not required, a headset with a single camera for tracking as opposed to a multi-camera tracked headset is sufficient. For lower budgets, minimal interaction and lower-fidelity projects, hardware that uses mobile VR devices, such as Google cardboard, may be adequate.

Whilst VR systems have dramatically dropped in price since their initial release, they also require an appropriate system to run VR (i.e. PCs or laptops). Here it is important to ensure that the system is 'VR ready'.

3.3 VR Innovations

For a better understanding of the possibilities of VR for serious games, the subsequent sections explore innovative ways in which VR has been used in the past. Areas with extensive experience in VR-based serious games are healthcare, therapy and education. VR has also been explored for its use as a unique, artistic experience, which can help to create greater impact than traditional methods may otherwise achieve. These case studies can offer lessons and ideas for applications in the law enforcement area.

3.3.1 Pain Therapy

To date, the healthcare industry has been one of the predominant areas for the adoption of VR technologies, to aid both medical practitioners and patients. Examples of VR applications in the healthcare industry include improving impaired balance,[3] eating disorders (Perpiñá, Botella, & Baños, 2003), autism (Kandalaft, Didehbani, Krawczyk, Allen, & Chapman, 2013), pain management (Li, Montaño, Chen, & Gold, 2011), medical training procedures (Grantcharov et al., 2004), limb rehabilitation (Henderson, Korner-Bitensky, & Levin, 2007) and improving memory in the elderly (Optale et al., 2010).

For instance, hospitalised patients can profit from VR applications in experiencing less anxiety during illnesses and better coping mechanisms within an often daunting medical environment (Mosadeghi, Reid, Martinez, Rosen, & Spiegel, 2016), an effect that employs VR as a distractor. VR distractions can also be useful in the treatment of pain, potentially reducing the use of opioids and other pharmacological pain management methods (Morris, Louw, & Grimmer-Somers, 2009). For example, it has been shown that, by engaging multiple senses and providing a platform for interaction, serious games have helped children to become less receptive to pain (Le May, Paquin, Fortin, & Khadra, 2016). Functional magnetic resonance imaging (FMRI) confirmed this link, as the brain interprets pain differently in patients using VR (Hoffman, 2004). Results on the reduction of anxiety in patients were less conclusive.

[3] https://journals.sagepub.com/doi/full/10.1177/0269215513509389

3.3.2 Traumatic Experiences and Illnesses

VR games are being trialled extensively in a military context. Jobs in the defence sector can be highly physical and involve exposure to high-risk tasks and environments, confronting personnel with challenges to their mental health and well-being. Physical and mental stressors are especially prevalent during deployments overseas but may also occur in non-operational environments. Potentially traumatic events are related to exposure to threatened or actual violence (death, sexual violence or injury); non-traumatic stressors may be related to life in the military such as distance from family and friends during a deployment or adjustments after returning from deployment.

Serious games have been trialled as tools to protect well-being and in the rehabilitation of injured soldiers assisting in their treatment and care. For instance, *BraveMinds* is an immersive VR exposure therapy tool for returning veterans with post-traumatic stress disorder (PTSD). It simulates exposure to an improvised explosive device (IED) with a 360-degree headset and a haptic plate to give the feeling of an IED explosion. In addition, a smell kit is used to replicate the smell of fuel, burning plastic and body odour (Ungerleider, 2014). *BraveMinds* creates an environment with a high degree of reality; the simulated world is real but not too real. This leaves some room for the imagination of players. By populating the scene and allowing the veterans to add details from their own experiences, it is possible to identify areas where assistance may be needed (Ungerleider, 2014).

Another aspect of VR technologies has been trialled is in the treatment of anorexia, a disease linked to a disturbed body image in which patients wrongly believe they are overweight, even if they are below a healthy weight limit. To reduce body image disturbances in patients suffering from anorexia, a full body illusion (FBI) was created by stroking the user's actual body at the same time as the user watched their virtual body being stroked. The body contact was intended to create a sense of embodiment, that is ownership over a virtual avatar (although it can be argued that this was an unnecessary measure, as the first-person perspective obtained through VR itself may be sufficient to induce a sense of embodiment) (Keizer, van Elburg, Helms, & Dijkerman, 2016). Evaluation demonstrated that the experience resulted in a more accurate estimate of body size for more than two hours after the experiment.

Another interesting area for VR is the treatment of drug addiction. One of the hardest challenges for people suffering from addiction is accepting that the addiction is a problem. VR has been used to support recovering drug addicts[4] by measuring physiological responses to potential triggers placed in a VR scene. This approach is similar to exposure therapy, in which users learn to endure uncomfortable situations and identify what might trigger their cravings. Health professionals can then offer advice on how to deal with these feelings (Kuntze et al., 2001).

3.3.3 Skill Learning

The education and training of medical professionals is another common field for VR applications. In particular, surgical simulators have been adopted, for instance, for the training of laparoscopic surgeries. Laparoscopic surgery has become a relatively common surgical practice, because it is less invasive and therefore promises quicker recovery compared to traditional open surgery. Unfortunately, laparoscopic training involves a steep learning curve and can often lead to complications in surgery with newly qualified or trainee surgeons (Larsen et al., 2009).[5] In 2006, a study investigated whether trainee laparoscopic surgeons could achieve a basic proficiency in technical skills by training in VR prior to training in the operating theatre in order to reduce errors on patients (Aggarwal et al., 2006). The study assessed the performance of 20 trainee laparoscopic surgeons compared to the performance of 20 trained surgeons. Results indicated that the VR simulation could reduce the learning curve prior to training on real patients.

Another promising facet of VR-based training is addressed in professional sports, such as climbing. Climbing marries together both technical and puzzle-solving skills as well as pure physical strength. Often climbers will be faced with problems that seem impossible, until shown the correct technique by a peer or coach. A company called Uniform created a prototype for a VR training aid called *GRIP*, which is used in combination with electronic wristbands (Shorter & Amico, 2016). If a climber finds a particular route challenging, they can scan the bottom hold with their wrist band. They can then put the VR headset on to receive virtual coaching.

[4] https://news.vanderbilt.edu/2018/03/19/virtual-reality-world-offers-drug-addicts-low-risk-place-to-just-say-no/

[5] https://www.bmj.com/content/338/bmj.b1802.long

The virtual coaching is given by both Shauna Coxey (British Bouldering champion) and her coach Mark Glennie, who many climbers will look up to as inspirations. The coaches will talk them through the route and give them suggestions on how to achieve the climb. To add more motivation to this platform, Uniform has added an element of gamification: Once the user reaches the end of the route, they can swipe their wristband on the top hold and receive a reward.[6] This project presents an interesting combination of practical skills mixed with virtual reality learning.

A more serious note strikes with a VR training platform for people who were convicted as juveniles and served up to 20 years in prison (Taylor & Emma, 2017). The prospect of release can cause anxiety, as the world outside will be a very different place compared to the one at the time of their conviction. The training starts by showing inmates a series of VR experiences from the outside world using 360-degree videos, helping them to familiarise themselves with the technology and at the same time adjust to new experiences. Once familiar with the VR headset, they were asked to carry out mundane tasks expected of them after release that they never had to do in prison (e.g. doing laundry or grocery shopping when living alone). By completing this training, the aim was to leave inmates better prepared for everyday situations. In addition, participation also offered the chance for early release.

3.3.4 Artistic Experiences

As mentioned previously, VR can be a great platform for offering experiences that are otherwise costly or in some cases impossible. This can also be used to tell stories or enable users to achieve a sense of empathy. With the use of VR, users have been teleported to popular tourist destinations to relive historic events at a museum,[7] watch a film in a virtual cinema, visit a live music festival or even travel to Mars.[8]

Such experiences can also allow us to step into the world of people with unfamiliar or exceptional life stories. In 2017, *Unpacked VR*[9] was created. This was a supplement to an art exhibition that took place on international migrants' day. The aim of the exhibition was to humanise refugees by showing the destruction that war brought to the refugees' homes. To do

[6] http://tv.thebmc.co.uk/videos/grip-a-virtual-reality-training-aid-for-climbing/
[7] https://www.museumnext.com/2019/01/how-museums-are-using-virtual-reality/
[8] https://www.framestore.com/fieldtriptomars
[9] https://research.shu.ac.uk/centric/project/unpacked-vr/

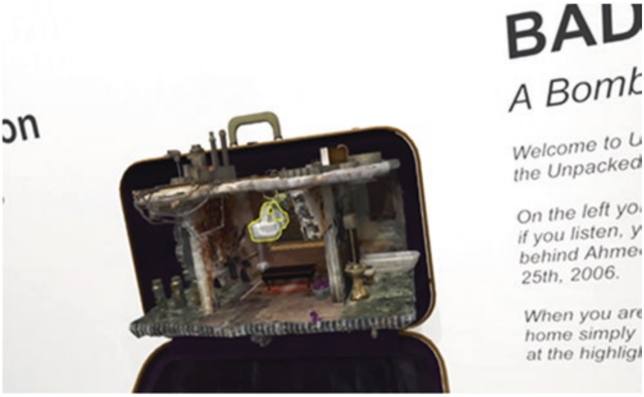

Fig. 3.6 Impression of Unpacked VR. (Picture credit: CENTRIC)

this, artist Mohamad Hafez and writer Ahmed Badr worked together to capture real stories of migrants' experiences. These stories were reconstructed in suitcases showcasing the homes that the refugees had left behind. One of these suitcases was turned into a VR environment to allow members of the public to be immersed in the exhibition (see Fig. 3.6). VR users were placed in the virtual exhibition, being teleported inside one of the artefacts. Recorded interviews with the migrants were played through the headphones, making the immersive environment even more impactful.

3.4 VR Development

3.4.1 General Principles

The development considerations and processes of VR applications are similar to the development of other game platforms such as detailed in Chap. 8. However, there are a few areas specific to VR which are worth drawing attention to (Tanriverdi & Jacob, 2001). These can be summarised in the following advice:

1. 3D models should be efficient. Whilst technology is advancing, high-resolution 3D models can still cause the system to slow down, which can increase the chance of cybersickness. Texture maps (normal, height, specular, etc.) can be used to give the illusion of a highly detailed model without increasing processing time.

2. How will users navigate in the environment? If using room-scale VR, the user will often only have a small area to move around, which will be a limiting factor in the development. If a controller is used to navigate through environments, precautions must be taken to limit possible effects of motion sickness; for example by slowing down the speed of movement.
3. What is the purpose of using VR instead of a standard desktop application? How can virtual reality enhance a user's experience and in which way? These are important questions before embarking on VR developments. For example, if the purpose is to produce a sense of awe, then the development should largely focus on the artistic outcomes more so than if the purpose is to educate.
4. Who is the target audience? If the audience has past experience with computer games or VR, then more advanced game mechanics can be included.
5. 3D sound is important and can add to the impression of immersion and presence which is crucial to VR.
6. Testing should be done with a wide variety of people from different backgrounds with different physical capabilities and differing levels of experience in terms of relevant technologies and computer games.
7. Always ensure that the product being developed is ethical and will not cause harm, especially to vulnerable people.

3.4.2 Basics VR Development Processes and Methodologies

Polcar, Gregor, Horejsi, and Kopecek (2016) developed a methodology for creating VR applications, which splits the development into six phases: assignment, analysis, creation, testing and implementation. This methodology is a useful general framework to guide VR design considerations.

1. The *assignment phase* involves collecting the requirements, aims and objectives for the VR application in addition to defining the target audience.
2. The *analysis phase* involves using the information gathered from phase one to formulate a plan of all objects involved in the creation of the VR game. If any objects are to perform actions, these actions will be defined in this phase. The objects can have varying states, which can be mapped out using a state diagram.

3. During the *creation phase* all assets will be created including the scripts, 3D assets and 3D animations.
4. The *testing phase* should run throughout the process, including the test of scripts, environments and interfaces to ensure that all elements work together and the desired look and feel is achieved.
5. In the *implementation phase* the product is tested with end users in the setting that the final application will use.
6. In the *operation phase* data is gathered from users to check for any necessary modifications.

3.4.3 Interactions Within Virtual Environments

The nature of VR lends itself to natural interaction methods, which reduces the risk of any ambiguity for the user. The replicating of real-world interactions makes interactions in VR simple and intuitive and helps users to adapt quickly to the interface. On the other hand, there are also risks involved in using natural interactions. For instance, user may miss feedback to show that they are interacting with the interface successfully. This means that users can be interacting with objects without being aware that they are doing so.

At times unusual gestures are needed for interactions, which are unfamiliar from real-world settings, for example to make physical alterations to a character or an object such as changing its colour or shape. There will be objects that in the real world a user would be able to interact with, whilst this functionality is unavailable in the game. In these cases, visual guidance is necessary to inform users which objects can be manipulated and which not. Otherwise users can easily become irritated. Also, most users will be accustomed to information displayed on screens in front of them. In the case of VR, it can take some time to adjust to the 360-degree field of view. Therefore, it can be important to encourage users through visual prompts, such as arrows, to guide their gaze to relevant content in other areas of the environment (Affordances, 2019).

One of the key advantages of VR is that there are few limitations to what can be simulated. This enables users to interact in new ways that are not feasible in the real world. Such experiences are referred to as 'magic interactions' (Jerald, 2015), as they can extend beyond the powers of real-world interactions. For example, in order to interact with an object in VR, the object does not necessarily have to be close to the user. Users can interact with the interface simply by looking at objects. However, if this is used too frequently or in a way that lacks context, it can distract and confuse the user and ruin the sense of immersion.

'Active interaction' denotes situations in which a user is aware of interacting with an object (e.g. during clicking or scrolling to interact with an interface). The opposite to this is 'passive interaction', which occurs when a user is less or un-conscious that they are interacting with an interface in VR (e.g. tracking head rotations and motions for movement through a virtual environment or crowds of people that move out of the way when the user approaches). If executed correctly, both type of interactions can add to the plausibility illusion and a sense of presence. For this reason, interactions should be subtle. If used incorrectly, especially passive interactions can frustrate the user and cause feelings of lacking control over the environment.

When designing an interaction interface, it is important to take affordances into consideration. *Affordance* is a term introduced by the psychologist James Gibson (Gibson, 1979) and refers to features of an object or element that enable users to determine possible interactions simply by looking at it. With regard to virtual environments, affordances determine whether interactions with objects work the way a user expects and, if not, whether these interactions could be improved. False affordances occur when users cannot determine the correct interaction from looking at the object.

In VR, it is sometimes difficult to avoid false affordances. This is partly because objects are available in the same way as in the physical world. For instance, when users see a surface in a virtual reality game, they would expect to be able to place objects on the surface. It causes confusion, if this is not the case. The proper design of visual elements in VR can help to avoid these false affordances (e.g. by removing handles from doors that cannot be interacted with). If interactions with objects are not intuitive, it is important to provide clear instructions in addition to either audio, haptic or visual feedback.

3.5 Challenges of Virtual Reality-Based Serious Games

3.5.1 Cybersickness

A common symptom of using VR is cybersickness, that is a feeling similar to motion sickness when using a VR environment. There are a number of theories as to why people may experience cybersickness. The three most important ones are shortly summarised below (cp. LaViola Jr, 2000):

1. *Sensory conflict theory* is the most widely accepted theory to explain cybersickness.[10] It occurs when the body is stationary, but a sense of self-motion remains. Normally, when subjected to motion, the brain receives vestibular information (i.e. information relating to balance and orientation). In VR, balance and orientation information is often missing. This lack of vestibular information can create conflicting messages in the brain, which can cause cybersickness.
2. *Poison theory* is an evolution-based theory that posits that physiological effects will occur when the body is trying to reject poison. In the case of cybersickness, the body misinterprets visual-vestibular information, which can trigger an emetic response.
3. *Postural instability theory* suggests that humans seek postural stability and that a significant change in the environment will lead to a loss of postural control. The theory states that the degree of motion sickness is proportional to the amount of postural instability (Warwick-Evans, Symons, Fitch, & Burrows, 1998). This is in reference to a lack of control over acceleration, meaning that postural control cannot be used to gain postural stability.

Artificially stimulating the vestibular system has been suggested as a way to combat cybersickness. This has been trialled using a motion platform (see Sect. 3.2.4) and by direct vestibular stimulation sending electrical signals to cranial nerves (LaViola Jr, 2000). Alternatively, certain design techniques can be used, for example, a tunnelling effect around the user's vision by dynamically reducing the field of view (Fernandes & Feiner, 2016). This is barely noticeable to the user but seems to reduce the effects of cybersickness. Another method is to create a static frame of reference that is constantly in the user's field of view, that is does not move with the user's head movements. Such a frame is sometimes referred to as an anchor.[11] Another option is to simply remove all locomotion movement in the environment and to replace it with teleportation. Cybersickness can further occur if there is a lag between the user's movements and the display. In order to avoid lag, the 3D environment should be as efficient as possible by using lower-fidelity models and adding more detail to the textures through the use of normal maps and specular maps.

[10] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8446269&tag=1
[11] https://vr.arvilab.com/blog/combating-vr-sickness-debunking-myths-and-learning-what-really-works

3.5.2 Ethics

Whilst virtual reality continues to gain momentum, the ethics around the use of VR are sometimes contested. There are several areas discussed in terms of ethical implications. Spiegel (2017) lists the following concerns developers should be aware of (Spiegel, 2017):

1. Cybersickness (see above)
2. Dissociation disorders
3. Self-neglect
4. Lost sense of reality ('blurred line')
5. Real-world object collisions
6. Manipulation/marketing

Earlier in this chapter we mentioned the benefits of VR for mental health. Yet, it is also possible that VR can pose a risk for mentally vulnerable users. A study published in 2014[12] reports that nearly half of UK adults interviewed believed they had symptoms of a diagnosable mental health condition at some point in their life. With this in mind it is vital to consider the implications of VR on users suffering from mental health conditions whilst developing virtual reality applications.

This is relevant as VR applications can have side effects. Some of them are related to issues of embodiment after exposure to VR. Embodiment is a sense of having ownership over a virtual body presented to the user in the virtual reality. Whilst this can be used to help mental health disorders such as body dysmorphia (see Sect. 3.3.2), there is a possible link between embodiment and dissociation disorders such as depersonalisation and derealisation (Aardema, O'Connor, Coˆte´, & Taillon, 2010). Derealisation refers to losing the sense of belonging to the real world and living in a dream world instead; in contrast, a user experiencing depersonalisation will feel detached from their own body and thoughts. They feel as if they are watching the world unfold around them like a movie and are simply observing their emotions but not feeling them first-hand.

Another negative consequence discussed is post-VR sadness (Searles, 2016). This term refers to a state in which users report feelings of sadness after removing the VR headset including a lack of motivation for real-

[12] https://digital.nhs.uk/data-and-information/publications/statistical/adult-psychiatric-morbidity-survey/adult-psychiatric-morbidity-survey-survey-of-mental-health-and-wellbeing-england-2014

world activities after being exposed to powers and experiences in the VR environment that are not possible in the real world. Whilst this is often a short-lived feeling immediately after removing a VR headset, the feeling can strengthen into a dissociation episode, which can continue for a longer period of time.

Whilst there has long been a concern about video games influencing users to engage in acts of violence and other criminal activities in reality, the higher sense of immersion in VR seems to bring this argument to the forefront once again, as here the line between the two realities becomes increasingly blurred. Also, the World Health Organization (WHO) recently classified gaming disorder as a registered illness (WHO, 2018), the illness occurs when users become addicted to playing video games and lose control over their gaming behaviour. This in turn can result in self-neglect, when players become so deeply distracted by the virtual environment that they forget to care for their physical self. This can cause issues with cardiovascular health, personal hygiene, over-exhaustion, starvation and dehydration.[13] Severe cases have resulted in deaths, often caused by over-exhaustion leading to cardiovascular issues.[14] The risk of addiction to VR gaming could increase due to the added sense of immersion and heightened feelings of escapism.

VR can further disorient users affecting players' balance. VR platforms can also cause trip hazards, for example due to objects in the play area or headset wires (although the increasing use of wireless technologies should reduce the latter risk). In the meantime, users should be made aware of such risks before participating in any VR activity. Whilst precautionary measures can prevent collisions with objects in the real world – such as a warning grids alerting the user when they are approaching the perimeter of the playing area – users must remain mindful of their surroundings including observers entering the playing area. Pregnant users may be advised not to enter VR environments due to the risk of falling.

There are further considerable concerns about the potential of (mis) using VR environments for targeted advertising and misinformation. Personal data used in targeted political and commercial advertising campaigns is often gathered without the users' knowledge. For instance, it has been claimed that infrared cameras with virtual reality could be used to

[13] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5700714/

[14] https://www.theguardian.com/technology/2015/aug/09/who-killed-the-video-gamers-simon-parkin-taiwan

gather personal data about people's lives or working environments alongside information about how they interact (e.g. exploiting capabilities to gather information on how long a gaze fixates on one specific area). This information could be used to target vulnerable people (Redmiles, 2018) or to impact decision-making.

3.6 Conclusion

Virtual reality has considerable potential to enhance serious games. Numerous applications exist that demonstrate how VR – either on its own or in combination with other approaches – can support areas from professional learning to support and recovery of personnel. VR is not without challenges, notably in terms of physical and psychological reactions as well as ethical considerations, but they can be managed by careful design and deployment. Overall, VR offers an effective and efficient approach to broaden the appeal and application of serious games.

References

Aardema, F., O'Connor, K., Coˆte´, S., & Taillon, A. (2010). Virtual reality induces dissociation and lowers sense of presence in objective reality. *Cyberpsychology, Behavior and Social Networking, 13*, 429.

Affordances. https://www.coursera.org/lecture/3d-interaction-design-virtual-reality/affordances-yNvcu. Accessed 14 Jun 2019.

Aggarwal, R., Grantcharov, T. P., Eriksen, J. R., Blirup, D., Kristiansen, V. B., Funch-Jensen, P., et al. (2006). An evidence-based virtual reality training program for novice laparoscopic surgeons. *Annals of Surgery, 244*(2), 310. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1602164/

Blach, R. (2008). Virtual reality technology - an overview. In *Product engineering* (pp. 21–64). Dordrecht, Netherlands: Springer Netherlands. https://doi.org/10.1007/978-1-4020-8200-9_2

Earnshaw, R. A. (2014). *Virtual reality systems*. London: Academic press.

Fernandes, A. S., & Feiner, S. K. (2016). *Combating VR sickness through subtle dynamic field-of-view modification*. IEEE Symposium on 3D User Interfaces. pp. 201–210.

Gibson, J. J. (1979). *The theory of affordances the ecological approach to visual perception* (pp. 127–143). Boston: Houghton Mifflin.

Grantcharov, T. P., Kristiansen, V. B., Bendix, J., Bardram, L., Rosenberg, J., & Funch-Jensen, P. (2004). Randomized clinical trial of virtual reality simulation for laparoscopic skills training. *British Journal of Surgery, 91*(2), 146–150.

Henderson, A., Korner-Bitensky, N., & Levin, M. (2007). Virtual reality in stroke rehabilitation: A systematic review of its effectiveness for upper limb motor recovery. *Topics in Stroke Rehabilitation, 14*(2), 52–61.

Hoffman, H. G. (2004). Virtual-reality therapy. *Scientific American-American Edition, 291*, 58–65.

Jerald, J. (2015). *The VR book: Human-centered design for virtual reality.* San Rafael: Morgan & Claypool.

Kandalaft, M. R., Didehbani, N., Krawczyk, D. C., Allen, T. T., & Chapman, S. B. (2013). Virtual reality social cognition training for young adults with high-functioning autism. *Journal of Autism and Developmental Disorders, 43*(1), 34–44.

Keizer, A., van Elburg, A., Helms, R., & Dijkerman, H. C. (2016). A virtual reality full body illusion improves body image disturbance in anorexia nervosa. *PLoS One, 11*(10), e0163921. https://doi.org/10.1371/journal.pone.0163921

Kuntze, M. F., Stoermer, R., Mager, R., Roessler, A., Mueller-Spahn, F., & Bullinger, A. H. (2001). Immersive virtual environments in cue exposure. *Cyberpsychology & Behavior, 4*(4), 497–501. https://www.lakeviewhealth.com/resources/blog/virtual-reality-addiction-treatment/

LaViola Jr., J. J. (2000). A discussion of cybersickness in virtual environments. *ACM SIGCHI Bulletin, 32*(1), 47–56.

Larsen, C. R., Soerensen, J. L., Grantcharov, T. P., Dalsgaard, T., Schouenborg, L. Ottosen, C., Schroeder, T. V., Ottesen, B. S., (2009) Effect of virtual reality training on laparoscopic surgery: randomised controlled trial. BMJ 338 (may14 2):b1802-b1802

Le May, S., Paquin, D., Fortin, J., & Khadra, C. (2016). *DREAM project: Using virtual reality to decrease pain and anxiety of children with burns during treatments.* Paper presented at the Proceedings of the 2016 Virtual Reality International Conference, 24.

Li, A., Montaño, Z., Chen, V. J., & Gold, J. I. (2011). Virtual reality and pain management: Current trends and future directions. *Pain Management, 1*(2), 147–157.

Morris, L. D., Louw, Q. A., & Grimmer-Somers, K. (2009). The effectiveness of virtual reality on reducing pain and anxiety in burn injury patients: A systematic review. *The Clinical Journal of Pain, 25*(9), 815–826.

Mosadeghi, S., Reid, M. W., Martinez, B., Rosen, B. T., & Spiegel, B. M. R. (2016). Feasibility of an immersive virtual reality intervention for hospitalized patients: An observational cohort study. *JMIR Mental Health, 3*(2), e28.

Optale, G., Urgesi, C., Busato, V., Marin, S., Piron, L., Priftis, K., et al. (2010). Controlling memory impairment in elderly adults using virtual reality memory training: A randomized controlled pilot study. *Neurorehabilitation and Neural Repair, 24*(4), 348–357.

Perpiñá, C., Botella, C., & Baños, R. M. (2003). Virtual reality in eating disorders. *European Eating Disorders Review: The Professional Journal of the Eating Disorders Association, 11*(3), 261–278.

Polcar, J., Gregor, M., Horejsi, P., & Kopecek, P. (2016). *Methodology for designing virtual reality applications*. Paper presented at the Proceedings of the 26th DAAAM international symposium, 768.

Redmiles, E. (2018). Think Facebook can manipulate you? Look out for virtual reality. Retrieved from http://theconversation.com/think-facebook-can-manipulate-you-look-out-for-virtual-reality-93118

Searles, R. (2016). *Virtual reality can leave you with an existential hangover*. https://www.theatlantic.com/technology/archive/2016/12/post-vr-sadness/511232/. Last Accessed 17/06/2019

Shorter, M., & Amico, L. (2016). Grip: an internet-enabled virtual coaching experience https://uniform.net/thinking/grip-an-internet-enabled-virtual-coaching-experience

Spiegel, J. S. (2017). The ethics of virtual reality technology: Social hazards and public policy recommendations. *Science and Engineering Ethics, 24*(5), 1537–1550. https://doi.org/10.1007/s11948-017-9979-y

Tanriverdi, V., & Jacob, R. (2001, Nov 15). Vrid. Paper presented at the 175–182. https://doi.org/10.1145/505008.505042. Retrieved from http://dl.acm.org/citation.cfm?id=505042

Taylor, D., & Emma, F. (2017). This prison is using VR to teach inmates how to live on the outside. Retrieved from https://news.vice.com/en_us/article/bjym3w/this-prison-is-using-vr-to-teach-inmates-how-to-live-on-the-outside

Ungerleider, N. (2014). Virtual reality for vets with PTSD recreates the smells, sounds, and feelings of an IED. Retrieved from https://www.fastcompany.com/3031510/virutal-reality-for-vets-with-ptsd-recreates-the-smells-sounds-and-feelings-of-an-ied

Warwick-Evans, L. A., Symons, N., Fitch, T., & Burrows, L. (1998). Evaluating sensory conflict and postural instability. Theories of motion sickness. *Brain Research Bulletin, 47*, 465.

WHO| gaming disorder. (2018). Retrieved from http://www.who.int/features/qa/gaming-disorder/en/