CHAPTER

7

Clinical applications of virtual reality in patient-centered care

Swati Pandita, Andrea Stevenson Won

Department of Communication, Cornell University, Ithaca, NY, United States

Introduction

Research on the clinical applications of virtual reality (VR) has rapidly progressed in the past 20 years. While potential applications range from medical education to surgical visualization, this chapter will focus predominantly on patient-centered care, including the diagnosis and treatment of health conditions. The most common applications of patient-centered VR include mental and physical therapeutic interventions, pain management, and neuropsychological diagnostic and assessment tools (Sutherland et al., 2018). This review is intended to help evaluate VR for the treatment of particular modalities, as well as to manage expectations of what VR can do now and may be able to do in the future. The chapter will begin with a broad definition of VR and its technological requirements, followed by a discussion of current VR interventions. The chapter will conclude with considerations for designing VR patient-centered care interventions and speculation on future applications.

Understanding virtual reality

Defining virtual reality

At its most basic level, VR is an interactive computer-generated experience that users react to as if it were a real, physical, environment. The human brain actively models the world using sensory information. By replacing auditory, visual, and even tactile and olfactory stimuli from the physical world with digital input, researchers can control the representations, or percepts, provided to the brain, creating a "virtual reality."

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In the physical world, our eyes see different content as we move through the environment. Virtual environments (VEs) mimic this real-world property through real-time rendering, where images are constantly created, updated, and displayed as a response to users' tracked movement through virtual spaces. Real-time rendering, thus, gives users the illusion of being completely surrounded by a visual world.

While VEs frequently focus on representing visual aspects of the environment, they may also include sound, possibly spatialized sound, and sometimes limited haptic or touch feedback, for example, by vibration of the hand controllers or other specialized devices. Rarely, smell may be included.

In any VR experience, the orientation of a user's head must be tracked in order to render the appropriate content. In setups with positional tracking, users can also change their position in the virtual space, by moving horizontally or vertically in the X, Y, and Z axes (e.g., they can walk around rather than just swiveling their head). Sensors also track the movement of hand controllers and any other additional trackable devices (such as the HTC Vive's "puck" that can be attached to any body joint or object, see Fig. 7.1). Popular consumer systems such as the HTC Vive (Vive, 2016) or the Oculus Rift (Oculus, 2018) have 6° of freedom on both head and hands, which include orientation, or rotational tracking, and positional tracking. Thus, a user can interact with a VE by moving around

FIGURE 7.1 An example of a tracker, which can be attached to any object. This image shows HTC Vive's "puck," which can be attached to any body joint or object. *Photos taken and edited by author Swati Pandita.*

the room and potentially moving virtual objects using the hand controllers. Tracked movement is not only helpful for rendering VEs and allowing for interaction but also provides a stream of data, which can be used in conjunction with other data sets, such as self-report, to analyze behavior.

Types of virtual reality setups

VR experiences are supported by a variety of platforms. In its simplest form, mobile VR combines a smartphone with a headset such as Google Cardboard or Gear VR. In these cases, the phone presents content on a split screen to display a VE in which the user can rotate his or her head to look around. The phone's accelerometer tracks head orientation, and virtual content is then updated on the screens in front of the user's eyes. Similar to the Gear VR, but without the need of a smartphone driven computer, the Oculus Go is a standalone headset that serves as an in-between mobile and tethered headsets (Fig. 7.2).

More complex setups can include head-mounted displays (HMDs) with positional tracking and hand controllers, such as consumer systems like the Oculus Rift or Quest, or the HTC Vive. In HMD-based VR, the environment is displayed within the headset, and the view of the physical world is completely obscured. In networked VEs, multiple users can interact within the VE, as long as they each have a headset and the ability to have their movements tracked. In the past 5 years, these types of setups have become widely available on the consumer market, and their portability, ease of use, and low price point mean that their use is rapidly expanding.

Larger institutions may also have setups in which images are projected on three to six walls in a room. These immersive VEs are sometimes referred to as CAVEs (Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992) In such environments, the user may wear stereoscopic glasses to give the

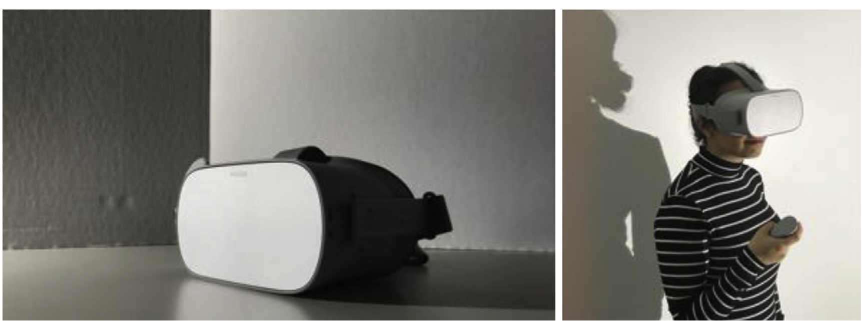

FIGURE 7.2 The Oculus Go pictured here is an example of a head-mounted display (HMD), that is untethered (not attached to a computer) and also does not rely on a phone. *Photos taken and edited by author Swati Pandita.*

content a 3D appearance, and the correct perspective and stereo projections of the environment are displayed as a function of the user's movement and interactions within the VE. These environments lend themselves well to collaborative work. In such cases, only one user is tracked, but their interactions and the content can be seen by their teammates, who are also in the room. Participants can see one another's actual bodies and respond to each other's gestures. These environments require a permanent, dedicated space installation and are generally expensive.

Creating content in virtual reality

There are two primary methods of creating content to be viewed using an HMD. The first is to create a spherical or 360-degree video. Such videos capture the real-world photo realistically, in such a way that the video creates a "sphere" around the user so that content updates as the user moves his or her head. While such content may be filmed to be stereoscopic, this kind of content only supports orientation—users cannot change their position by moving forward or back in the VE. Viewers also cannot interact with content, as the video is recorded.

In contrast, game engines like Unity or Unreal allow the creation of a virtual world with digital objects that users can interact with. Such environments have video game quality graphics with varying degrees of realism. 3D objects help create an interactive scene for users and are made using 3D modeling programs like Autodesk Maya, 3DS Max, and Blender. Avatars (virtual representations of humans) can also be created using specific software such as Adobe Fuse, Daz3D Studio, or FaceGen.

Often, users can be embodied in these virtual spaces, by controlling an avatar, which responds to their movements in the real world. For example, if a person wearing an HMD and holding a hand tracker holds his or her hand in front of their eyes, they will see their avatar's hand on the screens of their HMD. The illusion of control and realistic interaction of a VE play into the feeling of psychological realness. Having a virtual body can allow a user to feel a greater sense of presence or "being there" within the VE (Heeter, 1992).

VR is not only capable of changing a user's environment but also the way they are embodied. It can change a user's appearance by modifying the appearance of the avatar they control. VR can also change the user's perspective. In VR, users can embody either a first-person perspective, in which a VE is rendered from the avatar's viewpoint (as in the physical world, where only the hands and the front of the torso are visible without the use of a mirror). However, users can also see their virtual body and the actions that are performing from a third person perspective, an out-of-body experience that is not possible in real life.

Patient-centered care

Patient-centered care applications of VR primarily involve diagnostics and assessment and therapeutic uses. VR has been used to diagnose attention deficit hyperactivity disorder (ADHD), Parkinson's disease (PD), Alzheimer's disease (AD), and paranoia. In the case of therapy, VR has been employed in a variety of contexts, including anxiety disorders, body dysmorphia, pain management, and physical therapy.

Diagnostic uses of VR and technological considerations

Diagnosing ADHD with VR: Because of its ability to both manipulate stimuli and track patients' reactions, VR has great potential as a diagnostic tool. An example of this is with ADHD patients. Traditional assessments of neuropsychological function include clinical interviews, psychometrically sound behavior rating scales, and continuous performance tests (CPT). Out of the three, CPTs are the standard and test executive function (issues of goal directed behavior: impulsivity, hyperactivity, and attention in ADHD) most directly by requiring participants to maintain attention and react to specific stimuli in the face of various distractors (Areces, Rodríguez, García, Cueli, & González-Castro, 2018).

CPT often assesses cognitive impairment in traditional laboratory settings that cannot fully emulate the natural conditions in which ADHD symptomology arises. For individuals with ADHD, a more naturalistic setting might be sitting in a classroom with various visual and auditory distractions while being asked to complete a given task. VR can simulate these classroom settings by presenting multiple stimuli, recording response times to assessment tasks, and tracking the amount of movement per given task (Rizzo et al., 2000). Studies using such VR simulations found that children suffering from ADHD were more likely to show signs of restlessness, movement of their head, nondominant arm, and opposite leg. Therefore, VR can readily simulate naturalistic settings in which symptomology may arise and decrease chances of type II error or lack of diagnosis.

Assessing AD and PD with VR: Just as movement data are used to diagnosis individuals with ADHD, the same can be done for identifying individuals with neurodegenerative disorders such as AD and PD. AD is the most common neurodegenerative disorder (Alzheimer's Association, 2015), primarily affecting one's memory and blunting overall cognition. Physical symptoms include impaired executive functioning seen through slowness, rigidity, and tremors (Alzheimer's Association, 2015). In contrast, PD primarily affects one's ability to engage in planned motor action such as walking, writing, grasping, or holding objects.

Early stages of AD and PD can be detected through deficits in visuospatial abilities (Binetti et al., 1996; Levin, Llabre, & Weiner, 1989). Serino, Morganti, Di Stefano, and Riva (2015) created a VR assessment tool that measured differences in spatial encoding, storing, and syncing and found that individuals who suffer from AD have trouble with storing and synching allocentric object views as compared with healthy individuals. Although PD is primarily characterized as a motor disorder, researchers have started to study the role of vision in movement disorders (Davidsdottir, Wagenaar, Young, & Cronin-Golomb, 2008). With this shift in perspective, VR has been particularly helpful in classifying PD subtypes, which are differentiated by side of hemispheric damage onset (Davidsdottir et al., 2008). The characterization of AD and PD symptoms as abnormal changes in spatial bias makes VR an even better fit for assessing PD as it plays to its strength of being a flexible and responsive visual medium. A later section of this chapter will discuss how VR has been used as a *treatment* modality for PD.

Assessing paranoia with VR: Paranoia occurs when an individual falsely believes that others intend to harm him/her. Severe forms of paranoia, such as persecutory delusions, are seen in psychotic disorders like schizophrenia. Paranoia can also occur as a result of a traumatic event, such as physical assault. Paranoia can arise from misinterpreting social cues such as everyday facial expressions.

However, due to the subjective nature of the experience, there is no standardized assessment for paranoia. In order to create an assessment, Freeman et al. (2014) ran participants through a 4-minute VR train ride populated by computer agents (humanoid avatars controlled by the computer) with neutral expressions that could facilitate paranoia. In this study, all computer agents were programmed to have naturalistic gaze, but some were programmed to respond to the participant's gaze by looking in their direction. The study was interested in predicting the frequency of paranoid thought up to 6 months after the VR intervention. Participants were individuals who had suffered from physical assault a month prior and thereby susceptible to paranoid thought. Upon completing the virtual experience, participants answered surveys that measured paranoid thought and PTSD symptoms, which were used as predictors for the recurrence of a paranoid event. Thus, the VE served as an assessment method for the severity of paranoia and PTSD symptoms.

Technological considerations for diagnostic uses: There are several aspects of VR that make it an ecologically valid tool for neuropsychological assessment. HMDs can improve a user's attentional focus on their assessment task by occluding distracting stimuli from the physical world (e.g., movement and noise). Attention assessments may be more reliably measured in VR due to more consistent stimulus presentation and more reliable scoring. Tracked movement can detect behaviors that may not be easily perceptible to the human eye, which, in turn, can improve neuropsychological assessment.

For effective use, VEs for diagnostic use must be easy to use, avoiding complex controls (e.g., use of multiple buttons). Nonverbal behavior such as eye gaze and body movement must be tracked in order to assess behaviors associated with disorders. Similarly, since VEs are often used in conjunction with other assessment apparatus (e.g., a treadmill for PD), it is important that the headset is compatible with other gear. It may also be important that headsets and sensors are wireless if connections might compromise patient safety by restricting movement.

Treating anxiety disorders and phobias with VR and technological considerations

Generalized anxiety disorder (GAD) is characterized by consistent and excessive daily worrying for a period of 6 months or greater. Experiencing constant anxiety can impair one's ability to take care of their personal health, social interactions, work, and everyday activities. Individuals suffering from anxiety typically feel restless, easily fatigued, and irritable (NIMH, 2018). Phobias share a similar etiology to anxiety disorders; however, phobias are specific to an object or situation. Treatment for GAD and phobias typically includes psychotherapy or talk therapy, cognitive behavioral therapy (CBT), exposure therapy, and pharmacological interventions in the form of antidepressants or antianxiety medication.

VR can induce powerful perceptual cues that can recreate an anxiety-inducing moment. These cues can recreate an anxiety-inducing moment that a patient can relive through and reappraise with a therapist. The reality of the experience is shown through patient reports of anxiety symptoms such as "sweating, the butterflies, and weakness" while in the virtual worlds, which serve as evidence to the "realness" and immersion of the experience (Anderson, Rothbaum, & Hodges, 2003). By allowing individuals to interact with the fear memory, in conjunction with traditional CBT techniques such as extinction and habituation, the fear structure is slowly modified to a less aversive memory.

The treatment of phobias requires an extensive recreation of the environment in which graded versions of the phobia exist, making VR the perfect platform for administering CBTs. The most well-known forms of VR CBTs are exposure therapies (Powers & Emmelkamp, 2008). A nonexhaustive list of VR therapies includes some designed for flight anxiety (Rus-Calafell, Gutiérrez-Maldonado, Botella, & Baños, 2013), arachnophobia (Bouchard, Côté, St-Jacques, Robillard, & Renaud, 2006; Hoffman, Garcia-Palacios, Carlin, Furness, & Botella-Arbona, 2003; Shiban et al., 2016), claustrophobia (Botella, Baños, Villa, Perpiñá, & García-Palacios, 2000; Malbos, Mestre, Note, & Gellato, 2008), acrophobia or fear of heights (Emmelkamp et al., 2002; Rothbaum et al., 1995), and kinesiophobia of the back and neck (Bolte, de Lussanet, & Lappe, 2014; Chen et al., 2014).

A high level of stimulus control in virtual experiences is also advantageous. For example, in VEs designed to address the fear of public speaking, therapists can control the audience's reactions such as how interested, bored, or neutral they look and whether or not they applaud upon speech completion (Anderson, Zimand, Hodges, & Rothbaum, 2005).

VR is also a treatment medium that is capable of recreating once in a lifetime events (e.g., 9/11, Vietnam War) that patients can relive and reappraise with the help of a therapist. Experience recreation in VR is often utilized in the treatment of posttraumatic stress disorder or PTSD (Difede et al., 2007; Rizzo, Reger, Gahm, Difede, & Rothbaum, 2009; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001).

Before a VR intervention, patient's needs are discussed and evaluated by the therapist in a series of imaginal therapy (describing the fear-inducing situation) and reflective questions. These fear-inducing scenarios can then be typically recreated in a VE. Scenarios are graded from least to most fear inducing, where patients begin with the former situation and gradually work their way to the next scenario until their anxiety has decreased. In VE, the therapist can communicate with the patient via microphone, helping guide the patient throughout the exposure session (Anderson et al., 2003).

While each phobia is unique in its magnitude and fear-inducing stimuli, certain considerations need to be taken into account when designing VEs for phobia treatment: (1) Therapists need control of the scene, ranging from what a patient sees, feels (tactile), and hears, in the environment to modify the magnitude of the fearful stimulus. (2) Patients will ideally be embodied in an avatar to induce a sense of presence and realness within the VE. However, early therapies did not include an avatar body and were still successful in treating phobias (Difede & Hoffman, 2002), possibly due to patient's limited experiences and expectations of VR at the time (e.g., not expecting an avatar body). (3) Patients need agency or the ability to leave the scene whenever it becomes too frightening or overwhelming. This allows a patient to feel safe and more receptive toward starting or continuing treatment. (4) Therapists need a way to communicate with patients while they are in VR in order to guide them through appraising fearful situations in a less harmful way. (5) The VE should allow patients to change between perspectives (first to third) in order to get an alternative interpretation of the situation.

Body rescripting for body dysmorphia and technological considerations

The concept of negative body image, or high levels of dissatisfaction with one's body, is prevalent in body image disorders. Perceived body image can affect the likelihood of an individual engaging with and adhering to health-related behaviors (Manzoni et al., 2016). Individuals with negative body image are thought to be less adherent to weight maintenance treatments and efforts (Riva, 2011). The use of positively appraised virtual avatars for individuals with high body image dissatisfaction can decrease social physique anxiety and improve exergame experience (Song, Kim, & Lee 2014). Thus, some researchers think individuals with body dysmorphia perseverate or are stuck on a negative body image.

The allocentric lock theory posits that individuals are locked into an allocentric (third person view) of their past self, such as a negative memory of body image, which is no longer updated with egocentric (first person) sensory input of strenuous diet changes and change in body shape. If initial feelings of body dissatisfaction are not updated, people may give up on their weight maintenance efforts or try extreme diets that can lead to worse outcomes such as disordered (binge) eating. VR CBT in conjunction with a standard behavioral inpatient program, which provides individuals with weight maintenance guidelines, a low-calorie diet, and physical training, was used to update the allocentric memory or stored objective representation of oneself, in individuals seeking treatment for morbid obesity over a 6-week period (Manzoni et al., 2016). Upon 1 year of completing the VR CBT therapy and inpatient program, individuals in VR CBT as compared to traditional CBT maintained their weight loss (Manzoni et al., 2016). Thus, individuals were able to improve their level of body dissatisfaction through body rescripting and changing from allocentric and egocentric views of the self by using VR CBT (Riva, 2011).

Clinicians need to provide patients with various scenarios in which they would engage in behavior affected by their body dissatisfaction. The treatment should take place in a setting where the patient feels safe, and the patient should be able to leave the VE at her/his own discretion. VEs for body rescripting must include the ability to switch between allocentric and egocentric perspectives of the body (allow the patient to see themselves from the first and third person). Similarly to exposure therapies, the therapist must be able to talk to the patient while they are in the VE. Communication in VE is imperative to guiding patients through reappraisal of previously negative situations through body rescripting.

Lastly, custom avatars should be given careful consideration. Patients are more likely to identify with avatars that share physical similarity with them, such as age and race (Fox, 2012). The ability to identify with an avatar can increase a patient's level of presence within a VE, thereby affecting therapeutic VR outcomes. Avatars can also accurately portray a patient's health condition, which can further increase avatar adoption and presence. In light of individuals suffering from body dysmorphia, who are already hyperaware of their own bodies and may be hypercritical of bodies that are assigned to them, researchers should carefully consider avatar design and how it may affect a patient's avatar adoption, subsequent presence levels, and treatment outcomes.

Depression and technological considerations

Individuals with depression often engage in overly self-critical behavior that can maintain a negative mood state. Clinical researchers are addressing this behavior through self-compassion eliciting VEs, which encourage patients to engage in perspective taking (Falconer et al, 2014, 2016). Falconer et al. (2016) created an 8-minute scenario in which 15 patients practiced delivering compassion to a child. Their movements and speech were recorded, and then they were switched to experience receiving compassion as a child themselves. Their previously recorded compassionate response was then played to them, as a child, so they could see their own comforting words and gestures. The intervention proved successful, in that three repetitions of the scenario led to reductions in depression severity and self-criticism. The authors also found a significant increase in self-compassion after a 4-week follow-up, with four patients showing significant clinical improvement.

Self-compassion therapy in VR hinges on the ability to track, record, and rerender movement. The ability to track movement data in VR is important for instilling a sense of presence in the virtual world and connection with the virtual body, but most importantly, it allows for the ability to record virtual experiences and replay them back to an individual from the perspective of another virtual body. This also leads to the ability to easily switch virtual bodies in order to experience multiple perspectives. Other requirements, previously discussed, include ensuringthat the patient feels safe in the VE, can leave the environment at their discretion, and that the environment is easy to use. Lastly, depressed individuals have difficulty in actively seeking treatment, thus when designing interventions, one must consider the portability of the VR intervention and ease of access. With the increased interest of serious games and accessibility of consumer-grade VR technology, mental health in VR is soon becoming a greater possibility.

Pain management and technological considerations

Pain is an adaptive sensation that helps us avoid damage to ourselves and promote one's health and safety (Melzack & Katz, 2014; Scholz & Woolf, 2002; Woolf, 2010). Thus, people naturally attend to pain as it signals that there is something wrong, requiring immediate attention. However, pain management is necessary for the successful outcome of medical procedures and adherence to treatment.

Pain management varies by pain type, which is classified by several factors: (1) its chronicity, or the length of time one endures pain for, (2) its frequency, or how often it occurs, and (3) cause for onset. Acute pain is classified as pain that lasts no more than 6 months, with less frequency, and has a known cause for onset. Conversely, chronic pain lasts for more than 6 months, occurs more frequently, and the direct cause for onset is often unknown. VR works as a noninvasive and nonpharmacological treatment for acute pain (Li, Montaño, Chen, & Gold, 2011).

Many VR pain management interventions work on the underlying assumption that our attentional capacity for any perceptual event is limited. Therefore, distraction, or reorienting attention away from pain sensation during painful medical treatments such as wound care, dental pain (Hoffman et al., 2001), and IV placement (Gold, Kim, Kant, Joseph, & Rizzo, 2006), is key to pain management with VR. Various VR environments have been designed to distract individuals from burn wound pain (Hoffman et al., 2000, 2008), phantom limb pain (Murray et al., 2007), cold pressor pain (Dahlquist et al., 2008), dental pain (Hoffman et al., 2001), cystoscopy (Walker et al., 2014), and palliative care for terminal cancer patients (Niki et al., 2019). An early example of a distraction task was Snow World, where patients aimed snowballs at snowmen in a fantastical winter environment (Hoffman, 2004). At its best, VR interventions can lessen perceived pain intensity during treatment and reduce treatment times as compared to standard distractions provided by TV, stories, music, and caregivers (Gold, Belmont, & Thomas, 2007).

Acute pain treatment often occurs in a hospital setting, thus equipment must be easy to clean, or sterilize, transport, and set up. Due to pain's attention-orienting abilities, VEs must be attentionally engaging. Like any other treatment, medical professionals need to see what the patient is viewing in their headset to ensure that the experience is working properly. The tasks in the environment must be easy to understand and be hands-free or require limited mobility (interactivity) in the event of medical procedures (e.g., reduced movement or flinching while cleaning deep wounds is preferred). The equipment must also be able to withstand specialized environments, such as hydrotanks in the case of burn wound pain (Hoffman et al., 2004; 2008).

Pain management and rehabilitation in chronic pain and physical therapy and technological considerations

VR and chronic pain management: While there is considerable evidence to suggest VR's effectiveness as a pain distractor in acute pain management, less is known about VR and chronic pain management. VR interventions in this domain have included studies on chronic neck pain (Harvie et al., 2015; Sarig-Bahat et al., 2015), back pain (Bolte et al., 2014), walking-related pain (Gromala et al., 2011), complex regional pain syndrome (Sato et al., 2010), and phantom limb pain (Chan et al., 2007).

Chronic regional pain syndrome (CRPS) and phantom limb pain typically occur after a physically traumatic event, such as stroke or an amputation. In these conditions, the traumatic event is thought to trigger maladaptive cortical rewiring, which leads to chronic pain patients reporting heightened pain sensitivity and lowered pain tolerance. One popular form of therapy, known as mirror visual feedback (MVF) therapy, aims to modify this maladaptive wiring through providing visual feedback of the injured limb moving naturally (Ramachandran & Altschuler, 2009; Ramachandran & Rogers-Ramachandran, 1996). In traditional MVF, patients view a mirrored image of their intact limb positioned to appear in the same place as their affected limb, while their injured limb is kept out of sight. Moving the intact limb thus gives the appearance of two healthy limbs (Mercier & Sirigu, 2009). Multiple MVF sessions in conjunction with routine physical therapy may relieve pain.

Like traditional MVF, nonimmersive VRMVF works by a similar principle, with the use of a virtual mirror and sensor tracking instead of a physical mirror. Some early studies in phantom limb pain and CRPS mirrored movement from the intact to injured sides (Chan et al., 2007; Yavuzer et al., 2008). A well-cited study by Sato et al. (2010) illustrated one complex setup: the researchers tracked movement in both limbs (e.g., hands) by different devices. The intact hand was precisely measured through a data glove that tracked finer gestures such as grasping an object. In addition, a sensor was attached to the forearm, above the affected hand, and this sensor tracked global movement, such as moving an arm up and down. The hand on the computer screen moved along with the patient's hand and arm movement. Thus, the hand's position was controlled by the affected side, whereas the ability to grasp an object was controlled by the intact (glove wearing) side. Similar treatments with different configurations of hardware have been used to treat individuals with idiopathic facial pain (Won & Collins, 2012) and phantom limb pain (Fukumori, Gofuku, Isatake, & Sato, 2014).

PD: Patients suffering from PD can also benefit from VR rehabilitation environments that improve coordinated movement. PD patients typically present with gait disturbances, which make them more prone to swaying and falling. Complex gait tasks, which involve multiple and simultaneously coordinated movements, such as walking and talking, are particularly difficult for PD patients. A common treatment for gait instability is treadmill training (TT), but this does little to help with complex gait disturbances. Mirelman et al. (2011) created a PD treatment to help improve both cognitive and motor skills in PD patients by combining TT with multistimuli decision-making tasks in VR, known as obstacle negotiation. The VE demanded participant's attention, calling for multiple object tracking and heightened perceptual processing in order to avoid obstacles while walking in VR. Upon 6 weeks of completing the intervention, patients not only improved in walking speed but also stride length in the dual task conditions.

Physical therapy: Strokes are a major cause of motor impairment, affecting one's ability to conduct everyday activities. After a serious stroke episode, sufferers can report paresis, or loss of limb control and movement (Pollock, Baer, Pomeroy, & Langhorne, 2007), along with difficulty in thinking and sensing. This can lead to underutilization of the affected limb, which results in overuse, increasing wear and tear, of the intact limb (Pollock et al., 2007). Typical interventions for stroke patients include repetitive muscle movement, which can be boring, decreasing patient motivation and adherence to prescribed rehabilitation treatments. Virtual games provide a solution to this problem, motivating patients to move for the purposes of fun and engagement. Similar to the aforementioned posture training in PD patients, VR interventions can also improve "dynamic balance" (postural stability) in stroke patients (Cho, Lee, & Song, 2012), who suffer from postural imbalances and uneven weight distribution and also have to engage in repetitive muscle movement training to improve postural stability.

Technological considerations: Treatment should be cheap, ideally portable, and easy to use for the long term. Portability and ease of use are essential for supporting treatment adherence, allowing for continuity of care at home. Patients may not need to be embodied in a full body avatar, but their affected body part should at least be present in the VE. A sense of presence should be established through synchronous limb movement in real time, and the task may require the use of both the affected and intact limb to be tracked.

Many of these therapies require extensive patient movement and detailed sensory feedback on these movements. In such therapies, movement tracking to follow patient progress can be particularly useful. While VR may allow for more engaging tasks (Won et al., 2017), equipment may be heavy or get sweaty. If participants are moving around the VE, they must be protected from accidently falling and injuring themselves or others. Thus, the actual hardware used must be assessed for compatibility with the patient, and guardian systems of some kinds are necessary.

General considerations and accessibility

Decisions about what needs to be represented in the VE to achieve specific clinical goals are imperative to a successful (virtual) experience. Designers must also decide what type of sensory stimuli is needed for a given level of interactivity and responsivity in an environment. For example, is it necessary to incorporate spatialized sound? Do users require the ability to pick up or otherwise interact with objects and do they need haptic feedback when they do so?

While designers must make decisions about how to represent objects in the environment, they must also decide how to represent individual users. Questions about representation include, but are not limited to, how a person views their self in a VE. Do they have an avatar body? If so, does the appearance of the avatar indicate gender, race, or ethnicity? In addition to self-avatars, the appearance and capabilities of other social actors, whether these are avatars controlled by other, real people, or agents controlled by the computer, should be considered if they are to be included in the experience.

Treatments occurring in VR are often time consuming. VR interventions may require many appointments because individuals are not advised to be in VEs for extended periods due to reports of dizziness, disorientation, or motion sickness. While immersed, a user might lose spatial awareness of the room, which can cause the user to bump into objects, putting the patient at risk for injury. Thus, participants in a clinical setting must be protected from their environment to an extent, and participants in a home setting will need to have safeguards in place to prevent injury.

Researchers and clinicians must be considerate of those who are at an increased risk of in VR. Examples of such cases include those with epilepsy or seizure disorders or people who have recently undergone concussions. Other groups that can undergo deleterious VR experiences are elderly adults, who suffer vision impairment as lens flexibility and visual acuity slowly decrease as we age. VR experiences can induce greater amounts of eyestrain in individuals, which is a problem for both individuals with normal and poor eyesight. Children also have special needs associated with VR (Won et al., 2017).

Another known issue in VR is eyestrain due to issues with the technology. One example is the vergence-accommodation problem, which can also affect healthy individuals. When an individual looks at an object in the physical world, two perceptual processes occur concurrently at the same point: accommodation and vergence. However, in VR, the accommodation point (the surface of the HMD screen) is much closer than the vergence point, which is simulated to look much further away in order to provide depth perception. Thus, the person's lens is accommodating to a screen that is a few inches away from the face, and the brain thinks the point of convergence (where eyes meet to view the object) is further away. This discrepancy can cause eye fatigue and discomfort (e.g., headaches).

Along with issues of eyestrain come problems of fit with those who have smaller heads or nose bridges, as well as individuals wearing glasses. While this problem may be solved by future iterations of the technology, it must be kept in mind that currently, VR is not equally comfortable or useable for all potential patients.

While the majority of this chapter was spent discussing the technical needs for designing virtual reality treatment (VRT) interventions, another aspect of VRTs is perceived accessibility. This is especially important for individuals suffering from mental health disorders. Concerns for safety and ability to leave the environment made patients more likely and willing to try VRTs over conventional CBTs with in vivo exposure (Garcia-Palacios et al., 2007). In a similar vein, clinicians must consider individuals who need help but have little motivation to go to a clinic and receive treatment. This is a reality for depressed individuals, who often are aware of their need for treatment, but cannot be tasked with seeking it. Thus, making treatments more easily accessible through consumer-grade VR technology would be helpful for individuals seeking at home treatment.

Earlier in this chapter, various methods of self-referential perspective taking in VR were introduced as treatments for self-critical behavior in depression, extinguishing phobias, and unlocking negative body images in body dysmorphic disorders. The ability to switch between perspectives allows individuals to reappraise how patients think about themselves. Given VR's ability to help with mental health conditions that bring about negative affect, it comes as no surprise that VR could be leveraged as an emotional feedback mechanism. Such that, if individuals with mood disorders saw their virtual selves present with positive affective emotions, such as joy, this would reflect in an actual mood change. Seeing a joyful self could show a depressed person that feeling joy is possible, even if they cannot simulate the feeling themselves. Thus, with the combination of perspective taking and 3D visualizations, VR can continue to pave the way for innovative treatments for mood disorders.

The future of VR and technical improvements

To review, immersive media for patient care offers the following advantages:

(1) *Ecological validity*: Enhanced ability to provide realistic experiences
(2) *Flexibility*: Potential to offer greater variety of test or therapeutic stimuli to subjects
(3) *Tracking:* Improved means of monitoring the effect of stimuli

(4) *Interactivity*: Increased ability of the subject to interact with and respond to stimuli
(5) *Standardization* of tests/treatments
(6) *Control:* Improved ability to calibrate the treatment experience

Potential improvements that could broaden the reach of VR in patient care in specific areas are listed below. For example, VR is becoming untethered. Standalone wireless headsets, such as the Oculus Quest, which was released in May 2019, use cameras positioned on the headset to detect the scene around the user and use this information to track the user's movement in the actual, physical space. Researchers and clinicians may expect at least some of the following improvements as well:

(1) As the visual quality of headsets improves, light field displays and eye tracking may allow for better depth perception and less fatigue when wearing headsets.
(2) Headsets will continue to become lighter and more customized to allow them to be comfortable for a wider range of users.
(3) Tracking facial expressions and eye movements will allow for more realistic social presence.
(4) Tracking of hands and the rest of the body without requiring users to hold sensors will allow more naturalistic gestures or gestures from users with injuries and will also reduce the need for sterilizing these controllers in a hospital environment.

The present chapter reviewed the clinical applications of VR within the realm of patient-centered care. Currently, applications include VR interventions that serve diagnostic, mental health improvement, pain management, and rehabilitation purposes. These factors can be influenced by the technological aspects of a VR experience such as visual display type and quality, which in turn are affected by computer processing power. As VR hardware and software continue to improve upon their technical aspects, the applications of patient-centered VR will only grow.

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