The Use of Virtual Reality for Pain Control: A Review

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Virtual reality (VR) is a relatively new technology that enables individuals to immerse themselves in a virtual world. This multisensory technology has been used in a variety of fields, and most recently has been applied clinically as a method of distraction for pain management during medical procedures. Investigators have posited that VR creates a nonpharmacologic form of analgesia by changing the activity of the body's intricate pain modulation system. However, the efficacy of VR has not been proven and the exact mechanisms behind VR's action remain unknown. This article presents a comprehensive review of the literature to date exploring the clinical and experimental applications of VR for pain control. The review details specific research methodologies and popular virtual environments. Limitations of the research, recommendations for improvement of future studies, and clinical experiences with VR are also discussed.

Introduction

Over the past two decades, the use of virtual reality (VR) for medical and psychiatric purposes has been gaining attention. What initially began as a form of entertainment has expanded its application into a variety of areas, including surgical training and treatment of psychiatric disorders (eg, attention deficit hyperactivity disorder, phobias, post-traumatic stress disorder) [1–3]. In the past 10 years, VR has also been introduced into medical settings as a means to attenuate pain perception during painful medical procedures. In this context, VR has been investigated and clinically applied as an advanced form of distraction, creating what investigators have termed *VR analgesia* [4•,5••]. Simpler, empirically supported forms of distraction include imagery, relaxation, and positive thinking [6–8]. More technology-specific distracters, such as TV and video games, have also been explored as means to reduce pain and distress associated with medical procedures [9]. VR distraction is unique in that it is immersive and engaging, integrating many sensory experiences, and thus capturing a greater degree of attention. This becomes possible through the use of interactive virtual environments (VEs) with head-tracking systems, visually stimulating scenery, and audio and tactile feedback (Table 1).

VR enables users to become active participants in a "virtual world." Participants enter the virtual world through a combination of a head-mounted display (HMD), headphones with sound/music and noise reduction, and a joystick, rumble pad, or other device for manipulation/navigation of the VE (Fig. 1). In advanced models, head-tracking systems are built into the HMD, enabling the VR system to track the motion of the user's head and present the 360° illusion of being completely surrounded by the virtual world. This combination of visual, auditory, and tactile stimuli helps immerse the user in the VE, creating a sense of presence.

Several theories have been proposed to explain why distraction may inhibit or decrease perception of pain. In 1965, Melzack and Wall [10] proposed the Gate Control Theory. This theory posits that central nervous system activities (eg, attention, emotion, memory) play a role in sensory perception. When pain signals travel through the body, they must pass through "nerve gates" before the body can determine the level of awareness. In other words, the level of attention paid to the pain, the emotion associated with the pain, and past experience with the pain all play a role in how that pain is individually interpreted. McCaul and Malott [11] expanded on this theory in 1984, describing the human being's limited capacity for attention. They stated that an individual must attend to a painful stimulus in order for it to be perceived as painful. Therefore, if an individual is distracted, the perception of pain will be decreased. Wickens [12] proposed the Multiple Resources Theory, which states that resources in different sensory systems function independently. Thus, it is better to use multisensory distractions. This lends support to multimodal VR technology.

Table 1. Commonly used virtual environments from clinical and experimental studies

Virtual environment	Description	Study
Virtual reality		
SpiderWorld (modified version of *KitchenWorld*; Division Ltd., San Mateo, CA)	User controls a spider in a 3-D virtual kitchen environment. User can "pick up" objects, "eat" candy bars, and "touch" other spiders. User is also able to kill the spider.	Hoffman et al. [14,21]
SnowWorld (www.vrpain.com)	3-D virtual canyon with snow and ice. Users aim with their gaze, and throw snowballs at snowmen and igloos using the spacebar or mouse of a computer.	Hoffman et al. [14–16,22,28], Wright et al. [20], van Twillert et al. [25], Sharar et al. [26••]
Virtual Gorilla program [40]	User takes on the persona of a gorilla and interacts with other gorillas in the habitat. A joystick is used to maneuver through the environment.	Gershon et al. [18,31]
Bush Soul (Rebecca Allen, 1997)	Expansive, otherworldly planet surface in which the user can navigate and explore.	Gold et al. [33]
Street Luge (Fifth Dimension Technologies, Irvine, CA)	User races down a hill while lying on a skateboard. Game is fast-paced with tactile feedback via a rumble pad.	Gold et al. [34]
Augmented reality		
Hospital Harry (Australasian CRC for Interaction Design, Brisbane, Queensland, Australia)	User operates the system by inserting plastic figures into the camera unit. This creates an animated character named "Hospital Harry." User can manipulate the character using the plastic figure. Auditory narration prompts user to perform tasks with the figure.	Mott et al. [27]
Adapted video/computer game		
Quake (Activision, Eden Prairie, MN)	Video game presented via HMD. Users are on a track and use a pointer to shoot monsters. A head-tracking system allows for interaction with the environment.	Das et al. [23]
Magic Carpet® (Electronic Arts, Redwood City, CA), *Sherlock Holmes Mystery*® (Frogwares, Dublin, Ireland), and *Seventh Guest*® (Virgin Interactive, London, England)	CD-ROM games appropriate for patients 10–17 years old that is viewed using VR equipment (eg, VR HMD).	Schneider and Workman [29]
Escape (VIRTUAL i-O, Portland, OR)	Video presented via VR glasses with earphones. Video includes 3-D scenes of skiing down the Swiss Alps and drag racing.	Wint et al. [30]
Free Dive (Breakaway Games Ltd., Hunt Valley, MD)	Underwater 360°, 3-D VE presented via HMD. User scuba dives with turtles and fish while searching for treasure chests. Speakers simulate the sounds of breathing through scuba equipment.	Dahlquist et al. [38]

3-D—three dimensional; HMD—head-mounted display; VE—virtual environment; VR—virtual reality.

Figure 1. A 12-year-old boy playing *Street Luge* virtual reality game with head-mounted display, head tracking, and rumble pad.

In a recent review of VR pain attenuation, Gold et al. [5••] hypothesized that VR may change the activity of the body's intricate pain modulation system by acting directly and indirectly on signaling pathways of the pain matrix through attention, emotion, memory, and other senses (eg, touch, auditory, visual), thereby producing analgesia. One possible modulation pathway was suggested in a study conducted by Bantick et al. [13], which tested the effect of distraction on pain perception using functional MRI (fMRI). During the distraction task (an adapted Stroop task), subjective reports of pain intensity decreased, and fMRI showed an overall decrease in activation in the pain matrix and an increase in activity in the anterior cingulate cortex and orbitofrontal regions of the brain. VR, arguably a more powerful distracter, could potentially utilize these or other brain regions to attenuate perception of pain.

The exploration of VR use for pain control has only recently begun. Studies have been conducted using the technology during a variety of medical procedures, but not all studies were scientifically rigorous in their design or methodology. A careful review of the literature is necessary to delineate single case studies from randomized controlled trials (RCTs) in order to address the validity, reliability, and generalizability of VR for meeting acute, chronic, or other pain management needs in children/adolescents and adults.

Method

For the purposes of this review, literature searches of web-based scientific databases were conducted using PubMed, Medline, and the Computer Retrieval of Information on Scientific Projects (CRISP; hosted by the National Institutes of Health [NIH]) to identify published manuscripts and current NIH-funded studies examining VR for pain control. Search terms included VR and/or pain, analgesia, pain management, and distraction. Case studies and RCTs with children and adults are discussed below. Studies are organized first according to study methodology (case study, RCT) and second, by type of medical procedure (Table 2). Additionally, CRISP-identified studies are presented to highlight the current trends in VR and pain management research. The review concludes with a discussion of limitations, future directions, and a brief description of the authors experience with VR technology and pediatric response.

Case Studies

Hoffman et al. [14] presented the first evidence supporting the use of VR for pain management. This case study employed a crossover design comparing VR with a video game (Nintendo 64) in two male adolescent patients with burns (ages 16 and 17 years) who were experiencing pain during their burn care. Investigators found declines in pain ratings comprised of pain intensity, anxiety, and time spent thinking about pain in both patients during the VR condition.

Hoffman et al. also investigated the use of VR in two patients (ages 51 and 56 years) with dental pain [15] and the use of a water-friendly VR system in a 40-year-old male undergoing burn care [16]. Both studies found decreased pain ratings in the VR condition compared with standard of care.

In a study by Steele et al. [17], a 16 year old with cerebral palsy participated in a crossover design comparing VR with standard of care during physiotherapy. The VR distraction consisted of a game in which the user could interact with the virtual world, aim a virtual gun, and shoot creatures with a hand-held trigger. The patient reported 41.2% lower pain scores in the VR condition versus standard of care as measured by a standardized self-report pain intensity scale.

Gershon et al. [18] examined VR to alleviate pain and anxiety during port access in an 8-year-old boy diagnosed with acute lymphomatic leukemia. The study compared three treatment conditions: 1) no distraction, 2) VR distraction via computer, and 3) VR distraction via HMD. Investigators computed an average of pain intensity and anxiety ratings reported by the patient, parent, and nurse to create a pain score for each condition. Results revealed a lower pain score and less behavioral distress during the VR HMD condition. The boy's rating of his own anxiety in the VR HMD condition, however, was higher than in the VR computer condition. Investigators theorized that this increase in anxiety was the result of the boy's inability to see the procedure. More recent investigations have yielded mixed results on the role of visual occlusion in the effectiveness of VR.

Patterson et al. [19] used hypnosis presented via VR as a means to manage pain and anxiety in a patient with severe burn wounds. Pain intensity and anxiety levels dropped 40% following the VR hypnosis intervention;

however, similar decreases were noted in the audio-only intervention as well.

Wright et al. [20] explored the use of VR in a 67-year-old man receiving transurethral microwave thermotherapy. The study compared standard of care to standard of care with VR. The patient reported less pain intensity and anxiety in the VR condition, as measured by a visual analogue scale (VAS).

Randomized Control Trials

Burn care

A variety of VR technologies have been used to investigate VR use for the pain control during burn care. Hoffman et al. [21] explored the use of VR to alleviate pain during physical therapy in adult patients with burns. Twelve patients (age 19–47 years), while receiving physical therapy to increase their range of motion, spent 3 minutes with standard analgesia and 3 minutes with VR plus analgesia. Following each condition, patients were asked to rate their pain intensity, anxiety, and time spent thinking about pain on a VAS. Results showed that pain ratings were significantly lower in the VR plus analgesia condition ($P < 0.008$). Ten of the patients also demonstrated a greater range of limb motion when immersed in VR.

The same investigators examined the use of VR for pain control during three consecutive physical therapy treatments in seven patients (age 9–32 years) with deep burns over 6% to 60% of their bodies [22]. Pain intensity and affective pain were measured using a VAS following each treatment. A mean of these five ratings was calculated to create an average pain score. Range of motion was measured following each treatment. Results revealed significant pain reduction during the first three physical therapy sessions with VR ($P < 0.001$) and pain reduction remained constant with repeated use. Additionally, range of limb motion was greater following the VR condition in all but one of the physical therapy sessions.

The first RCT examining VR use exclusively for children with burns examined seven children (age 5–18 years) [23]. In this within-subjects design, children switched between treatments with an analgesic and analgesic treatment with VR during wound debridement. Results showed that VR coupled with an analgesic was significantly more effective in reducing pain according to a validated self-report pain intensity scale ($P < 0.01$). Three children (43%) self-reported equal pain intensity in both conditions; however, parent reports and nurse reports indicated that, behaviorally, these children were exhibiting less distress in the VR condition.

Chan et al. [24] examined the use of a VR prototype in providing relief to children with burns. The VR prototype consisted of graphic animation presented via eyeglasses, which the children controlled using a computer mouse. This descriptive exploratory study used a within-subjects design to compare VR versus standard of care in eight children (mean age, 6.54 years) during routine dressing changes. Results showed no significant differences in pain intensity, as measured by a standardized pain scale, between the two conditions. Nurses, however, using a standardized measure, observed decreases in the children's behavioral distress during the VR intervention.

In another study, van Twillert et al. [25] compared the within-patient effects of VR with alternate forms of distraction (eg, TV, music) and standard of care during dressing changes in 19 participants with burns (age 8–65 years). Pain intensity was measured using a visual analogue thermometer, an adapted version of the VAS for patients with burns. Results demonstrated that the VR and alternate distraction conditions were significantly different from the standard of care ($P < 0.01$), but not from each other. Enthusiasm for the VR game did not predict its success, and younger participants were more willing to participate. Measures of anxiety were not significantly different in any of the conditions, and participants noted minimal simulator sickness.

Sharar et al. [26••] published an article combining data from three studies. It examined the efficacy of VR in reducing pain associated with postburn physical therapy in 88 patients (age 6–65 years). Of the 88 patients, 66 (75%) were children between 6 and 18 years old. Standard analgesic care was compared with VR plus standard of care during postburn physical therapy, and pain ratings were taken using a graphic rating scale (GRS). Investigators found significant reductions in reported pain intensity, unpleasantness, and time spent thinking about pain in the VR condition ($P < 0.01$). The study found no age, sex, or ethnicity differences.

Mott et al. [27] tested the efficacy of augmented reality (AR), an alternate form of VR. Rather than immersing the player into an imaginary environment, AR technology overlays images onto the physical world. Although AR does not employ an HMD, it contains similar multimodal characteristics of sight, touch, and sound. The study examined 42 children (age 3–14 years), and compared AR with cognitive behavioral therapy (CBT) techniques (eg, distraction, breathing, positive reinforcement) during dressing changes. Both conditions were coupled with an analgesia. Pain scores, measured using age-appropriate standardized pain intensity scales, were significantly lower in the AR group compared with the CBT group for patients with dressing times greater than 30 minutes ($P = 0.01$). The authors noted the limitations of the AR equipment as being heavy, not waterproof, and limited to an older appeal group.

Hoffman et al. [28] used a water-friendly VR system in wound debridement for 11 patients (age 9–40 years). The investigation found that, according to GRS ratings, VR lowered ratings of worst pain and pain unpleasantness, and increased ratings of fun ($P < 0.05$), but only in

Table 2. Clinical investigations examining virtual reality for pain control

Study	Study type	Patients, *n*	Age range, *m* (SD)	Conditions	Primary findings in VR condition
Burn care					
Hoffman et al. [14]	Case study	2	16–17	VR*/video game*	Decreased pain, anxiety, and time spent thinking about pain
Hoffman et al. [21]	RCT	12	19–47	VR*/standard analgesia	Decreased pain, anxiety, and time spent thinking about pain
Hoffman et al. [22]	RCT	7	9–32	Repeated VR*/No VR*	Pain ratings and degree of VR immersion remained constant
Hoffman et al. [16]	Case study	1	40	VR (water-friendly)/no VR	Decreased pain ratings
Patterson et al. [19]	Case study	1		VR hypnosis/audio only	Pain levels dropped in both conditions
Das et al. [23]	RCT	7	5–18	VR*/analgesia	Reduced pain scores in four subjects
Chan et al. [24]	Exploratory	8	6.54 (2.27)	VR*/standard of care	Nurses observed less behavioral distress
van Twillert et al. [25]	RCT	19	8–65	VR*/TV*/standard of care	Lower pain scores than standard of care only
Sharar et al. [26••]	RCT	88	6–65	VR*/analgesia	Reduced pain intensity, unpleasantness, and time thinking about pain
Mott et al. [27]	RCT	42	3–14	AR*/CBT*	Lower pain scores
Hoffman et al. [28]	RCT	11	9–40	VR (water-friendly)*/no VR*	Lower pain ratings and unpleasantness in subjects who were immersed in VR
Cancer pain					
Schneider and Workman [29]	Pilot study	11	10–17	VR*/standard of care	Children preferred VR to previous treatments
Wint et al. [30]	Pilot study	30	10–19	VR*/standard of care	No significant differences
Gershon et al. [18]	Case study	1	8	VR*/computer/no distraction	Lower pain score and less behavioral distress; higher anxiety
Gershon et al. [31]	RCT	59	7–19	VR*/distraction/standard of care	Lower physiologic arousal and nurse-reported pain ratings
Schneider et al. [32]	RCT	20	18–55	VR*/standard of care	Decreased symptom distress and perceived treatment time
Routine procedures					
Gold et al. [33]	RCT	100	8–12	VR via HMD/VR via computer/cartoon/no distraction	Lower frequency of moderate to severe pain intensity in VR via HMD
Gold et al. [34]	RCT	20	8–12	VR*/topical anesthetic	No change in pain intensity pre- and post-IV; higher satisfaction ratings

*With analgesia.
AR—augmented reality; CBT—cognitive behavioral therapy; HMD—head-mounted display; IV—intravenous; RCT—randomized controlled trial; M—mean; SD—standard deviation; VR—virtual reality.

Table 2. Clinical investigations examining virtual reality for pain control *(Continued)*

Study	Study type	Patients, *n*	Age range, *m* (SD)	Conditions	Primary findings in VR condition
Miscellaneous medical treatments					
Hoffman et al. [15]	Case study	2	51–56	VR/movie/control	Lower pain ratings
Steele et al. [17]	Case study	1	16	VR/standard of care	Lower pain scores
Wright et al. [20]	Case study	1	67	VR*/local anesthesia	Reduced pain and anxiety ratings

*With analgesia.
AR—augmented reality; CBT—cognitive behavioral therapy; HMD—head-mounted display; IV—intravenous; RCT—randomized controlled trial; M—mean; SD—standard deviation; VR—virtual reality.

patients who reported being present in the VR game. The five patients who did not report feeling immersed in the game did not show significant reductions in pain ratings.

Cancer pain

VR has also been used to treat pain associated with cancer treatment. Pilot studies have been conducted examining the feasibility of VR in reducing pain during cancer treatment in children. Schneider and Workman [29] asked 11 children (age 10–17 years) receiving chemotherapy to recall previous treatments and compare their experience with VR to previous experiences with standard of care using an investigator-developed questionnaire. Eighty-two percent stated that the chemotherapy with the VR distraction was better than previous treatments. All children reported that they would like to use VR in future treatments.

Wint et al. [30] examined the efficacy of VR glasses in reducing pain experienced during lumbar puncture. The pilot study used a between-groups design with 30 adolescent patients with cancer (age 10–19 years). Seventeen patients were placed in the VR condition and 13 in standard of care. Pain intensity scores, using a self-report VAS, were not statistically different between the two groups. Investigators reported a trend toward lower scores in the VR group, but the trend was not significant.

Gershon et al. [31] conducted a larger study looking at 59 children and adolescents (age 7–19 years) receiving port access associated with cancer treatment. The study compared three conditions: 1) VR distraction via HMD, 2) VR distraction via computer, and 3) standard of care. Results showed VR HMD distraction to be significantly better than standard of care, according to measures of physiologic arousal (ie, pulse) and nurse-reported VAS pain ratings ($P < 0.05$). No other differences were found.

In 2004, Schneider et al. [32] published a crossover-designed study examining the effect of VR on pain in women receiving chemotherapy treatment for breast cancer. Patients chose one scenario (deep-sea diving, walking through a museum, or solving a mystery), which was projected onto a headset with corresponding sounds. Significant findings included decreased symptom distress ($P < 0.05$) and perceived time playing the VR game/receiving treatment ($P < 0.001$), termed the *time-elapse compression effect*.

Routine medical procedures

VR use has also been investigated with routine pediatric medical procedures. Gold et al. [33] examined 100 children (age 8–12 years) receiving routine outpatient blood draw. Children were randomly assigned to one of four conditions: 1) no distraction, 2) cartoon distraction, 3) VR via computer, or 4) VR via HMD. Visual occlusion was controlled across all four conditions by creating a pass wall through which the children had to place their arm for the blood draw. Children in the VR HMD condition reported a lower frequency of moderate to severe levels of pain intensity compared with children in the other three conditions ($P < 0.05$). Other analyses revealed no differences in pain intensity and state anxiety among the four conditions. State anxiety was negatively associated with VR presence.

Gold et al. [34] also examined 20 children (age 8–12 years) requiring intravenous (IV) placement for contrast for an MRI/CT scan. Children were randomly assigned to VR presented via HMD plus a topical anesthetic or the topical anesthetic alone. Children in the VR condition reported no significant change in pain intensity between pre- and post-IV placement, whereas children in the control condition demonstrated a fourfold pain increase ($P < 0.01$), as measured by a standardized pain intensity scale. Caregivers preferred the VR condition in terms of child cooperation and pain reduction. The VR condition also received higher satisfaction ratings from the children, their caregivers, and the nurse performing the procedure. Additionally, children reported no simulator sickness and a high level of presence.

Current National Institutes of Health Studies

Two NIH-funded studies are currently investigating VR for pain control. Lynnda Dahlquist (University of Maryland, Baltimore College) is examining differences between interactive VR, active VR, and passive VR. One aim of the study is to assess a younger sample of children (age 6–8 years). Additionally, the investigator aims to pilot the use of VR distraction for patients receiving care in the division of Hematology-Oncology. David Patterson (University of Washington) is exploring the combination of VR and hypnosis. Patterson will test this novel combination during dressing changes in patients with burns and in college students receiving thermally induced pain. He will compare high and low VR technology delivered through a water-friendly system. Patterson will also examine the relationship between hypnotic suggestibility and the effectiveness of VR.

Experimental Virtual Reality in Healthy Populations

Recently, VR research has expanded to examine experimentally induced pain in healthy populations. In these studies, the investigators induce pain and monitor the effects of VR on pain perception and pain tolerance. This enables investigators to test the direct effects of VR on pain inhibition while eliminating other confounding variables, such as disease pathology, medications, or the hospital environment. Tse et al. [35] tested the effects of visual stimulation on pain threshold and pain tolerance in a between-groups study of 72 university student volunteers. In the experimental condition, visual stimulation of natural scenery without sound was presented via eyeglasses. In the control condition, participants were presented with a static blank screen. Pain was administered with a modified tourniquet. Results showed an increase in pain threshold and tolerance during the experimental condition. Another study using experimentally induced ischemic tourniquet pain tested the effects of VR in 20 healthy adults. Magora et al. [36] found that the VR condition increased pain tolerance ($P < 0.001$). Additionally, participants self-reported lower affective distress and pain unpleasantness when immersed in VR ($P < 0.001$).

Hoffman et al. [37] administered experimental pain using a blood pressure cuff to 22 college students during VR and non-VR conditions. Results showed significant differences, with VR distraction decreasing pain intensity by an average of 52%, across male and female students. Dahlquist et al. [38] used cold pressor pain with 41 children (age 6–14 years) to assess whether the use of an HMD enhanced the effects of a video game for children and adolescents. The authors found that the HMD resulted in additional benefit for the older children (ie, increasing pain tolerance), but had no effect for the younger children.

Scientific Concerns

Although VR research is showing initial promise in its ability to decrease pain perception and other negative aspects of painful medical and experimental procedures, results should be interpreted cautiously in light of some basic scientific limitations. In general, sample sizes continue to be small, thus reducing generalizability of the findings. Additionally, although VR has been tested in specified populations, the methodology used to test the technology has been highly variable. Investigators have used a variety of VEs, pain measures, and study designs. Results from one population cannot be generalized to another population unless similar methodology is applied. Future studies should use consistent and experimentally rigorous methodologies and recruit a greater number of participants to increase the power and generalizability of results.

There are additional concerns regarding the measurement of pain and other health outcomes collected during VR investigations. Although some research teams have used standardized measures, many researchers have relied on unstandardized, investigator-developed questionnaires. Additionally, self-report measures have been the primary mode of data collection in lieu of integrated multirater and multimodal pain assessment. Investigative teams should combine standardized subjective self-report questionnaires with behavioral, observational, and physiologic indices in order to better evaluate the relationships between VR interventions and associated health outcomes (eg, pain, anxiety, distress).

Another concern, raised early in the research, was the possibility that VR may be effective primarily due to its ability to impede the patient's view of the painful procedure [14]. In a study by Gershon et al. [18], the participant reported increased levels of anxiety while immersed in an HMD. The investigators hypothesized that this effect may be due to the child's inability to view the procedure and fear of the unknown. However, in 2005, Gold et al. [33] designed a study controlling for visual occlusion of the medical procedure across all conditions and demonstrated that VR HMD remained superior. As this is the only study conducted with this strict methodology, future studies should incorporate similar rigor to evaluate the influence of visual occlusion versus VR analgesia during medical procedures. Additionally, future studies would benefit from assessing coping styles of the participants (ie, "attenders" [those who like to watch the procedure] vs "distracters" [those who like to look away]) in an attempt to examine the impact of coping style on the efficacy of VR for procedural pain.

There is also worry regarding the cost/benefit of VR. VR is an expensive mode of distraction when less expensive, more easily accessible modes (eg, TV, music, bubbles, toys) have been proven to be effective. Practically speaking, although costs associated with VR have significantly declined, the cost/benefit analysis as compared with other modes of distraction is still undecided. Recently, investigators have hypothesized that VR attenuates pain and creates analgesia at a level beyond that of simple distraction. To address this concern, it is necessary to explore the neurobiologic mechanisms behind the effect of VR. Researchers have begun to examine the neural correlates associated with VR pain distraction through the use of fMRI and experimentally induced pain [4•].

Clinicians/investigators should also be careful in their choice of VE, as not all VEs are created equally. A truly immersive VE provides the 360° illusion of being immersed in the virtual world, often with head tracking to allow for more complete interaction. Additionally, the game should involve other sensory modalities, such as auditory stimulation and tactile feedback. Many investigators have used an HMD to deliver video or computer games to the user, without the fully immersive elements (Table 1). These do not qualify as immersive VR. Investigations have also revealed differential effects due to quality of the VR system. Hoffman et al. [39] conducted a between-groups study testing the pain-attenuating effects of high-tech VR versus low-tech VR in healthy volunteers. The study found that participants in the high-tech VR condition reported a higher level of presence and greater pain reduction compared with the low-tech VR group. Continued investigation of immersive and interactive VR and the identification of neural correlates associated with VR analgesia will serve to further explain the use of VR for pain management.

Clinical Experiences with Virtual Reality

Hospitalized patients with an acute or a chronic medical condition often undergo numerous painful routine (ie, blood draw, IV placement) and sometimes invasive (ie, lumbar puncture, wound care, line placement) medical procedures. As analgesics or other pharmacologic interventions are not always indicated, VR is beginning to emerge as a first-line or adjunctive/complementary intervention for painful procedures. In addition to the well-documented pain associated with these procedures, patients also report fear, anxiety, and, to some degree, post-traumatic stress reactions (eg, nightmares, fear of the hospital) associated with exposure to painful medical procedures. In these authors' opinions, VR is promising as an adjunctive/complementary or first-line intervention to manage pain and distress associated with painful medical procedures. In addition to the positive outcomes previously described, preliminary investigations demonstrate that participants enjoy the VR experience and report minimal ill effects (ie, simulator sickness or nausea). During investigations conducted by the senior author, children and their caregivers have relayed that: "It [VR] made the medical test easier," "I would do it again," "The child was more cooperative," and "It was fun." Additionally, health care providers have commented that VR helped the child be less nervous, more calm, and more cooperative, thus making the procedure easier. Nurses have stated that procedures with VR require fewer needle sticks/attempts, and health care providers have reported that they prefer the VR condition to standard of care alone.

Conclusions

VR use for pain control is in its infancy. Investigations have demonstrated initial promise with specific populations and acute medical procedures. As VR technology decreases in cost and increases in availability, new VEs and integrated VR technology will enable clinicians and researchers to further investigate the usability of VR. Future studies in VR require greater scientific rigor, increased sample sizes, sound methodology, and increased attention to individual user characteristics. VR's promise in acute medical procedures may also contribute to the understanding and management of chronic pain. VR is emerging as both a viable first-line intervention and as an adjunctive therapy to pharmacologic agents. As VR researchers gain a better understanding of the neurobiologic mechanisms associated with VR analgesia, VR may shift from a simple form of immersive distraction to a powerful nonpharmacologic agent.

Disclosures

No potential conflicts of interest relevant to this article were reported.

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