Virtual anesthesia: The use of virtual reality for pain distraction during acute medical interventions

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Pediatric pain management for routine medical interventions continues to receive considerable attention. To date, investigators have demonstrated the efficacy of simple pain distraction strategies for acute procedures (ie, venipuncture) as well as more invasive interventions (ie, wound care, chemotherapy). Recent technological advances in the field of virtual reality (VR) have produced more engaging forms of pain distraction. Although clinical case studies and randomized control trials have begun to explore the utilization of VR anesthesia, this research is still in its infancy. In spite of some limitations, VR researchers have successfully demonstrated its feasibility, satisfaction, and innovation for decreasing pain associated with medical interventions. VR anesthesia also has the potential to minimize pharmacological therapy, thereby reducing risks associated with sedation. Future directions in VR anesthesia are contingent on further technological advances, sound methodology, and appropriate participant-to-intervention match. This manuscript reviews current literature on state-of-the-art pain distraction and future directions in VR.

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Pediatric pain management for routine medical interventions continues to receive considerable attention. To date, investigators have demonstrated the efficacy of simple pain distraction strategies for acute procedures (ie, venipuncture) as well as more invasive interventions (ie, wound care, chemotherapy). Recent technological advances in the field of virtual reality (VR) have produced more engaging forms of pain distraction. Although clinical case studies and randomized control trials have begun to explore the utilization of VR anesthesia, this research is still in its infancy. In spite of some limitations, VR researchers have successfully demonstrated its feasibility, satisfaction, and innovation for decreasing pain associated with medical interventions. VR anesthesia also has the potential to minimize pharmacological therapy, thereby reducing risks associated with sedation. Future directions in VR anesthesia are contingent on further technological advances, sound methodology, and appropriate participant-to-intervention match. This manuscript reviews current literature on state-of-the-art pain distraction and future directions in VR.

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Theory (GCT) and the limited-capacity of attention. The basic theory behind distraction dictates that attention is diverted away from a noxious stimulus and is instead focused on more pleasant stimuli, resulting in a reduction in the perception and experience of pain.

In the early 1960s, in response to the increasing awareness of the relationship between the mind and the body regarding pain perception, Melzack and Wall proposed the GCT. Placing particular emphasis on the complex interplay between the central nervous system (CNS) and the peripheral nervous system (PNS), they claimed that only certain “pain” messages are permitted to pass through to the brain; in other words, “nerve gates” determine the degree to which an individual receives a pain sensation. This theory rests upon the principle that various CNS activities (particularly attention, emotion, and memories concerning previous experience with the event) can play a significant role in sensory perception.

Around that time and in the decades that followed, various models concerning the limited-capacity of attention began to emerge. In a literature review that expanded upon these models, McCaul and Malott proposed that pain perception, which requires attention to noxious stimuli, could be disrupted by sufficient distraction that distributed the attentional resources. They also noted the existence of a pain threshold; in the event of extreme pain, attention could not be diverted from the pain sensation, and “enhanced coping” was a more appropriate response than distraction. Therefore, distraction was determined to be most effective when the pain was mild and the distraction itself was novel, intense, and unpredictable. This theory was based on research demonstrating the efficacy of sufficient distraction as opposed to placebo control and “no instruction” when coping with an individual’s pain.

Virtual reality and pain distraction

Over the last 15 years, the use of virtual reality (VR) has been utilized for various educational (computer assisted learning), training (simulation), and research purposes with nurses, physicians, and other healthcare providers. However, more recently, the technology has been modified for child and adult use in clinical settings. Many investigators have begun to use the technology to entertain, educate, and divert attention away from the associated symptoms of painful medical interventions. Distraction from needle-related pain has been researched and is an empirically supported form of non-pharmacological pain management.

A recent technological advance that has shown promise as an engaging mode of distraction is VR. VR is a relatively new medium of human–computer interactions whereby a human becomes an active participant in a virtual world. The human user can experience combinations of visual, auditory, and tactile stimuli that help “immerse” the individual into the computer-generated reality and create a sense of presence within the environment. The more immersed an individual becomes, the more that person feels like a part of the virtual world. The immersion process occurs through a head-mounted display (HMD) that consists of two display screens. This visual system within the HMD allows for three-dimensional interaction between the individual, the computer, and the generated graphic and audio content. In addition, a mechanical force feedback joystick can be used to provide tactile stimulation while the user navigates through the virtual world. A head tracking system is often employed to create a dynamic perception of the virtual world in correspondence with the head movements made by the individual in the real world. The combination of this hardware and software allows the individual to feel a sense of presence by having the environment change in real time with the user’s movements, which fosters the sense that the user is an active participant within the virtual world.

Clinical case studies applying virtual reality for pain management

The first “virtual reality mirror box” was introduced by Ramachandran and Rogers-Ramachandran to examine the effects of visual input on phantom sensations. They introduced an inexpensive new device called a “virtual reality box” to visually resurrect the phantom limb in order to study inter-sensory effects. Six of the 10 patients recruited for the study reported kinesthetic sensations in their phantom limb after viewing a mirror-image of movement in their normal hand; movement of the normal hand produced an image that appeared as movement in the phantom limb. In one subject, this effect occurred even though he had never experienced any sensation in his phantom limb over the past 10 years. Impossible postures (eg, extreme hyperextension of the fingers) were also induced in the phantom by means of optical illusion. In one case, this was described as a transient “painful tug” in the phantom. Five patients experienced involuntary painful “clenching spasms” in the phantom hand, the majority of which were relieved when the mirror was used to facilitate “opening” of the phantom hand; opening was not possible without the mirror. In 3 patients, touching the normal hand evoked localized touch sensations in the phantom limb. Interestingly, the referral was especially pronounced when the patients actually “saw” their phantom limb being touched in the mirror: a curious form of synaesthesia. These findings began to lay the foundation for the impact of visual perception on the brain mechanisms as it pertains to motor function and pain sensation.

Hoffman et al. provided the first evidence that entering an immersive virtual environment serves as a powerful adjunctive, nonpharmacologic analgesic in an experiment with two adolescents experiencing high levels of pain during daily burn wound care. Two male patients, ages 16 and 17, were recruited for the study; the former had a deep
flash burn on his right leg requiring surgery and staple placement and the latter suffered from 33.5% total body surface area deep flash burns on his face, neck, back, arms, hands, and legs. Both patients reported significant decreases in their pain ratings during VR immersion compared to distraction with a Nintendo 64™ video game. Hoffman and colleagues contended that VR was a “uniquely attention-capturing medium” that successfully shifted the majority of the patient’s mental focus away from the painful procedures occurring in the real world.

Additionally, Hoffman et al. explored the use of VR as a non-pharmacologic analgesic for dental pain.21 Two patients (aged 51 and 56 years old) suffering from adult periodontitis were studied in the treatment room of a periodontist. Each patient received periodontal scaling and root planing under three treatment conditions: (a) virtual reality distraction, (b) movie distraction, and (c) a no-distraction control condition. Patients provided sensory and affective pain ratings on 0-10 point scales, as well as subjective estimates of time spent thinking about pain during the procedure. For patient 1, mean pain ratings were equally severe while being exposed to a movie (7.2) or no distraction at all (7.2). Yet, during the VR exposure, this patient only reported mild pain. Patient 2 reported moderate pain with no distraction (mean = 4.4), mild pain while watching the movie (3.3), and almost no pain with VR immersion (0.6).

Steele et al. explored the use of VR analgesia during a physiotherapy program with a 16-year-old patient with cerebral palsy recovering from a Single Event Multi-Level Surgery.22 The patient completed 6 days of traditional pain management and physiotherapy (2 sessions per day) split equally between standard therapy and therapy supplemented with VR analgesia (order randomized). Using a subjective five-faces pain scale, the patient reported pain scores that were 41.2% less than those reported for the no-VR condition. This case study demonstrated the first evidence in support of VR distraction for post-operative pain in children.

Gershon et al. investigated the use of VR distraction for reducing procedural pain and anxiety for a pediatric cancer patient.23 The patient followed an A-B-C-A design comparing no distraction, non-VR distraction on a computer screen, and HMD-VR distraction during four consecutive outpatient oncology visits. The patient’s self-reported pain and anxiety scores, as well as physiological output (pulse rate) and observed behavior, provided support for decreased pain and anxiety resulting from VR distraction during invasive medical procedures.

Patterson et al. reported a case study exploring the utilization of VR-induced hypnosis to reduce pain and anxiety in a patient with severe burns.24 On the 40th day of hospitalization, in response to complaints of uncontrollable pain and anxiety, Patterson and colleagues induced hypnosis in the patient by immersing the child in a virtual three-dimensional world. Following hypnosis, the patient received suggestions for decreased pain and anxiety during wound care. The next day, a 40% drop on a Graphic Rating Scale was demonstrated in the patient’s pain and anxiety after VR-induced hypnosis. On the 42nd day of hospitalization, the patient was exposed to an audio-only version of the intervention, which corresponded to a similar decrease in pain. However, when the intervention was not used on the following day, the child’s pain rose to baseline levels.

Hoffman et al. demonstrated a water-friendly virtual reality technology with a 40-year-old burn patient undergoing wound care in a hydrotherapy tub for 19% total body surface area deep flash burns to his legs, neck, back, and buttocks.25 The intervention corresponded with a drop in the patient’s sensory and affective pain ratings as well as a reduction in the amount of time the patient focused on his pain during wound care.

The effects of VR distraction on pain-related human brain activity was also investigated by Hoffman and his colleagues.26 Participants were randomized to periods of VR distraction and no VR while enduring experimentally induced thermal pain in an fMRI. VR was found to significantly reduce subjective pain scores in addition to pain-related brain activity in all five regions of interest: the anterior cingulate cortex, primary and secondary somatosensory cortex, insula, and thalamus (P < 0.002, corrected).

### VR and randomized control trials

Several controlled group studies have demonstrated the beneficial effects of VR distraction in medical settings. Hoffman et al. explored the utilization of immersive VR to distract patients from pain during physical therapy.27 Twelve patients (aged 19 to 47 years), with an average of 21% total body surface area burned, performed range-of-motion exercises under the supervision of an occupational therapist. Patients spent 3 minutes of physical therapy with no distraction and 3 minutes of physical therapy in VR (condition order randomized and counter-balanced). Pain assessments were collected from five visual analogue scales per treatment condition. All patients reported less pain in the VR treatment condition. The reduction in pain by VR was statistically significant; average time spent thinking about pain during physical therapy dropped from 60 to 14 mm on a 100-mm scale.

Schneider et al. conducted a pilot study to evaluate the efficacy and feasibility of VR pain distraction for children (aged 10-17) receiving outpatient chemotherapy.28 Study results revealed positive outcomes, with 82% of the children (n = 11) stating that the chemotherapy treatment with VR distraction was better than previous treatments without the intervention. All of the subjects recruited for this study reported a desire for future interaction with the VR.

Hoffman et al. later explored whether immersive virtual reality distraction continues to reduce pain with repeated use.29 Seven patients (aged 9-32 years), with an average of 23.7% total body surface area covered in burns, performed
range-of-motion exercises with their injured extremity under supervision of an occupational therapist. Patients spent the same amount of time per session conducting physical therapy with and without VR distraction (condition order randomized and counter-balanced). The mean duration for three consecutive sessions of physical therapy with VR distraction was 3.5, 4.9, and 6.4 minutes. Pain ratings on visual analog scales were statistically lower for the VR condition, which remained constant over time. The results from this study indicated that the analgesic effectiveness of VR did not decrease across three sessions.

Sander Wint et al. examined the use of VR with adolescents with cancer undergoing lumbar punctures (LPs). Thirty adolescents were randomly assigned to groups: standard treatment for the LP (control, $n = 13$) or standard treatment plus VR distraction (experimental, $n = 17$), which consisted of wearing VR eyeglasses while watching a video. There were no statistically significant differences in pain scores among the treatment groups ($P = 0.77$); however, lower scores were reported in the VR group (median = 7.0, range 0-48) than in the control group (median = 9.0, range 0-59). Additionally, 77% of subjects in the experimental condition contended that the VR eyeglasses helped to draw their attention away from the procedure.

A cross-over design was implemented by Schneider and her colleagues to explore the use of VR as a distraction intervention to relieve symptom distress in women receiving chemotherapy for breast cancer. Twenty women, 18-55 years of age, served as their own controls for two matched chemotherapy treatments. Participants were randomized to VR distraction during one chemotherapy treatment and to a no-distraction control condition during alternate chemotherapy treatments. VR significantly decreased symptom distress and fatigue, was well received, and was easy to implement in the clinical setting. Additionally, participants experienced a significant time elapse compression effect ($P < .001$), reporting less time ($M = 42$ minutes) interacting with the VR than actually recorded ($M = 67$ minutes). A study to determine the feasibility of this approach was also conducted with an elderly population (ages 50-77), and results indicated that VR was once again an effective, uncomplicated, and welcomed mode of pain management. Participants in this study also reported experiencing a time elapse compression effect.

Gershon et al. conducted a pilot study to test the feasibility of VR for reducing pain and anxiety associated with an invasive medical procedure in children with cancer. Fifty-nine pediatric oncology patients (ages 7-19) whose treatment protocols required port access were randomly assigned to one of three treatment conditions: (a) a virtual reality distraction intervention, (b) non-virtual reality distraction, (c) or treatment as usual without a distraction. Parents, children, and nurses completed assessments of the child’s pain and anxiety resulting from the procedure. Researchers observed and recorded the patient’s pulse rate and behavioral indices of distress during the procedure. Lower pulse rates and nurse-reported pain (of the child) indicated decreased pain and anxiety when the child was in the VR condition as opposed to the no-distraction condition. However, no significant differences in pulse rate were found between the non-virtual reality condition and the no-distraction condition.

Das et al. conducted a cross-over randomized controlled trial investigating whether playing a virtual reality game could decrease procedural pain in seven children (aged 5-18 years) with acute burn injuries. Pain was assessed with a modified self-report faces pain scale and through interviews with parent/caregivers and nurses. The average self-reported pain score for pharmacological analgesia was 4.1 (SD = 2.9, scale of 0-10), whereas VR coupled with pharmacological analgesia yielded an average pain score of 1.3 (SD = 1.8).

Patel examined the efficacy of gaming as distraction from pre-surgical anesthesia. Previous research indicated that although midazolam was superior to parental presence (parent accompaniment prior to the procedure) for pre-surgical anesthesia, it also appeared to delay the patient’s ability to become fully alert following the procedure. Acknowledging the immersive and non-invasive qualities of Game Boy™ (Nintendo™), Patel explored its application in a preoperative holding area. Seventy-eight children (ages 4-12) were stratified by age (4-6, 7-9, and 10-12) and randomized to one of three treatment conditions: (a) standard of care (baseline parental presence), (b) midazolam, or (c) Game Boy™. Nurse assessments (using a modified version of the Yale Preoperative Anxiety Scale, mYPAS) of the child’s change in anxiety from the preoperative holding area to mask induction of general anesthesia revealed significant differences between all treatment groups measured, with the Game Boy™ condition experiencing the greatest change in anxiety. Results suggest that interaction with Game Boy™ prior to mask induction is more beneficial than parental presence alone or pharmacological therapy, particularly with younger children, ages 4-9.

Focusing on routine outpatient venipuncture, Reger et al. compared the experience of 57 children, aged 8-12, in four treatment conditions. Children were randomly assigned to no distraction at all, cartoon distraction, VR distraction presented on a flat screen computer, or the same VR distraction presented in an HMD. Children who were able to view the VR in an HMD reported significantly lower affective pain ($t(55) = 2.45, P = .02$) and needle pain intensity ($t(55) = 2.22, P = .03$) relative to children in the other treatment conditions. Accordingly, the child’s level of engagement with the intervention was inversely related to the child’s state anxiety during the procedure. When additional subjects were recruited, increasing the sample size to 100 participants, chi-square analyses revealed a significant finding that children randomized to the HMD VR condition never reported a score of affective pain above a 2 (out of 5); in contrast, 4-16% of children randomized to the other treatment conditions reported a 3 or higher.
Gold et al. tested the efficacy and suitability of VR pain distraction for pediatric IV placement. Twenty children (12 boys, 8 girls) requiring IV placement for a MR/CT scan were randomly assigned to two treatment conditions: (1) VR distraction using the “Street Luge” action game scenario by Fifth Dimension Technologies (5DT) presented via an HMD, or (2) standard of care (topical anesthetic) with no distraction. Children, their parents, and nurses completed self-report questionnaires that assessed numerous health-related outcomes, including anticipatory anxiety, affective pain, IV pain intensity, fear, anxiety sensitivity, simulator sickness, presence, and overall satisfaction with VR. Detailed analyses were completed on all variables, revealing several significant associations. In particular, responses from the Faces Pain Scale-Revised indicated a fourfold increase in affective pain (t(9) = −3.25, P = .01) within the control condition; by contrast, no significant differences were detected within the VR condition. Significant associations between multiple measures of anticipatory anxiety (general, IV placement, and imaging), affective pain, IV pain intensity, and measures of past procedural pain provided support for the complex interplay of a multimodal assessment of pain perception. Nonetheless, there was a sufficient amount of evidence supporting the efficacy of “Street Luge” as a pediatric pain distraction tool during IV placement: an adequate level of presence, no simulator sickness, and significantly more child-, parent-, and nurse-reported satisfaction with pain management for children in the VR group. VR pain distraction was positively endorsed by all reporters and is a promising tool for decreasing pain, fear, and anxiety in children undergoing acute medical interventions.

**VR in healthy populations**

The efficacy of VR pain distraction has also been examined in clinically healthy populations stimulated with experimentally induced pain. Seventy-two college students undergoing experimentally induced ischemia demonstrated a significant increase in both pain threshold and pain tolerance when viewing nature scenes on a VR eyeglass display as opposed to wearing the glasses and viewing a blank screen.

Hoffman and colleagues found that, in addition to enhancing pain endurance, VR also has the capacity to decrease experimentally induced pain perception. Twenty-two students (14 female, 8 male) were exposed to 8 minutes of increasing increments of pain, produced by a blood pressure cuff, without distraction. In the subsequent final 2 minutes of the study, participants were immersed in the VR environment and experienced a 52% drop in their self-reported pain.

**Summary of VR and pain distraction**

The previous review essentially exhausts the current literature on state-of-the-art applications of VR anesthesia for patients undergoing invasive medical procedures. Although numerous studies have begun to explore the utilization of VR as a pain distraction for acute medical procedures, this type of research is still in its infancy. Investigators to date have continued to build on the theoretical framework of both Gate Control Theory (GCT) and the limited-capacity of attention, while exploiting the rapidly evolving innovative technology of VR. VR pain distraction has become increasingly affordable, and initial research has demonstrated its efficacy for decreasing pain, anxiety, and fear, along with the feasibility of this approach for use in medical settings. Whereas theoretical and technical advances in VR are expected to continue, the larger scientific issues that are relevant in the VR/pain distraction literature include: the evolved selection of appropriate research and clinical methodologies; the collection of suitable outcome variables; and the task of properly matching the interactional and content features of different types of virtual environments (VEs) to the needs of various populations and procedures. Notably, customizing environments to match age, gender, and developmental maturity has yet to be adequately evaluated.

Although a fair number of case studies and randomized controlled trials (RCTs) have been conducted, specific questions still need to be investigated regarding VR applications in this area, including: the measurement of presence/immersion and its influence on successful outcomes; the occurrence of simulator sickness; the need for or impact of multi-sensory immersion; and the added value of using high-end versus low-cost equipment, particularly in terms of how it may impact access to this approach. So far, the literature has uniformly demonstrated that patients subjectively report decreases in negative health outcomes (ie, pain), increases in satisfaction/comfort, low incidence rates of simulator sickness when using VR for pain distraction, and varying degrees of presence/immersion. Although most investigators have utilized self-report indices, only a few have examined physiological and observational measures of pain and pain-related behaviors. This will likely emerge as a useful research direction in the future.

Although researchers have demonstrated initial promise for VR as a pain distraction approach, some basic limitations have also been raised. Some of these limitations include small sample sizes, the impact on generalizability due to a lack of diversity in VR-tested populations (age, gender, type of disease). The selection of health outcomes, and the limited spectrum of medical interventions (IV placement, venipuncture, chemotherapy, and burn care) that have been tested thus far. Due to the emergence and potential value of VR anesthesia, these limitations are now being addressed. Investigators are empirically testing their VR scenarios on selected populations, while recognizing the complex nature and interplay of health outcomes related to invasive medical interventions. Recent studies have begun to use multiple
self-reporters (child, caregiver, nurse) as well as physiological and observable outcomes. As well, researchers have begun to look at brain imaging and neural correlates associated with VR pain distraction. Such continued development of compatible VR systems and the application of scientific rigor to test their value will likely continue to propel the field of VR anesthesia forward.

Future directions in the utility of VR need to further examine both the quantitative and qualitative assessment of participants in order to locate the best participant-to-intervention match; this could lead to the identification of varying patterns among participants/procedures. Building these pathways will further enhance the potential pain distraction properties of VR, thus maximizing the efficacy of the intervention.

**VR applications in anesthesia**

Ten years ago, a review of VR in anesthesia noted a substantial gap between the existing technology and potential VR applications. Since that time, there have been significant developments seeking to bridge that gap, including high performance video cards, enhanced LCD displays, and object-oriented programming. Additionally, the past decade has witnessed a flourishing of collaborative efforts on the part of industries and academia, especially concerning research training and methodology; these efforts were perceived as essential to the continued rise of VR in medical practices.

Given the current state and growing affordability of VR technology for clinical application, the known limitations, recent advances, and ongoing evaluation, VR pain distraction has considerable promise in pain management. Specifically, VR anesthesia may hold promise for a diversity of routine medical interventions that traditionally require significant pharmacological intervention. Although VR anesthesia has demonstrated promise for decreasing pain, fear, and anxiety, it may also decrease additional pharmacological needs, such as sedatives and anxiolytics, therefore decreasing overall risks associated with sedation. Future investigations will benefit from evaluating pharmacological needs associated with painful interventions as a result of VR anesthesia and how this may vary due to the type, severity, and enduring nature of the specific pain or procedure.

**Appendix: A brief summary of VR technology**

The term “virtual reality (VR)” was first introduced to our society in the early 1980s by Jaron Lanier. Virtual reality, later defined as an advanced human–computer interface that simulates a realistic environment and allows participants to interact with it, was initially used by aero-space and defense industries for the purpose of flight and warfare simulation training.

VR systems are comprised of: VR software; a computational device; advanced computer graphics; an image and audio display system; a tracking device that tells the computer where the user is looking based on head movement; and interaction devices such as a joystick or data glove. A critical factor of running VR software is the cost of rendering the polygons used in creating the virtual environments to provide real-time displays. Recently, due to the rapid development of personal computers and video card technology, most VR software can be run on PCs, and even on laptop computers.

The most popular VR image display is a head-mounted display (HMD); in other words, the VR is projected onto video screens that are embedded in a scuba mask-like device that rests upon a person’s head. The main components of HMDs are liquid crystal device (LCD) display screens, optics designed to present a focused image on a screen, and sound equipment (ie, earphones or headphones). Although the majority of technological advances in VR have focused on helmet HMDs, another type of HMD exists that consists solely of an eyeglass displays. The advantages of helmet HMDs are visual occlusion from real world stimuli and stereo speakers that enhance the immersive VR experience. Initial prototypes for helmet HMDs were heavy and bulky, causing significant neck and back pain. Therefore, current helmet HMDs are much lighter and smaller; for example, a helmet HMD for military training, with XGA resolution (1024 × 768), weighs less than 2.5 kg. Some commercial helmet HMDs, which can display SVGA (800 × 600), usually weigh less than .5 kg.

The least cumbersome HMD resembles a pair of regular eyeglasses with a built-in LCD screen. In spite of its less immersive nature, this HMD has definite advantages. Most HMDs are developed for the users who are in a sitting or standing position; however, eyeglass-display HMDs can be used in patients that are in the supine or decubitus position. Furthermore, if the medical procedure happens around the face (eg, mask induction, dental treatment), the larger helmet-like HMDs are actually a hindrance rather than assistance to the procedure. Several types of eyeglass-display HMDs with head trackers are already available in the VR commercial market.

Tracking devices tell the computer the position of the user in order to create a sense of presence by moving the image displayed as the user moves. The methods used to detect changes in positions include: electromagnetic, mechanical, optical, ultrasonic, and inertial. Current VR pain distraction utilizes HMD tracking mechanisms. Clinical investigations have demonstrated that more than a 50 -ms lag between position detection and changes to the virtual environment can cause a person to experience simulator sickness, which is the most common side effect from VR. Tactile feedback devices are still in the midst of development. Healthy and clinical (ie, rehabilitation)
populations have tested with various types of tactile feedback, including a joystick with a built-in rumble pad (it vibrates to simulate movement), a rumble chair, a vibrating chair, and an interaction vest that delivers pressure to the chest or back.

A decade ago, high resolution, fully rendered real-time VR displays cost an astounding 100,000 British pounds. Fortunately, the price of an affordable VR computing system is now around $1,500, with 3D HMDs going for $1,000 to $3,000, and an affordable head tracker costing about $1,000.

Pain distraction, particularly for chemotherapy and venipuncture, is most effective when it soothes the patient in addition to providing sufficient engagement. For this reason, commercial video games are usually inadequate for VR pain distraction, which has led several VR researchers to either develop or modify existing software. One of the most well studied clinical VEs is “SnowWorld.” In 1996, Hoffman and his colleagues developed a VE for burn patients known as “SnowWorld,” which produces the illusion of flying through an icy canyon with a frigid river and waterfall, as snowflakes drift down. Patients were able to throw snowballs at snowmen and navigate through an environment that depicted a cool and serene world.

Another clinically investigated VE, known as “Bush Soul,” was originally created as an interactive art installation by Rebecca Allen, a graphic artist at UCLA. It was later modified for clinical purposes, exposing patients to an otherworldly plant-inhabited planet in which a person explores a surreal and responsive world. In recent years, many commercial companies have developed more sufficient VR software for pain distraction, such as 5DT’s (Fifth Dimension Technologies) Virtual Reality Pain Distraction Software (VRPDS), which includes two VEs: “Street Luge” and “Jolly Jumpin Jellies.” Although “Street Luge” has been tested in clinical settings, “Jolly Jumpin Jellies” has yet to be explored as a suitable VE for clinical care.

Future research exploring VR distraction in children and adolescents should place more emphasis on matching environments to a patient’s age and gender. In our experience, an 8-year-old child could adapt easily to driving through a VR world, however, for a child under 7, a more controllable environment is preferential. For younger children, it is more appropriate to use familiar characters, such as animals or cartoonish figures, with bright backgrounds, to avoid the onset of fear or anxiety from the introduction of an alien environment. Additionally, researchers are now trying to introduce the concept of “multiple players” to enhance the patient’s presence within the VE. Hoffman is currently developing a “SuperSnowWorld” which would allow a patient and his or her caregiver to see each other’s avatars and work together.

References


32. Schneider SM: Using virtual reality as a distraction to mitigate chemotherapy symptoms, in the Proceedings of the 11th International Conference on Human Computer Interaction, 2005


