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Topical review

Virtual reality for persistent pain: A new direction for behavioral pain management

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1. Introduction

Recent research indicates that immersive virtual reality (VR) can be used as a tool in treating acute pain [9,22,24]. For example, VR-based behavioral interventions have been used to decrease acute pain among individuals undergoing painful medical procedures (eg, wound cleaning of burn injuries [9,13,14,21], urological endoscopies [35]), physical therapy (eg, for blunt force trauma [15], for burned skin [11,12]), dental pain [5,10], and experimental pain in healthy volunteers (eg, thermal pain) [16,17]. Although these data suggest that VR holds promise as a tool to help reduce acute pain, there has been limited investigation on the use of VR in the treatment of patients with persistent pain.

The purpose of this topical review is to identify and highlight ways in which VR can be used either alone or in combination with other treatments for persistent pain. The review is divided into 3 parts. First, we briefly describe VR methods currently used in the management of acute pain. Second, we discuss several potential applications of VR as a behavioral intervention for persistent pain. Third, we highlight important future directions for research in this area.

2. VR for acute pain: previous research

VR-based behavioral interventions have been used in acute pain management for over a decade [11]. VR-based interventions often have been developed as an adjunctive intervention designed to distract patients from acute pain that has not responded to conventional approaches,such as opioid medications [9,12,13,21]. The rationale for the use of VR-based distraction for acute pain is that because pain requires conscious attention, VR draws attention into the computer-generated world, leaving less attention available to process incoming pain signals.

In most VR approaches to acute pain management, an immersive virtual environment is selected that is likely to divert attention away from acute pain, such as SnowWorld [9,21]. In SnowWorld, patients can use a computer mouse to maneuver around and interact with (eg, by throwing snowballs at snowmen, penguins, and wooly mammoths) a snow-covered virtual environment while listening to music. Display devices that can be used to display virtual environments used in distraction interventions can range in complexity and cost, from fully immersive environments, such as SnowWorld, displayed in a wide field of view with a high-resolution, head-mounted display on the high end, to desktop computers that use inexpensive polarized or shutter glasses in combination with stereoscopic projectors or large 3-D monitors.

3. Potential applications of VR to persistent pain

3.1. VR for distraction

Distraction methods such as counting strategies, visual distraction, and audio distraction are components of many cognitive–behavioral therapy protocols for chronic pain [19,33]. The question arises: under what conditions might VR prove particularly useful

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or necessary as a distraction method for chronic pain? VR may be particularly useful for individuals with persistent pain who have difficulty diverting their attention away from or disengaging their attention from ongoing pain [31].

There is evidence that VR can enhance the level of immersion in a distracting environment and that this occurs even when an individual is experiencing pain [31]. Repeated VR trials in which a person with persistent pain is exposed in a laboratory to a highly engaging virtual environment (eg, SnowWorld [9]) are one way to build confidence in one's ability to use distraction for pain control. One might expect an enhanced sense of immersion if the VR technology uses head, hand, or body tracking to foster interaction with the scene [18]. New haptic devices potentially enable one to combine visuals, sound, touch, and smell (olfactory displays) that can further enhance a sense of immersion.

3.2. VR for pain-related movement patterns

One of the major challenges of living with persistent pain is that pain is typically increased when a patient moves the painful body area. The increases in pain that occur during movement can be substantial and can lead patients to avoid and become fearful of daily activities such as walking or transferring from one position to another [32].

VR potentially provides a way of exposing patients to movements that they may avoid because of pain or fear. One can also easily move a patient from one VR environment to another, thereby enabling rapid and broad exposure to many different challenges. Along these lines, Gromala et al. [8] have used VR to help patients cope with pain that can occur during walking. They have developed a virtual walk in which the patient is on a treadmill while wearing VR headgear. The patient is watching an avatar that is walking in a slow and mindful fashion through a virtual environment. During the walk, physiological responses are monitored, and visual (3-D display) and auditory feedback is provided to the patient with the goal of fostering relaxation and decreasing pain. Arceneaux et al. [1] also have described a VR device for managing walking-related pain.

Recent advances in VR technology designed to accurately simulate walking and stopping during interaction with topographical features (eg, experiencing the slope force simulating the grade of a virtual hill) or virtual stair climbing offer the possibilities of enhancing the sense of immersion and presence of such treadmill-based VR walking environments [4,34].

VR technology can also be used to simulate movement of specific body parts that the patient is unable to control or avoids using. Cole et al. [3] have demonstrated VR is an effective way to reduce phantom limb pain in both arm and leg amputees; they used motion capture from patients' stumps to generate simulated motion in a virtual limb. When compared to a control group using basic pain distraction methods, amputees who used this VR technology reported far lower levels of phantom pain in the affected arm or leg. In a small series of amputees having phantom limb pains ($n = 5$), VR has been used to provide mirror visual feedback of movement patterns that reduces pain [25]. Ramachandran and Seckel [30] have suggested that a similar approach could be used to treat persons with fibromyalgia who experience pain during movement.

3.3. Integrating VR with other behavioral interventions

VR also can be combined with other behavioral interventions that are currently being used to treat persistent pain. The behavioral intervention that has received the most attention in VR pain research is hypnosis. Patterson et al. [28] pioneered the use of hypnosis delivered via a VR environment in the treatment of pain. In a case study of a patient with a severe burn injury, he found that a VR hypnosis protocol reduced pain by up to 40%. A subsequent series of 13 cases of patients with burn injuries reported by this group [29] found the VR hypnosis not only produced substantial decreases in pain and anxiety, but also reduced patients' requirements for opioid medications by 50%. Oneal et al. [26] published the first study to test the effects of a VR hypnosis protocol for chronic pain. In this study, the effects of 33 sessions of VR hypnosis were evaluated in a patient whose chronic neuropathic pain had failed to respond to prior conventional medical treatment. After VR sessions, the patient reported either no pain or a reduction of pain for hours afterward. A limitation of the study, however, was that 1 month after completing treatment, the patient's pain ratings had returned to their pretreatment level. Further research is needed to determine whether more VR or additional training in maintenance strategies could enhance the long-term effects of this VR protocol.

There are several reasons for integrating VR with established behavioral interventions for pain [2]. First, such a combined intervention may be beneficial for patients who fail to respond to a conventional behavioral treatment such as meditation or hypnosis [26]. Second, VR can standardize the presentation of images, instructions, and environmental sounds used in hypnosis (or other behavioral interventions) for persistent pain [2,27]. Finally, once patients have achieved enhanced pain control via a combined VR/behavioral intervention protocol, they may be more motivated and more successful with practicing the behavioral intervention on its own in their home environment. Given the promising results of VR hypnosis for acute pain, future research seems warranted to explore other proposed VR/behavioral treatment combinations—for example, VR in combination with meditation [7] or VR in combination with exposure therapy [23].

4. Future directions

VR technologies are rapidly evolving. One of the most promising areas for future study is developing and evaluating tailored VR environments that are optimally effective in pain control for a given patient. In the future, it may be practical to tailor VR environments on the basis of visual, auditory, tactile [31], and even olfactory stimuli [6]. Tailoring of VR not only could enhance the sense of immersion and presence in the VR environment, but it could also enhance pain control, thereby making training processes more efficient and more readily available to larger numbers of patients. As costs of VR equipment continue to drop and increasingly accessible ways of delivering VR become available (eg, VR delivered by home computers coupled with low-cost 3-D television displays and 3-D input devices), it will become more practical to use home-based training for patients with persistent pain.

Several key questions remain to be addressed if the promise of home-based VR for pain control is to become a reality. First, we need to better understand the mechanism or mechanisms by which VR effects pain. If VR primarily works through distraction, then efforts should be made to ensure that the displays used continue to be sufficiently complex and novel. On the other hand, if VR works by fundamentally altering the way we think of and perceive reality (eg, by creating a sense of being present in a different state), then the technology required may simply need to be sufficient to create a sense of immersion. Second, developmental research is needed to ensure that specialized VR pain control applications work as well in the home as, for example, a game played on a game console. Much of this work will be at the human–computer interface, where methods need to be developed to ensure that VR applications work as well at home as in laboratory settings. There may also be challenges on the hardware side, though new technologies may help. For example, Microsoft Kinect is a new camera-based VR input device that is unobtrusive and eliminates the need for wires and gloves. New displays such as autostereoscopic displays (no glasses needed) are likely to provide a more user-friendly component that is much less prone to breaking, running out of battery power, or otherwise causing problems that could disrupt home-based VR training.

There is a clear need for studies to help develop and refine VR protocols for managing persistent pain. The efficacy of VR in different populations of persons having persistent pain needs to be determined. The efficacy of VR for persistent pain may vary across age groups. Evidence indicates that older adults report lower ratings of pain when exposed to pain while being presented with an immersive VR protocol [20]. New software technologies are needed to support the creation of custom environments. New 3-D modeling and VR design software may be developed with the goal of making designing custom VR therapies as easy as sketching a storyboard and related 3-D models, perhaps as in the style of SketchUp (http://www.sketchup.google.com/).

One important research issue is how to enhance generalization of treatment effects from a VR environment to daily situations in which pain is a problem. Several strategies could be used. First, laboratory- or home-based VR training could be combined with a more portable behavioral intervention. Second, one can now construct a 3-D stereoscopic VR display for a smartphone that can be linked to customizable VR software (http://www.projects.ict.usc.edu/mxr/diy/) that could potentially be adapted for use in pain management. Finally, in VR, one can directly expose patients to progressively more difficult pain-related situations inside the clinic in order to foster more adaptive coping responses to pain.

In summary, research on VR interventions for persistent pain is in its infancy. This technology, however, holds considerable promise. It is our hope that pain researchers and clinicians will more actively pursue research and clinical efforts so that this promise may be realized.

Conflict of interest statement

The authors report no conflict of interest.

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