Seminars in Anesthesia, Perioperative Medicine and Pain (2005) 24, 203-210

ELSEVIER

Seminars in Anesthesia, Perioperative Medicine and Pain

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

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KEYWORDS:
Virtual reality (VR);
Pain distraction;
Pain management;
Medical intervention

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.

Pediatric acute pain management is a goal that all clinicians aspire to achieve for their patients in the emergency department, hospital settings, and in community practice. Although often challenging and daunting, excellent pediatric pain management has been shown to have implications for child and family satisfaction, healing, and other functional outcomes, including academic, social, psychological, and physical functioning. Conversely, poor pain management has been associated with poor consumer satisfaction, delayed healing, and lower functioning. To this end, attempts to minimize pain and distress associated with routine acute medical interventions (ie, venipuncture) as well as more invasive procedures (ie, wound care, port placement, chemotherapy) have been identified as a vital endeavor.[1]

In the pediatric pain literature, studies have focused primarily on developmentally appropriate interventions including coping strategies suggested by the U.S. Department of Health and Human Services, such as imagery, breathing, relaxation, social support, and positive thinking.[2-5] Although these simple forms of distraction have received attention and validation in practice, other forms of distraction have emerged, such as cartoons, multimedia television, Game Boy™, and virtual reality. This later set of pain distracters is based on two significant theories: Gate Control

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0277-0326/$ -see front matter © 2005 Elsevier Inc. All rights reserved.
doi:10.1053/j.sane.2005.10.005

Theory (GCT)[6] and the limited-capacity of attention.[7-9] 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.[10]

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.[6] 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.[7-9] 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.[10] 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.[11]

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.[12,13] 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.[14,15] The more immersed an individual becomes, the more that person feels like a part of the virtual world.[16] 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.[17] 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.[18]

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.[19] 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.[20] Two male patients, ages 16 and 17, were recruited for the study; the former had a deep