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The effectiveness of virtual reality distraction for pain reduction: A systematic review

Kevin M. Malloy, Leonard S. Milling *

University of Hartford, Department of Psychology, 200 Bloomfield Avenue, West Hartford, CT 06117, USA

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ABSTRACT

Virtual reality technology enables people to become immersed in a computer-simulated, three-dimensional environment. This article provides a comprehensive review of controlled research on the effectiveness of virtual reality (VR) distraction for reducing pain. To be included in the review, studies were required to use a between-subjects or mixed model design in which VR distraction was compared with a control condition or an alternative intervention in relieving pain. An exhaustive search identified 11 studies satisfying these criteria. VR distraction was shown to be effective for reducing experimental pain, as well as the discomfort associated with burn injury care. Studies of needle-related pain provided less consistent findings. Use of more sophisticated virtual reality technology capable of fully immersing the individual in a virtual environment was associated with greater relief. Overall, controlled research suggests that VR distraction may be a useful tool for clinicians who work with a variety of pain problems.

Contents

1. Introduction

Pain is perhaps the most universal of medical complaints. A recent survey conducted by the Centers for Disease Control found that one in four U.S. adults had suffered a day-long episode of pain in the previous month and one in ten said that the pain had lasted a year or more (National Center for Health Statistics, 2006). Pain can be caused by injury, disease, or invasive medical procedure (e.g., bone marrow aspiration). It can be acute, intermittent, or chronic in nature. The costs to society of pain are staggering. For example, a survey of 28,902 working U.S. adults estimated that lost productive time due to absence and reduced job performance from common pain conditions cost $61.2 billion per year (Stewart, Ricci, Chee, Morganstein, & Lipton, 2003).

A variety of psychological methods have proven to be effective for reducing pain, including cognitive-behavioral procedures (see Butler, Chapman, Forman, & Beck, 2006; Morley, Eccleston, & Williams, 1999) and hypnosis (see Montgomery, DuHamel, & Redd, 2000; Patterson & Jensen, 2003). Distraction is a time-honored psychological pain intervention that has been shown to possess considerable efficacy (see Blount, Piira, & Cohen, 2003; Dahlquist, 1999a,b; Powers, 1999). Typical distraction interventions include deep breathing, listening to

* Corresponding author. Tel.: +1 860 768 4546; fax: +1 860 768 5292.
E-mail address: milling@hartford.edu (L.S. Milling).

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soothing music, and watching a favorite video. Because humans have finite attentional resources, a distraction task that consumes some portion of those resources is believed to leave less cognitive capacity available for processing pain (McCaul & Malott, 1984).

Of late, there has been growing interest in the use of virtual reality technology as a method of pain reduction (Botella, Palacios, Banos, Quero, & Breton-Lopez, 2008; Gorman, 2006; Riva, 2008). In virtual reality, users interact with a computer-simulated, three-dimensional environment. Virtual reality technology provides multi-sensory information that helps the person to become fully immersed in the simulated world. Users wear a head-mounted display helmet, which is a helmet that provides a stereo visual image, thereby creating a sense of space and depth. A motion tracker in the head-mounted display helmet measures the position of the head and adjusts the visual image accordingly. As a result, users feel as though they can look around and move through the simulated environment. Headphones provide sounds that further help the person to become immersed in the virtual world. Input devices such as joy sticks, wands, and data gloves enable users to move through the simulated environment and to interact with virtual objects.

Until recently, evidence of the effectiveness of virtual reality (VR) distraction for pain reduction came primarily from case materials and studies using a one-group pre-post design. Table 1 summarizes the main characteristics of these studies. For novel psychological interventions, case materials and uncontrolled outcome studies can play an important role in identifying potentially useful avenues of investigation and new methods of clinical practice. However, case studies have limited generalizability and the one-group pre-post design is highly vulnerable to internal validity threats (Campbell & Stanley, 1966).

Not surprisingly, past reviews of research on the use of VR distraction for pain reduction have featured these case materials and uncontrolled studies (e.g., Mahrer & Gold, 2009; Wismeijer & Vingerhoets, 2005). However, during the last few years, there have been a growing number of controlled investigations of the effectiveness of VR distraction for reducing pain. Accordingly, this article provides a comprehensive review of controlled studies of the effectiveness of VR distraction for relieving pain. To our knowledge, this is the first comprehensive review limited to controlled research on the effectiveness of VR distraction for pain reduction.

2. Method of review

To be included in this review, studies were required to use a between-subjects or mixed model design in which VR distraction was compared with at least one alternative intervention, or a placebo, attention, standard care, or no-treatment control condition in reducing pain. Studies in which audio-visual glasses were used to passively view scenes, thereby failing to provide an opportunity to interact with a computer-simulated environment, were not considered to be examples of virtual reality (e.g., Sander Wint, Eshelman, Steele, & Guzzetta, 2002). These studies were excluded from the review. An exhaustive search of the PsycINFO and MedLine databases, as well as an examination of related reviews in this area identified 11 studies satisfying these criteria. Search terms included combinations of virtual reality, distraction, pain, analgesia, interventions, and treatment outcomes. Table 2 summarizes the major characteristics of the 11 studies, including type of pain, size and nature of samples, treatment conditions, and key findings. The studies are organized into the following five groups, according to the type of pain: (a) experimental pain; (b) chronic pruritus; (c) port access and venous punctures; (d) IV placement; and (e) burn injuries.

3. Summary of controlled studies

3.1. Experimental pain

Several studies have evaluated the effectiveness of VR distraction for reducing experimental pain experienced by both adults and children. Hoffman et al. (2006) compared the effectiveness of high-tech and low-tech VR equipment in reducing thermal pain. These investigators hypothesized that greater VR *immersion* (i.e., an objective, quantifiable index of the nature of the sensory input delivered by a VR system) provided by high-tech equipment would increase *presence* (i.e., the subjective illusion in the participant's mind that he or she had gone inside the virtual world), in turn producing more pain reduction.

Participants were 77 healthy undergraduate volunteers, ages 18 to 23, who were randomly assigned to one of three conditions. In the *high-tech VR helmet* condition, participants wore a head-mounted display helmet with a 60-degree diagonal field of view. In the *low-tech VR helmet* condition, participants wore a head-mounted display helmet with only a 35-degree diagonal field of view. A larger field of view increases the amount of peripheral vision stimulation, presumably enhancing the illusion of entering the virtual world. While wearing the VR helmet, participants experienced a virtual environment called *SnowWorld*, in which they glided down an icy canyon, aimed at targets by altering their gaze (head orientation), and used a keyboard button to throw snowballs at snowmen, igloos, robots, and penguins. Participants saw the sky when they looked up, a canyon wall when they looked left, and a river when they looked down. They heard sound effects, such as splashing when snowballs hit the river. Participants in the *no-distraction control* condition experienced the pain trials without intervention.

All participants underwent baseline and post thermal pain trials. Participants assigned to the high-tech and low-tech VR conditions were administered the post thermal pain trial while experiencing *SnowWorld*. Results showed that compared with participants in the low-tech VR condition, those in the high-tech VR condition reported greater reduction of pain unpleasantness, worst pain, and time thinking about pain. Consistent with prediction, the results suggest that greater pain reduction is associated with use of high-tech equipment that enhances immersion in the virtual environment.

In a related study by this group, Patterson et al. (2006) evaluated the individual and combined effects of VR distraction and hypnosis on thermal pain. Participants were 103 healthy undergraduates, ages 18

Table 1
Case materials and non-controlled studies of VR distraction for reducing pain.

Study	Methodology	Type of pain	Virtual environment
Chan et al. (2007)	Non-controlled	Burn injury	*Ice Cream Factory*
Das et al. (2005)	Non-controlled	Burn injury	*Quake*
Gershon et al. (2003)	Case material	Port access	*Virtual Gorilla*
Hoffman, Garcia-Palacious, Patterson, Jensen, et al. (2001)	Case material	Dental	*SnowWorld*
Hoffman, Patterson, Carrougher, and Sharar (2001)	Non-controlled	Burn injury	*SnowWorld*
Hoffman, Patterson, Carrougher, Nakamura, et al. (2001)	Case material	Burn injury	*KithchenWorld*
Hoffman et al. (2003)	Non-controlled	Ischemic arm pain	*SpiderWorld*
Hoffman, Sharar, et al. (2004)	Non-controlled	Thermal pain	*SnowWorld*
Hoffman, Patterson, et al. (2004)	Case material	Burn injury	*SnowWorld*
Steele et al. (2003)	Case material	Postsugical	Untitled shooting game

Table 2
Characteristics of studies of VR distraction for reducing pain.

Study	Sample	Virtual environment	Interventions	Summary of key findings
Experimental pain				
Hoffman et al. (2006)	77 students 18–23 years	*SnowWorld*	HT—high tech VR helmet LT—low tech VR helmet C—no VR distraction	HT reduced pain more than LT.
Patterson et al. (2006)	103 students 18–40 years	*SnowWorld*	VR—VR distraction H—hypnosis VR + H—VR plus hypnosis AC—attention control	VR reduced pain regardless of suggestibility level. Suggestibility moderated effect of H and VR + H.
Dahlquist et al. (2007)	40 children 5–13 years	*Finding Nemo* "Jellyfish Race"	ID—Interactive distraction PD—Passive distraction ND—No-distraction	ID increased pain tolerance and threshold more than PD and ND.
Dahlquist et al. (2009)	41 children 6–14 years	*Free Dive*	VR—VR helmet NVR—no VR helmet C—no intervention	VR increased tolerance more than NVR and C in older children; VR and NVR increased tolerance more than C in younger children.
Chronic pruritus				
Leibovici et al. (2009)	24 patients 18–84 years	*Air Lock*	VR—VR distraction NVR—Non VR distraction	No difference in pain between VR and NVR.
Port access and IV placement				
Nilsson et al. (2009)	42 cancer patients 5–18 years	*The Hunt of the Diamonds*	NVR—Nonimmersive VR SC—standard care	No difference in pain between NVR and SC.
Gershon et al. (2004)	59 cancer patients 7–19 years	*Virtual Gorilla*	VR—VR distraction NVR—Non VR distraction C—no-treatment control	VR reduced pulse rate and nurses' pain ratings more than C. No difference between VR and NVR.
Wolitzky et al. (2005)	20 cancer patients 7–14 years	*Virtual Gorilla*	VR—VR distraction C—no-treatment control	VR reduced pulse rate and observer pain ratings more than C.
Gold et al. (2006)	20 pediatric patients 7–12 years	*Street Luge*	VR—VR distraction SC—standard care	VR reduced parents' ratings of how much intervention reduced pain more than SC.
Burn Injuries				
Hoffman et al. (2008)	11 burn patients 4–40 years	*SnowWord*	VR—VR distraction C—no VR distraction	VR reduced pain more than C.
Mott et al. (2008)	42 burn patients 3.5–14 years	*Hospital Harry*	AR—Augmented realty SC—standard care	AR resulted in less pain than SC, especially for long dressing changes.

to 40, who were randomly assigned to one of four treatment conditions. Participants in the *VR* condition experienced the *SnowWorld* environment described in Hoffman et al. (2006) as they underwent a thermal pain stimulus. In the *hypnosis* condition, participants listened to an audiotape that included imagery of traversing a snowy canyon, followed by posthypnotic suggestions for comfort and pain reduction. Thereafter, they were administered the pain stimulus. Participants in the *VR plus hypnosis* condition heard the same hypnosis audiotape, including the posthypnotic analgesia suggestions, and thereafter experienced *SnowWorld* while undergoing thermal pain. Finally, participants in the *attention control* condition listened to an audiotape called 'Relaxing Sound from Nature" and received the pain stimulus.

Results showed that participants receiving VR distraction reduced pain more than participants who did not receive VR distraction. Hypnotic suggestibility moderated the effect of the posthypnotic analgesia suggestions, but not VR distraction. That is, all participants receiving VR distraction reduced pain more than those who did not, regardless of suggestibility level. However, only participants in the high range of suggestibility reduced pain using the post hypnotic suggestions. Likewise, combining VR distraction and posthypnotic suggestions reduced pain more than VR distraction alone only for participants in the high range of suggestibility. The results suggest that VR may be a useful alternative to hypnosis for reducing pain experienced by individuals who do not fall in the high range of hypnotic suggestibility.

Dahlquist et al. (2007) compared the effectiveness of interactive and passive VR distraction in reducing cold pressor pain. Participants were 40 healthy children, ages 5 to 13. Two VR distraction interventions were used in this study. In the interactive VR distraction intervention, participants used a joystick and an adjustable head-mounted display helmet with integrated headphones to play the Sony Playstation 2® *Finding Nemo*® "Jellyfish Race" game. This intervention required participants to manipulate a joystick to control "Marlin," who chases "Dory" while avoiding being stung by jellyfish. In the passive VR distraction intervention, participants wore the head-mounted display helmet to watch and hear prerecorded footage of another individual playing the same game, but they were unable to manipulate the environment.

All participants underwent a baseline cold pressor trial without intervention on Trial 1 and then were randomly assigned to one of three experimental conditions. In the *interactive distraction-first* condition, participants experienced the interactive VR distraction intervention on Trial 2 and the passive VR distraction intervention on Trial 3. Participants in the *passive distraction-first* condition experienced the interventions in counterbalanced order. Participants in the *no-distraction control* condition received no intervention on Trial 2, followed by the interventions in counterbalanced order on Trials 3 and 4.

Participants receiving the interactive and passive VR distraction interventions showed significant improvements in pain tolerance and threshold from Trial 1 to Trial 2, whereas those in the control condition did not. The interactive distraction intervention produced the highest pain tolerance and threshold, whereas no-distraction resulted in the lowest tolerance and threshold. Thus, interactive VR distraction was significantly more effective than passive VR distraction and no distraction in improving threshold and tolerance. The investigators speculated that the interactive VR distraction intervention was the most effective because it alone provided tactile and kinesthetic feedback to participants and because it alone required youngsters to

actively problem solve to win the game. That is, the interactive VR distraction intervention incorporated an active cognitive processing component that the other two conditions lacked.

In a second study in this series, Dahlquist et al. (2009) evaluated whether using a VR head-mounted display helmet enhanced the effectiveness of videogame distraction for children experiencing cold pressor pain. Participants were 41 healthy children, ages 6 to 14. Two distraction interventions were used. In the distraction with VR helmet intervention, participants used a joystick and a head-mounted display helmet with integrated headphones to play a prototype of the videogame *Free Dive*®. In this game, participants experience an underwater virtual environment in which they scuba dive with sea turtles and tropical fish while searching for treasure chests. In the distraction without VR helmet intervention, participants used a joystick to play the same videogame on a computer screen. Thus, the only difference between the two interventions was the use of a VR helmet.

Participants were randomly assigned to one of four conditions in which they underwent either one or two baseline cold pressor trials and then received the interventions in counterbalanced order. Pain threshold and tolerance was significantly higher on Trial 2 for youngsters receiving the interventions than for those undergoing a second baseline trial. Moreover, older children (ages 11–14) achieved greater pain tolerance during the VR helmet intervention than during the non-VR helmet intervention. In contrast, younger children (ages 6–10) experienced no difference in tolerance with the two interventions. Thus, the results indicate that all children achieved gains in pain tolerance using videogame distraction, but only older children (ages 11–14) benefited more when the game was delivered using VR.

Together, the results of these studies suggest that children are likely to benefit more from interactive rather than passive videogame distraction (Dahlquist et al., 2007) and that interactive distraction may be especially beneficial to older children (i.e., ages 11–14) when it is presented using VR technology (Dahlquist et al., 2009).

As a group, these experimental pain studies demonstrate the tremendous potential of VR distraction for reducing pain experienced by both adults and children. The findings of these studies suggest that virtual reality environments which enhance *presence* (i.e., the subjective illusion that the person has gone inside the virtual world) and that incorporate an active cognitive processing component are most likely to be most successful in reducing pain.

3.2. Chronic pruritus

Chronic pruritus is a chronic skin condition lasting longer than 6 weeks that causes an itch, thereby stimulating an urge to scratch. Chronic pruritus can be caused by dermatologic, internal, or psychological factors. It can produce red, flaky, and very itchy skin that can be quite uncomfortable and debilitating for the patient.

Leibovici et al. (2009) evaluated the efficacy of VR distraction for reducing the pain and discomfort associated with chronic pruritus. Participants were 24 patients, age 18 to 84 years, with forms of chronic pruritus (i.e., atopic dermatatits, psoriasis vulgaris) seen in the dermatology department or outpatient clinic of a university hospital. These individuals were randomly assigned to *VR distraction* or *non-VR distraction* conditions. In the VR distraction condition, participants wore a light-weight virtual reality visor with sounds to play *Air Lock*, an interactive game in which they manipulated a computer keyboard to catch rapidly moving, colored balls in a net (F. Magora, personal communication, March 2, 2010). After catching all of the balls in a trial, the screen illuminated. It took between 8 and 10 min to complete the game. Participants assigned to the non-VR distraction condition played the same game on a standard computer screen.

Results showed that there was no difference in self-reported itching intensity between the VR distraction and non-VR distraction conditions during the intervention. However, observer ratings of scratching behaviors during the intervention indicated that 11 of the 12 patients in the VR condition engaged in no scratching and only 1 patient engaged in repeated scratching. In the non-VR condition, only 5 patients exhibited no scratching, whereas 6 patients demonstrated light scratching, and 1 patient engaged in repeated scratching. Unfortunately, formal statistical analyses of the differences in observed scratching were not reported.

3.3. Port access/venous puncture

A port is an appliance surgically implanted beneath the skin through which drugs can be repeatedly injected and blood samples can be drawn. Ports are primarily used to treat cancer patients, including for delivering chemotherapy agents. A venous puncture involves the needle puncture of a vein.

Nilsson et al. (2009) evaluated the efficacy of non-immersive VR distraction to reduce the pain associated with venous puncture and subcutaneous venous port access. Participants were 42 pediatric oncology patients, ages 5 to 18, being treated for leukemia, lymphoma, central nervous system tumors, and other childhood cancers. These patients were assigned to a *VR distraction* condition or a *standard medical care control* condition. It is not clear whether group assignment was random.

The VR distraction intervention utilized an environment called *The Hunt of the Diamonds* in which the youngster "steered" a virtual world using a remote control to catch diamonds floating in an amusement park. The 3-D virtual world provided sights and sounds, although it was described by the investigators as *non-immersive* because the game was not experienced using a head-mounted display helmet. Instead, the game was presented on a standard personal computer monitor.

Patients assigned to the VR distraction condition experienced *The Hunt of the Diamonds* environment while undergoing the venous puncture or port access. Results showed there were no differences between the VR distraction and standard care control conditions on self-report, observational, or physiological indicators of pain. The results are consistent with the position that non-immersive VR distraction may not be a particularly effective intervention for reducing pain.

Gershon et al. (2004) examined the efficacy of VR distraction for alleviating the distress experienced by youngsters undergoing port access. Participants were 59 children, ages 7–19, being treated at an outpatient oncology unit and required to undergo port access as part of their medical treatment. These youngsters were randomly assigned to one of three treatment conditions. In the *VR distraction* condition, patients experienced a virtual environment called *Virtual Gorilla* using a head-mounted display helmet. In the *non-VR distraction* condition, patients experienced the Virtual Gorilla program on a computer monitor. In the *no-distraction control* condition, patients underwent the port access without distraction.

Virtual Gorilla is an educational tool for children visiting the gorilla habitat at Zoo Atlanta. In this program, participants assume the persona of an adolescent gorilla in a virtual gorilla habitat. Participants use a joystick to navigate through the virtual habitat and to interact with other virtual gorillas. Depending on how a participant's gorilla behaves, the other gorillas might respond with happiness or annoyance. After practicing for 5 min, patients used the program during the port access procedure.

Results showed that there was a significant difference between the VR distraction condition and the no-distraction control condition on pulse rate and nurse's ratings of pain. However, the VR distraction condition was not significantly different from the non-VR distraction condition on these variables. There were no significant difference by condition on child, parent, and observers' ratings of pain. The investigators attributed the lack of significant differences to a relatively small

sample size, as well as to low baseline ratings of pain, leaving little room for improvement due to treatment.

In a similar study, Wolitzky et al. (2005) evaluated the efficacy of immersive VR distraction for reducing the pain experienced by children undergoing port access. Participants were 20 pediatric cancer patients, ages 7–14, who were randomly assigned to *VR distraction* or a *no-VR distraction control* condition. The *Virtual Gorilla* environment described in Gershon et al. (2004) was used as the intervention in the VR distraction condition. Participants assigned to this condition wore a head-mounted display helmet and used a joystick to navigate through the gorilla habitat. Participants in the no-VR distraction control condition underwent the port access without VR distraction.

Results indicated that youngsters in the VR distraction condition had significantly lower pulse rate and observer ratings of pain. It should be noted that the observer ratings were carried out by the first author, who was not blind to the treatment condition. Differences on children's self-reports of distress approached, but failed to achieve significance. The lack of differences on this variable may possibly have been a function of a small sample size. Together, the results of Gershon et al. (2004) and Wolitzky et al. (2005) provide limited support for the utility of immersive VR distraction for reducing the discomfort associated with port access and venous puncture.

3.4. IV placement

An intravenous (IV) catheter is used to introduce medications or fluids directly into the bloodstream. The IV catheter is a small plastic tube with a needle inside that helps push the tube through the skin and into the vein. After the tube is placed, the needle is removed and only the tube is left in the vein.

Gold et al. (2006) studied the efficacy of VR distraction for reducing children's distress during IV placement. Participants were 20 children, ages 7–12, needing IV placement for magnetic resonance imaging (MRI) or computerized tomography (CT) scan. Participants were randomly assigned to either *VR distraction* or *standard medical care control* conditions. In the VR distraction condition, participants experienced the *Street Luge* virtual environment in which they raced down hill laying on top of a big skate board. Participants in this condition wore a head-mounted display helmet and navigated through the virtual environment using a rumble pad that provided tactile feedback and music via headphones. Children in the control condition reported a four-fold increase in affective pain (i.e., worry and bother related to pain) following IV placement. In contrast, there was no significant increase in affective pain in the VR distraction condition. However, the change in affective pain and pain intensity did not significantly differ between the VR distraction and control conditions. However, there was a significant difference between treatment conditions on parents' beliefs about how much the intervention had reduced their child's pain. Once again, the very small sample size makes it difficult to interpret the lack of significant differences between the conditions. All in all, the results can best be described as promising, but inconclusive.

3.5. Burn injury

Burn wound care ranks among the most painful of medical procedures. Treatment of a serious burn injury often includes daily "tanking sessions" during which the old bandages are removed, dead tissue is washed away in a hydrotank (i.e., debridement), topical antibiotics are applied, and new bandages are put on.

Hoffman et al. (2008) evaluated the efficacy of VR distraction for reducing the pain associated with burn injury debridement in the hydrotank. Participants were 11 burn patients, ages 4 to 40, with burns severe enough to require inpatient hospitalization at major regional burn center. The virtual environment used in this study was *SnowWorld*, described earlier in Patterson et al. (2006).

A challenge of using virtual reality technology during hydrotherapy is that patients sit partially submerged in a tub of water. Therefore, a standard head-mounted display helmet powered by electricity would not be feasible. Consequently, in this study, *SnowWorld* was delivered using a water-friendly, photonic, nonelectric system. This system provided video images in the form of light from projectors via glass fiber optic cables to a custom VR helmet with two eyepieces positioned about an inch in front of the patient's eyes. The VR helmet offered a 105-degree field of view and completely blocked the patient's view of the real world. Navigation through *SnowWorld* was accomplished using a joystick.

A 6-minute period of the debridement procedure during which the patient had previously experienced the most pain was used to test the effectiveness of this intervention. The 6-minute period was divided into two equivalent 3-minute segments. During one 3-minute segment, patients used VR distraction to reduce the pain. The other 3-minute segment served as a no-treatment control period. Patients were randomly assigned to either *VR-first* or *VR-last* conditions.

Results showed that ratings of worst pain, pain unpleasantness, and time thinking about pain were significantly lower using VR distraction than during the control period. In this design, the first rating period comparing the VR distraction-first group with the no-treatment-first group is equivalent to a standard between-subjects pre-post controlled study. Unfortunately, the investigators did not report analyses of the treatment × order interaction in pain reduction, perhaps because of the small sample size of this study. Patients' ratings of presence in the virtual world (i.e., the extent to which patients felt like they had "gone into" *SnowWorld*) appeared to moderate the effect of the intervention. Patients with presence ratings above the median showed significant reductions on all pain indices, whereas patients with presence ratings below the median did not show significant reductions on ratings of worst pain and pain unpleasantness. Formal moderator analyses were not reported. All in all, the results of this study suggest the potential of this novel, water-friendly system for reducing the pain associated with hydrotherapy debridement.

Mott et al. (2008) evaluated the efficacy of an augmented virtual reality system to alleviate the pain of children undergoing dressing changes for burn injuries. Participants were 42 children, ages 3.5 to 14, receiving dressing changes in the outpatient department of a burn hospital. *Augmented reality* involves projecting a virtual image onto the physical world (rather than immersing the person into a completely artificial environment) and using a hand-held screen to provide visual, auditory and kinesthetic feedback.

Participants were randomly assigned to *augmented reality* or *standard medical care control* conditions. The augmented reality intervention featured a 7 in. LCD screen and a camera into which the child inserted plastic figurines. This created a 3-dimensional character called "Hospital Harry" that the child was instructed via audiotape to manipulate. The standard care condition included the use of distraction, positive reinforcement, relaxation, and an age-appropriate video program. All children received typical analgesic medications.

Results showed that for children with medium dressing times (less than 30 min), there was no difference in self-reported pain reduction between the augmented reality and standard care groups. However, for children with long dressing changes (more than 30 min), the augmented reality intervention resulted in less self-reported pain than standard care. Furthermore, parent observations of their child's pain during dressing changes were lower in the augmented reality condition than in the standard care condition. These findings are especially noteworthy because the youngsters in the standard care condition received many of the typical psychological interventions for managing the pain associated with dressing changes.

Overall, the results of these two studies suggest that both immersive VR distraction and augmented reality distraction may be useful for reducing the excruciating pain associated with burn wound care.

Table 3
Effect sizes for studies of VR distraction for reducing pain.

Study treatment	Control condition	*N*	*d*
Hoffman et al. (2006)			
High-tech VR helmet	No-distraction	49	1.00
Low-tech VR helmet	No-distraction	51	0.52
Patterson et al. (2006)			
VR distraction	Attention control	52	1.38
Hypnosis	Attention control	51	0.46
VR distraction plus hypnosis	Attention control	52	1.01
Dahlquist et al. (2007)			
Interactive distraction	No-distraction	26	1.98
Passive distraction	No-distraction	26	1.98
Gershon et al. (2004)			
VR distraction	Standard care	44	0.66
Non VR distraction	Standard care	37	0.27
Wolitzky et al. (2005)			
VR distraction	Standard care	20	1.01
Gold et al. (2006)			
VR distraction	Standard care	20	0.12
Mott et al. (2008)			
Augmented Reality	Standard care	44	1.60

4. Effect sizes of interventions

An effect size (*d*) was generated for each active intervention in seven of the 11 studies included in this review. Effect size was calculated as the mean difference between an intervention condition and a no-intervention control condition divided by the pooled standard deviation. These standardized effect sizes were then corrected for small sample bias (Hedges & Olkin, 1985) because of the small samples evident in this literature. Effect sizes were not calculated for Leibovici et al. (2009) and Dahlquist et al. (2009) because these studies did not incorporate a no-intervention control condition. They also were not calculated for Nilsson et al. (2009) and Hoffman et al. (2008) because complete posttime descriptive data (i.e., means and standard deviations) were not presented. In generating effect sizes, each of the interventions was compared with a control condition of some kind. Two of the studies used a no-distraction control condition (Dahlquist et al., 2007; Hoffman et al., 2006), one used an attention control condition (Patterson et al., 2006), and the remaining four studies used a standard care control condition (Gershon et al., 2004; Gold et al., 2006; Mott et al., 2008; Wolitzky et al., 2005). Within each study, effect sizes for each intervention were averaged across all indicators of pain (e.g., self-report, observer ratings, and physiological) for which descriptive data were presented.

Table 3 presents VR intervention conditions, comparison and control conditions, sample sizes and mean effect sizes. The table reveals sizeable effect sizes for most of the 8 VR intervention conditions used in the reviewed studies. (The VR plus hypnosis condition used in Patterson et al. (2006) was not included here because it was not considered to be a pure VR intervention.) Cohen (1988) classifies effect sizes of .2 as small, .5 as medium, and .8 as large. According to this yardstick, 2 effect sizes fell in the medium range and 5 in the large range. When the effect sizes were weighted by the size of the samples from which they were obtained, the mean weighted effect size (D) for VR distraction was .94. This indicates that the average subject receiving some form of VR distraction for pain showed more improvement than about 83% of control subjects. Because complete posttime descriptive data were not available for all indicators of pain in many studies, these results should be interpreted with caution.

5. Discussion

The findings of controlled research indicate that VR distraction is an effective intervention for reducing experimental pain, as well as the pain associated with burn injury care. Perhaps the strongest evidence of the potency of VR distraction comes from studies of experimental pain. VR distraction was clearly shown to provide relief to adults undergoing thermal pain (Hoffman et al., 2006; Patterson et al., 2006), as well as children experiencing cold pressor pain (Dahlquist et al., 2007, 2009). Because experimental pain is relatively mild, time-limited, and has no health implications, the extent to which these studies generalize to the treatment of clinical pain is unclear.

On the other hand, in an experimental pain study, the treatment protocol and pain stimulus can be standardized to a much greater degree than in possible in a clinical setting. That is, every participant experiences the identical pain stimulus and every participant can be administered the identical intervention. This would not be the case in a clinical study, where patients would likely experience different types or levels of pain and a treatment protocol might need to be altered to suit the medical needs of the patient. In an experimental pain study, it is easier to regulate potential confounding variables such as demand characteristics and lack of blindness in observer ratings. Thus, clinical pain studies may have greater generalizability, but experimental pain studies permit better experimental control.

As for investigations of clinical pain, evidence of the efficacy of VR distraction was most clear-cut in studies of burn wound care. Hoffman et al. (2008) showed that VR distraction delivered via a water-friendly, photonic, nonelectric system reduced debridement pain experienced by patients, ages 4 to 40. Similarly, Mott et al. (2008) reported that augmented reality distraction alleviated the pain experienced by children, ages 3.5 to 14, undergoing dressing changes lasting longer than 30 min. However, studies of needle-related pain provided less encouraging findings (e.g., Gershon et al., 2004). However, in these studies, it is possible that the null findings may have been due either to small sample size, resulting in low statistical power (Gold et al., 2006; Wolitzky et al., 2005), or to the use of less sophisticated VR technology (Nilsson et al., 2009).

Indeed, a clear pattern evident in this literature is that immersive VR technology is more likely than non-immersive VR technology to generate relief from pain. Specifically, all but one (i.e., Gold et al., 2006) of nine studies that utilized a head-mounted display helmet reported a significant effect on at least one indicator of pain. In the two studies where non-immersive technology was used, neither experiencing a 3-D environment on a standard computer screen (Nilsson et al., 2009) nor wearing a VR visor similar in appearance to oversized sunglasses (Leibovici et al., 2009) were effective in reducing pain. Similarly, a high-tech VR head-mounted display helmet produced more pain reduction than a low-tech helmet (Hoffman et al., 2006). In addition to the greater sense of presence in the virtual world produced by high-tech VR equipment, virtual environments that incorporate an active cognitive processing component may yield more relief from pain (Dahlquist et al., 2007).

Chronic pain is defined as prolonged pain of at least three months duration. Only one study evaluated the effectiveness of VR distraction for relieving a chronic pain condition. Leibovici et al. (2009) reported that there was no difference in itching between VR distraction and non-VR distraction in dermatology patients experiencing chronic pruritus. However, there appeared to be a difference in observer ratings of scratching, although this difference was not tested statistically. Consequently, the results of this lone study on the effectiveness of VR distraction for reducing chronic pain can best be described as inconclusive.

Chronic pain is a particularly intractable, common, and costly health problem (Turk, 2002; Verhaak, Kerssens, Dekker, Sorbi, & Bensing, 1998). Chronic pain poses a special challenge to behavioral health clinicians. When a patient undergoes an invasive medical procedure, it is often possible to arrange for a clinician to be available to deliver psychological interventions of established efficacy, such as distraction, progressive muscle relaxation, guided imagery, and hypnosis. In contrast, it is unlikely that a clinician could always be present when a chronic pain patient is experiencing discomfort. In

such situations, patients are left to manage the pain on their own. No single treatment regimen is sufficient to eliminate chronic pain and a more useful approach is said to combine pharmacological, physical, and psychological elements (Turk, Swanson, & Tunks, 2008). As the cost of VR technology continues to fall, VR distraction may become an increasingly affordable and potentially efficacious self-management tool for chronic pain patients. For example, the head-mounted display helmet and motion tracker used in Gold et al. (2006) currently cost $2995 and $1995, respectively (downloaded from http://www.mining.5dt.net/main_orderform.php on June 21, 2010). More research on the effectiveness of VR distraction for managing chronic pain would seem warranted.

Virtual reality and hypnosis share a common element in that both involve having participants experience an imaginary state of affairs *as if* it were real. Hypnosis has been shown to be a very effective for reducing pain. For example, in their seminal meta-analysis of 23 studies evaluating the effectiveness of hypnotically-induced analgesia, Montgomery et al. (2000) found that the average person treated with hypnosis experienced more pain reduction than 75% of those in no-treatment and standard care control conditions. However, hypnosis was not equally effective for all individuals. This meta-analysis reported that the average effect size was D = 1.16 for participants in the high range of hypnotic suggestibility, D = 0.64 for those in the medium range, and only D = −0.01 for those in the low range. That is, hypnosis essentially had no effect on people falling in the low range of hypnotic suggestibility.

Consistent with these findings, Patterson et al. (2006) showed that posthypnotic analgesia suggestions significantly reduced thermal pain only for participants scoring in the high range of hypnotic suggestibility. In contrast, VR distraction reduced pain for all participants. Of note, only about 25% of the population falls in the high suggestibility range and as many as 45% falls in the low range (Hilgard, 1965; Spanos, Radtke, Hodgins, Stam, & Bertrand, 1983). The findings of Patterson et al. suggest the possibility that VR distraction may be a useful alternative to hypnosis as a method of pain reduction for a large segment of the population.

Several methodological issues evident in this literature should be highlighted. First, researchers need to mindful of the nature of the virtual environments used in their VR distraction interventions. Sophisticated VR technology goes to waste if the virtual environment lacks appeal. For example, scuba diving in a virtual underwater environment (Dahlquist et al., 2009) or throwing snowballs at snowmen in a virtual winter canyon (Hoffman et al., 2008) have tremendous intrinsic allure that could captivate attention for an extended period of time. On the other hand, we could see how a patient might quickly lose interest in exploring a virtual kitchen (see Hoffman, Patterson, Carrougher, Nakamura, et al., 2001). Along these lines, researchers are encouraged to measure the presence and fun produced by their virtual environments and to conduct approriate analyses of the moderator function of these variables on treatment outcome (see Baron & Kenny, 1986).

A second methodological issue concerns the dependent measures used in this literature. Self-report measures provide an index of the person's *pain perception*. Visual analogue or graphic rating scales in which the person rates pain intensity and unpleasantness along a 0–10 scale are examples. Observational measures provide an index of the person's *pain behavior* (e.g., grimacing, crying, and moaning). Self-report and observational measures offer complimentary information. Both types of measures are valuable, so long as the specific instruments are reliable and valid. Several studies used sophisticated behavioral observation rating scales, such as the Children's Hospital of Eastern Ontario Pain Scale (McGrath et al., 1985). However, when observers (e.g., parents and nurses) make a single global rating of a patient's pain perception, the results are inherently unreliable and are particularly vulnerable to demand characteristics such as knowing what treatment the patient received. Future research should strive to avoid this practice.

Finally, we noted that some studies failed to report complete pre and post data for all dependent variables and to perform appropriate statistical analyses. Of note, performing *t* tests on pre-post change scores for each treatment condition increases alpha beyond .05, is subject to a regression to the mean phenomenon, and nullifies the benefits of incorporating a control condition. Also, the absence of pre and post means and standard deviations for all dependent variables in each experimental condition hinders the use of meta-analysis. Consequently, journal editors may wish to require that future studies present complete descriptive data by treatment condition and perform appropriate statistical analyses.

More research is needed on a variety of fronts. First, future studies should compare the effectiveness of virtual reality distraction with well-established psychological methods of pain management such as hypnosis and cognitive-behavioral interventions. Such research can help to determine whether the benefits of using VR equipment to relieve various kinds of pain problems outweigh the monetary costs. Second, additional research is needed on the variables that moderate the effectiveness of VR pain reduction. As previously mentioned, investigators should routinely measure the presence and fun associated with their VR interventions and conduct appropriate moderator analyses to determine under what conditions VR distraction is effective. Finally, future investigations should explore the variables that mediate the effectiveness of VR distraction. To our knowledge, there has been no empirical research on possible biological (Gold, Belmont, & Thomas, 2007) and psychological mechanisms such as expectancy (Kirsch, 1985) and credibility (Devilly & Borkovec, 2000) that might explain how VR distraction works to relieve pain.

6. Conclusions

Ten years ago, Norcross, Hedges, and Prochaska (2002) conducted a Delphi poll on psychotherapy trends expected in the ensuing decade. A panel of 62 psychotherapy experts ranked the use of virtual reality technology 3rd among 38 therapeutic interventions expected to increase the most by 2010. At around the same time, a special issue of *Psychotherapy: Theory, Research, Practice, Training* forecast that the use of computer technology would be one of the major trends in clinical practice over the next 10 years (Wolf, 2003), noting that virtual reality held considerable promise as an intervention for a variety of problems, including distraction from pain (Glantz, Rizzo, & Graap, 2003; Riva, 2003).

However, these rosy predictions were based primarily upon case materials and uncontrolled outcome studies. Ten years later, there is solid evidence from controlled research that VR distraction is effective for reducing experimental pain, as well as the pain associated with burn injury care. The next 10 years will hopefully see the proliferation of methodologically-sound and statistically well-powered controlled studies of the effectiveness of immersive VR distraction for reducing the discomfort associated with a variety of invasive medical procedures, as well as chronic pain conditions.

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