



## Clinical note

# Virtual reality as an adjunctive pain control during burn wound care in adolescent patients

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## Abstract

For daily burn wound care procedures, opioid analgesics alone are often inadequate. Since most burn patients experience severe to excruciating pain during wound care, analgesics that can be used in addition to opioids are needed. This case report provides the first evidence that entering an immersive virtual environment can serve as a powerful adjunctive, nonpharmacologic analgesic. Two patients received virtual reality (VR) to distract them from high levels of pain during wound care. The first was a 16-year-old male with a deep flash burn on his right leg requiring surgery and staple placement. On two occasions, the patient spent some of his wound care in VR, and some playing a video game. On a 100 mm scale, he provided sensory and affective pain ratings, anxiety and subjective estimates of time spent thinking about his pain during the procedure. For the first session of wound care, these scores decreased 80 mm, 80 mm, 58 mm, and 93 mm, respectively, during VR treatment compared with the video game control condition. For the second session involving staple removal, scores also decreased. The second patient was a 17-year-old male with 33.5% total body surface area deep flash burns on his face, neck, back, arms, hands and legs. He had difficulty tolerating wound care pain with traditional opioids alone and showed dramatic drops in pain ratings during VR compared to the video game (e.g. a 47 mm drop in pain intensity during wound care). We contend that VR is a uniquely attention-capturing medium capable of maximizing the amount of attention drawn away from the 'real world', allowing patients to tolerate painful procedures. These preliminary results suggest that immersive VR merits more attention as a potentially viable form of treatment for acute pain. © 2000 International Association for the Study of Pain. Published by Elsevier Science B.V. All rights reserved.

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## 1. Introduction

Burns of a severity requiring hospitalization cause severe pain during wound care (e.g. dressing changes), despite treatment with potent opioid analgesics (Perry, 1981; Choiniere et al., 1989; Everett et al., 1990). Unfortunately, severe burns prompt changes in body chemistry that make controlling pain with pharmacologic therapies more difficult (Cooper and Pavlin, 1990). Perry et al. (1981) indicated that 84% of their patients given a typical dose of morphine still rated wound care pain as severe to excruciating. Since the degree of pain reported during hospitalization is associated with the degree of postdischarge mental and physical dysfunction (Ptacek et al., 1995), improved burn wound

pain management may have practical as well as humane purposes.

While opioid analgesics should be the cornerstone of nearly any burn wound care pain treatment plan, psychological or other pharmacologic interventions should be considered as an adjunct treatment (Patterson, 1992,1995). For example, benzodiazepines have been used to decrease anxiety and pain associated with medical procedures (Patterson et al., 1997). Cognitive-behavioral techniques offer another promising intervention. In essence, such interventions treat internal thoughts as modifiable behaviors and can alter the patient's attention to, and interpretation of, pain signals. Typical applications of cognitive-behavioral interventions for acute pain include avoidance or distraction strategies such as hypnosis (Patterson et al., 1992), mental imagery (e.g. picturing oneself without pain on a tropical island), mental effort (solving math problems during a painful procedure), engaging the patient in conversation, listen-

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ing to music, or watching a video (Geisser et al., 1995; see Tan, 1982 for a review). The efficacy of such techniques are often explained in the context of a gate-control heuristic (Melzack and Wall, 1965; Gasma, 1994). Specifically, attention, beliefs about pain, expectations, and attributions are thought to inhibit or modify the nociceptive signals (Turk et al., 1983).

Burn pain and wound treatment procedures often increase patients' anxiety, and acute pain is exacerbated by such emotional responses (Chapman, 1985; Chapman and Turner, 1986; France et al., 1988). Distraction from anxiety is one of the important uses of cognitive-behavioral techniques, particularly with children. As such, new methods to distract patients from acute pain and associated anxiety will likely be welcome as potential analgesic techniques.

We propose that immersive virtual reality (VR) may be an effective means of distracting patients from burn pain, particularly in pediatric and adolescent populations. Our rationale is as follows: humans have a limited amount of conscious attention available (Kahneman, 1973). Pain requires conscious attention (Chapman and Nakamura, 1998) and draws upon this limited resource. If patients become engrossed in stimuli such as VR, that draw heavily upon conscious attention (e.g. Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977), there will be less of this cognitive resource available to devote to the evaluation of nociceptive input, and patients will subjectively experience less pain (see McCaul and Malott, 1984).

In designing this research, we anticipated that immersive VR would likely be several orders of magnitude more effective than conventional distraction techniques (e.g. video games), particularly in pediatric and adolescent populations. The convergence of multisensory input (sight, sound, touch) gives VR participants a strong illusion of 'going into' the computer-generated environment, a sensation known as 'presence' in the virtual environment. We anticipated that VR would be a uniquely attention-capturing medium capable of maximizing the amount of attention drawn away from the patient's pain, allowing patients with burn injuries to tolerate pain better during wound care without increasing pharmacologic therapy. This notion is tested and reported for the first time in the present study. We predicted that for patients receiving conventional opioid treatment, immersive VR would reduce burn pain (measured using the pain-related measures described below) compared to a 2-D video game control condition.

## 2. Method

For the first session, in addition to their standard pharmacologies, each patient spent 3 min in VR and 3 min playing a video game during wound care. The order in which the treatments were administered was randomized and counterbalanced such that across subjects each distraction treatment had an equal chance of occurring first or

second for each patient. Pain and presence ratings, the primary dependent variables, were administered after each experimental treatment during a brief pause in wound care. At each pause (once after wound care with VR, and once after wound care while playing the video game), patients completed several retrospective 10 cm visual analog scales (i.e. VAS, Huskisson, 1974; Gift, 1989). Patients rated their *Worst pain*<sup>1</sup>, *Average pain*<sup>2</sup>, *Anxiety*<sup>3</sup>, how *Unpleasant* was wound care<sup>4</sup>, and how much their wound *Bothered* them<sup>5</sup>. Patients then rated how much time they spent thinking about their pain and/or burn wound<sup>6</sup>. After wound care, patients in the VR condition were also asked the following ratings using VAS. To what extent (if at all) did you feel nausea as a result of experiencing VR?<sup>7</sup> While experiencing VR, to what extent did you feel like you went into the virtual world?<sup>8</sup> How real did the objects in the virtual world seem to you?<sup>9</sup> Patients also filled out appropriate simulator sickness, presence and realism ratings after the video game control condition. Hendrix and Barfield (1995) describe several studies showing the reliability of a similar subjective measure of presence.

### 2.1. Experimental condition

A Silicon Graphics Octane MXE with Octane Channel Option<sup>10</sup> coupled with a wide field of view head mounted visual display was the primary system used to create an immersive, 3-D, interactive, computer-simulated environment<sup>11</sup>. A stationary Polhemus low energy source detected by movable Polhemus 6df sensors was used to measure the position of the user's head and hand position. Information about the sensor's position relative to the source was fed into the VR computer system. The computer quickly updated the virtual environment presented to the user by changing the viewpoint in VR when the user moved their head. The computer also moved the position of a cyberhand in VR when the user moved their real hand. That is, when the patient moved their hand in the real world, their cyberhand moved accordingly in the virtual world. The patient experienced SpiderWorld (a modified version of Division Ltd's DVS-3. 1.2 KitchenWorld<sup>12</sup> complete with counter-

<sup>1</sup> Where 0 = no pain and 10 = worst pain.

<sup>2</sup> Where 0 = no pain and 10 = worst pain.

<sup>3</sup> Where 0 = no anxiety and 10 = highest anxiety.

<sup>4</sup> Where 0 = not at all unpleasant, and 10 = the most unpleasant.

<sup>5</sup> Where 0 = not at all bothersome, and 10 = the most bothersome.

<sup>6</sup> Where 0 = zero min, and 10 = the entire time.

<sup>7</sup> Where 0 = none and 10 = very much (adapted from Kennedy et al., 1992).

<sup>8</sup> Where 0 = I did not feel like I went into the virtual world at all, 10 = I went completely into the virtual world.

<sup>9</sup> Where 0 = completely fake, 10 = indistinguishable from a real object.

<sup>10</sup> Silicon Graphics, Inc. 2011 N. Shoreline Blvd. Mountain View, CA 94043 USA (650)960-1980 <http://www.sgi.com/>

<sup>11</sup> A Division Provision 100, manufactured by Division Hardware Ltd (no longer in business) was also used for some of the treatments.

<sup>12</sup> Division Incorporated, 1400 Fashion Island Blvd, Suite 510, San Mateo, CA 94404, <http://www.division.com/>

tops, a window, and 3-D cabinets that could be opened. Patients could pick up a teapot, plate, toaster, plant, or frying pan by inserting their cyberhand into the virtual object, and clicking a 'grasp' button on their 3-D mouse. Using tactile augmentation (Hoffman et al., 1996; Carlin et al., 1997; Hoffman, 1998), patients could 'physically' touch the furry body of a virtual Guyana bird-eating tarantula with wiggling legs.

## 2.2. Control condition

A Nintendo 64 video game served as the control condition. Nintendo 64 is an advanced video game system. Unlike the 16-bit computer chip used in most PCs, Nintendo uses a 64-bit graphics chips made by Silicon Graphics Inc., with real-time rendering and CD-quality sound. For the Nintendo game 'Wave Race 64', patients compete in a jet ski race, maneuvering their craft through the wavy water using a joystick. For 'Mario Kart 64', patients maneuver their race car around a slick icy racetrack. The games give users feedback about their performance. We expected these games to be more engaging than other conventional distracters previously used (e.g. passive video tapes), because the user is actively involved in the task (first person experience), and the games are very popular with children and adolescents. However, we also expected the patients' sense of presence to be lower in this condition than in VR.

## 3. Case 1

### 3.1. Patient history

The patient was a 16-year-old male, hospitalized in a major regional burn center. He had 5% total body surface area (TBSA) deep flame/flash burn to his lower right leg sustained from ignited gasoline. For his first experimental session, he used 12 mg of oral hydromorphone (Dilaudid) during wound care, representing 1.6 opioid equivalents (OE) (Carrougher et al., 1998). The following day this patient was taken to surgery for excision and autografting of his burn wound. His second wound care studied (the following week) was the first wound care he received after his skin graft surgery. It involved a dressing change with staple and hypofix tape removal. For this procedure, the patient was given hydrocodone and acetaminophen (Vicodin), representing 0.59 OE.

### 3.2. Results for patient 1

According to 100 mm VAS pain ratings for session 1, VR was dramatically more effective than the video game control condition as a nonpharmacologic pain analgesic. The patient's pain scores decreased 80 mm for sensory pain (worst pain), 66 mm for average pain, and 80 mm for affective pain ratings (unpleasantness). The patient showed an 86 mm drop in bothersomeness, a 58 mm drop in anxiety, and a

93 mm reduction in the amount of time spent thinking about his pain during wound care. More specifically, during wound care, the patient reported spending 95% of the time thinking about his pain while playing the video game, and 2% of the time thinking about his pain while in immersive VR. As predicted, on a 100 mm scale with 100 = high, the patient rated his sense of presence much higher in VR than in the video game condition (100 mm vs. 17 mm, respectively), and he rated the realism of objects higher in VR than for the video game (55 mm vs. 11 mm, respectively). Simulator sickness was zero for both conditions.

For his second session, patient 1 was tested during staple removal from his grafted burn wound. Six staples were removed during VR, and five were removed while he played the video game Mario Kart 64. In VR, the patient's pain scores decreased 30 mm for sensory pain (worst pain), 31 mm for average pain, 27 mm for affective pain ratings (unpleasantness), a 79 mm drop in bothersomeness, a 22 mm drop in anxiety, and he showed a 53 mm reduction in the amount of time spent thinking about his pain during wound care compared to the video game control condition. Consistent with predictions, the patient also rated his sense of presence much higher in VR than for the video game (81 mm vs. 11 mm, respectively) and he rated the realism of the objects higher in VR than for the video game (71 mm vs. 02 mm for VR and video game respectively). Simulator sickness was rated zero in both conditions.

The patient returned for a third VR experience 1 week later (no wound care involved). He entered VR to determine whether his sense of presence would continue to drop with each treatment due to a reduction in the novelty of VR, and also to determine whether simulator sickness became a problem for longer exposures to SpiderWorld. The patient explored SpiderWorld for 10 continuous minutes. Presence in VR was 96 mm out of 100 (where 100 high presence). Simulator sickness was rated zero. Pain measures were not administered since the patient was no longer having trouble with pain. The video game condition was not used during this session.

## 4. Case 2

### 4.1. Patient history

The second patient was a 17-year-old male hospitalized at the same center. He had deep flash burns to his face, chest, back, stomach, upper legs, and both sides of his right arm, covering 33.5% of his total body surface area. He required skin grafting to his neck, chest and stomach. Donor skin was harvested from the uninjured portion of his back and the calves of his legs. As indicated by the staff, he experienced unusually high levels of pain during wound care. He used 14 mg of oral hydromorphone during the dressing change procedure. Wound care was restricted to removal of the

adherent dressing over his fragile donor site (back area), thus he was unable to observe the wound care.

#### 4.2. Results for patient 2

Patient 2 showed a 47 mm drop in pain intensity (worst pain), a 35 mm drop in average pain, a 55 mm drop in affective pain (unpleasantness), a 39 mm drop in bothersomeness, a 27 mm drop in anxiety, and a 61 mm drop in the amount of time spent thinking about this pain during wound care in VR compared to the control condition of playing a video game (see Fig. 1). The patient rated his sense of presence much higher in VR (43 mm) than in the video game (0 mm) and rated realism of the objects higher for VR (35 mm) than the video game (18 mm). The patient care nurse removed equal amounts of dressing from areas of newly healed and sensitive donor site skin from the same area of the patient's back during VR and the video game.

### 5. Discussion

These two cases provide preliminary evidence that entering a virtual environment can help control burn pain during wound care. The first patient's pain ratings showed considerable reduction while in VR relative to a video game control condition. While in VR, the patient's pain scores decreased dramatically for sensory pain, affective pain, anxiety, and he showed a large reduction in the amount of time spent thinking about his pain during wound care. VR and the video game control condition differed with respect to the patient's ability to physically look at his burn wound. In VR this was not possible; in the video game, this was possible for patient one, and nurses informally observed that he looked over at his wound briefly several times during the video game condition. The patient's inability to see the burn wound while in VR may have contributed to the reduction in the patient's pain. Simulator sickness was not a problem in this study but should be monitored closely in any medical

use of VR. Presence remained high for three immersions with no sign of habituation. The second patient had a large severe burn and experienced considerable difficulty with his wound care pain. Like subject 1, he showed dramatic drops in wound care pain during VR compared to the video game control condition. Since this patient's wound care was on his back, he was unable to see the burn wound in either condition, eliminating visibility of the wound as a confound between VR and video game conditions for this patient.

VR systems provide computer-generated sensory input to several senses (e.g. sight, sounds, touch). Such converging evidence, and the interactive nature of the experience, can make the virtual world presented difficult for the brain to ignore. Immersive VR is uniquely effective for giving participants the illusion of going into the virtual environment. This sense of presence is the essence of immersive VR (Laurel, 1995). Hoffman et al. (1998) speculate that the strength of the illusion of presence in the virtual world reflects the amount of attention drawn into the virtual environment. The effectiveness of VR distraction treatment may depend on how present patients feel in the virtual environment.

Undermedication is a problem that contributes to inadequate pain management (Melzack, 1990). Unfortunately, higher doses of morphine-based drugs increase the likelihood of side effects like respiratory failure, nausea, encephalopathy and constipation. Health care professionals also may worry (albeit unnecessarily) that patients will become addicted (Melzack, 1990) and must take into consideration the often large number of medications involved for a single patient. (Patient 2 experienced over 30 wound care procedures at the time of this writing). The potential applications of VR to pediatric populations is particularly appealing since children are severely undertreated for acute pain and anxiety (Melzack, 1990). Worsening the situation, children often develop strong conditioned responses to stimuli associated with burn pain wound care procedures (Patterson, 1995). Visual cues associated with dressing changes (e.g. the appearance of the nurse who cleans their wounds) can create anxiety that exacerbates the pain. By combining the use of classical conditioning principles with VR treatment, caregivers can minimize the impact of aversive conditioning. Anxiety-inducing sights and sounds common to the hospital environment (e.g. surgical tools, the nurses outfit, blood, disfigured wounds typically visible during procedures) are blocked out by the VR helmet.

Both patients in this study reported that VR reduced their awareness of pain. They appeared to be so devoted to the VR task that they did not think often about their pain while in VR. Unlike opioid analgesics which allow patients to consciously reflect upon the effectiveness of the drug, with distraction patients appear less aware that their pain has been reduced until after they come out of VR. This would appear to be a different route of analgesia than of opioid based pharmacologies, the latter of which is thought to rely on the physiological effects of binding with pain-

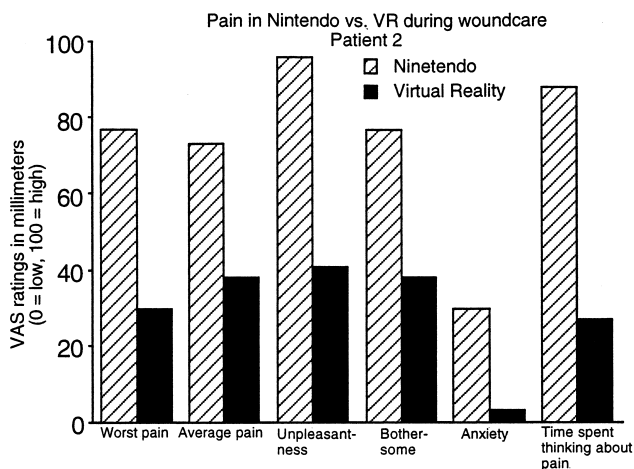


Fig. 1. Drops in pain ratings in VR compared to Nintendo64 (for patient 2).

reducing agonists. When patients come out of VR, their subjective experience of pain returns. Since patients can only conveniently remain in the VR environment for limited periods of time, this technique is perhaps best suited for procedural pain (although it may also prove valuable for 'breaks' from chronic pain).

This report involves two case studies and the substantial limitations of this methodology are well known (Campbell and Stanley, 1963). Although case studies are a good vehicle for presenting innovative techniques, evidence for effectiveness requires converging results from larger, more generalizable, carefully controlled studies. Future research might explore whether a VR world that generally leads to a high sense of presence is more effective than a VR world that generally leads to a lower sense of presence. Experimentally manipulating presence will lead to a better understanding of the relation between presence and pain, helping us achieve maximal nonpharmacologic analgesia. Since patients will not know presence is being manipulated, findings could greatly reduce the viability of a demand characteristics/placebo effect explanation for the efficacy of VR pain control. If controlled experiments show VR has analgesic effects, research will be needed to assess whether VR remains effective for pain management with repeated use and how to maximize longevity. Because burn injuries offer a paradigm for management of acute pain in general, the results of these investigations will likely be generalizable to other causes of acute pain.

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