

STANDING COMMITTEES

Academic and Student Affairs Committee

Research Spotlight: Immersive Virtual Reality, a non-pharmacologic analgesic for U.S. soldiers during painful burn wound cleaning sessions (for combat-related burn injuries)

INFORMATION

For information only.

BACKGROUND

Virtual Reality (VR) Analgesia technique invented by Hoffman and Patterson at the UW helps reduce pain of U.S. soldiers during painful severe burn wound cleaning sessions.

In 1996, Hunter Hoffman and David Patterson co-originated the new technique of using immersive VR for pain control and began collaborating with Sam Sharar, MD shortly thereafter. Hunter is a VR researcher from the UW Human Interface Technology Laboratory with a background in human cognition and attention. Since 1993 he has been exploring ways to increase the illusion of going inside virtual worlds (presence), how VR affects allocation of attentional resources, and therapeutic applications of VR.

SnowWorld, developed at the University of Washington HITLab in collaboration with Harborview Burn Center, was the first immersive virtual world designed for reducing pain. SnowWorld was specifically designed to help burn patients. Patients often report re-living their original burn experience during wound care, SnowWorld was designed to help put out the fire.

This interdisciplinary team puts burn patients, including veterans, into VR during wound care and physical therapy. Although this line of research is just beginning (with funding from NIH, the Paul Allen Foundation), Dr. Hoffman and his team are already finding significant drops in how much pain the patients experience during their short visit to virtual reality.

More information about Dr. Hoffman's work and Snow World can be found [here](#).

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Research Spotlight: Immersive Virtual Reality, a non-pharmacologic analgesic for U.S. soldiers during painful burn wound cleaning sessions (for combat-related burn injuries) (continued p. 2)

BIOGRAPHICAL INFORMATION



As an undergrad at the University of Tulsa, Hunter studied memory with Pawel Lewicki, magical thinking with Leonard Zusne (foreshadowing Hunter's later interest in VR) and bio-electromagnetics with Dr. O'Connor (foreshadowing Hunter's current interest in fMRI). Prior to grad school, Hunter then spent a year conducting memory research with Marcia Johnson at Princeton University on "reality monitoring": How people separate memories of real from memories of imagined events. He also studied perception using "illusory conjunctions" with Bill Prinzmetal. Marcia helped him get into graduate school at the University of Washington in Seattle where he worked with legendary eyewitness memory expert Elizabeth Loftus, famous for her research on the malleability of human memory for crimes, accidents, and childhood events, e.g., memory distortions caused by information encountered after the memory was formed. In grad school, he also studied the relation between attention and memory with Geoff Loftus, which influenced his future research in VR analgesia.

Hunter received a PhD in Cognitive Psychology (human memory and attention) at UW in 1992 and continued his post-doctoral research on social influences on memory with Larry Jacoby in Canada. In 1993, Hunter returned to Seattle and began virtual reality research at the UW Human Interface Technology Laboratory (HIT), one of the largest VR research laboratories in the world. The HIT laboratory was founded and is directed by Professor Tom Furness, one of the fathers of virtual reality.

Attachments

1. Pain Control During Wound Care for Combat-Related Burn Injuries, Journal of CyberTherapy and Rehabilitation, Summer 2008
2. Virtual-Reality Therapy, Scientific American, August 2004
3. Immersive Virtual Reality: Additional Information for Board of Regents

PAIN CONTROL DURING WOUND CARE FOR COMBAT-RELATED BURN INJURIES USING CUSTOM ARTICULATED ARM MOUNTED VIRTUAL REALITY GOGGLES

Christopher Maani, MD¹, Hunter G. Hoffman, Ph.D², Peter A. DeSocio, DO¹, Michelle Morrow¹, Chaya Galin¹,
Jeff Magula², Alan Maiers¹, and Kathryn Gaylord¹

We describe the first two cases where virtual reality was added to usual pain medications to reduce excessive pain during wound care of combat-related burn injuries. Patient 1 was a 22 year old male who suffered 3rd degree burns on 32% of his body, including his right hand, during a roadside bomb terrorist attack in Iraq. The nurse administered wound care to half of the right hand during VR and the other half of the same hand during no VR (treatment order randomized). This patient was the first to use a unique custom articulated robotic-like arm mounted VR goggle system. Three 0-10 graphic rating scale pain scores for each of the two treatment conditions served as the primary dependent variables. The patient reported less pain when distracted with VR. "Time spent thinking about pain" dropped from 100% during no VR to 15% during VR, "pain unpleasantness" ratings dropped from "moderate" (6/10) to "mild" (4/10). Wound care was "no fun at all" (0/10) during no VR but was "pretty fun" (8/10) during VR. However, Patient 1 reported no reduction in worst pain during VR. Patient 2 suffered 2nd and 3rd degree burns when his humvee was hit by a terrorist's rocket propelled grenade in Iraq. During his wound care debridement, "time spent thinking about pain" was 100% (all of the time) with no VR and 0 (none of the time) during VR, "pain unpleasantness" ratings dropped from "severe" (7/10) to "none". Worst pain dropped from "severe" (8/10) to mild pain (2/10). And fun increased from zero with no VR to 10 (extremely fun) during VR. Although preliminary, using a within-subjects experimental design, the present study provided evidence that immersive VR can be an effective adjunctive nonpharmacologic analgesic for reducing cognitive pain, emotional pain and the sensory component of pain of soldiers experiencing severe procedural pain during wound care of a combat-related burn injury.

INTRODUCTION.

U.S. soldiers injured in Iraq with significant burns are treated at the U.S. Army Institute of Surgical Research (USAISR) at Brooke Army Medical Center in San Antonio, TX. The mean length of inpatient stay for burn patients at this medical center is approx 25 days. (Kauvar et al.) Recovery often involves extensive outpatient physical therapy rehabilitation. Soldiers often move to San Antonio to continue their outpatient physical therapy for six months, a year or longer. Currently, wounded warfighter inpatients with severe burn wounds may have their bandages removed each day, so the wound can be inspected, cleaned and kept free of infection. Wounded warriors with severe burns remain conscious during daily wound care. Typically, they receive strong short-acting opioid analgesics and anxiolytics about twenty minutes prior to debridement (cleaning of dead skin from their healing burn wound). Despite early, aggressive

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use of opioid analgesics, patients frequently experience severe to excruciating pain during daily burn wound care. (Carrougner et al.) Excessive pain can increase the amount of time it takes caregivers to complete the wound care, and can increase how long the patient remains in the hospital before discharge. Clinical and laboratory studies of civilians have shown large drops in subjective pain during virtual reality, (Hoffman et al., 2008 & Hoffman, 2004) and fMRI results with healthy volunteers show reductions in pain-related brain activity during VR analgesia. (Hoffman et al., 2004) If VR reduces procedural pain in patients with combat-related injuries, this would be a valuable advance in combat casualty care with potential widespread military applications in the future. The two patients in this case report are the first to quantify whether VR distraction can reduce high levels of subjective pain reports in soldiers with combat-related burn injuries undergoing wound care and dressing change. Both patients used a unique articulated robotic-like arm that allowed the VR goggles to be placed near the patient weightlessly, eliminating the need for the patient to put on a VR helmet and reducing the amount of surface contact needed with the patient (see Figure 1A and 1B).



FIGURE 1A AND 1B. U.S. Army soldier receiving immersive Virtual Reality to reduce his pain during severe burn wound care, using our unique articulated arm mounted VR goggles designed by Hoffman and Magula, that hold the displays near the patient's eyes. Photos and copyrights Hunter Hoffman, UW.

SUBJECT

Patient 1 was a U.S. Army soldier medically evacuated from Iraq to USAISR after suffering severe burns covering 32% of his body approximately 45 days prior to this intervention. While a passenger in a vehicle that was attacked by an improvised explosive device (roadside bomb), he experienced full thickness burns on his hands, arms, anterior and posterior chest and distal thighs. In the following weeks, donor skin was harvested from unburned portions of his body and transplanted as skin grafts to many of his severe burn wounds. In keeping with the standard practice, continuous wound care and frequent dressing changes were required to optimize the healing process.

A 10 minute segment of wound care to the patient's right hand, identified from previous days' procedures as being

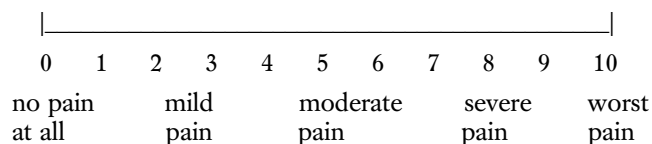


FIGURE 2. A snapshot of SnowWorld (the virtual world burn patients interact with during wound care). Image by worldbuilder Ari Hollander, www.imprintit.com, copyright Hunter Hoffman, UW., www.vrpain.com.

excessively painful, was divided into two equivalent five minute wound care segments. Pre-medication with two per-cocet tablets by mouth approximately 20 minutes prior to wound care served as the opioid analgesic for this session. During one of the five-minute sessions he received no VR distraction (i.e., standard pre-medication only). During the other five-minute treatment session, the participant looked into the articulated arm mounted VR goggles and underwent wound care while experiencing immersive, interactive VR (randomized to receive VR first or second).

During two brief pauses in the wound care procedure (once after each five minute wound care period), the patient completed three subjective pain ratings using Graphic Rating Scales (GRS) labeled 0 – 10 with respect to the preceding 5 minutes of wound care. "Please indicate how you felt during the past five minute session by rating your response on the following scales." Each question was accompanied by a pictorial example of the labeled graphic rating scale such as the "worst pain" rating shown below.

How much TIME did you spend thinking about your pain during the past five minutes? I thought about my pain during Virtual Reality 0 = none of the time, 1-4 = some of the time, 5 = half of the time, 6-9 = most of the time, and 10 = all of the time. How UNPLEASANT was your pain during the Virtual Reality (a similar 10-cm line with numeric and word descriptors beneath it: 0 = not unpleasant at all, 1-4 = mildly unpleasant, 5-6 = moderately unpleasant, 7-9 = severely unpleasant, and 10 = excruciatingly unpleasant)? Rate your WORST PAIN during the past 5 minutes.



How much FUN did you have during Virtual Reality (10-cm line with numeric and verbal descriptors: 0 = no fun at all, 1-4 = mildly fun, 5-6 = moderately fun, 7-9 = pretty fun, 10 = extremely fun)? To what extent (if at all) did you feel NAUSEA for any reason during Virtual Reality (10-cm line with numeric and verbal descriptors: 0 = no nausea at all, 1-4 = mild nausea, 5-6 = moderate nausea, 7-9 = severe nausea, and 10 = vomit)? While experiencing the virtual world, to what extent did you feel like you WENT INSIDE the computer-generated world (10-cm line with numeric and verbal descriptors: 0 = I did not feel like I went inside at all, 1-4 = mild sense of going inside, 5-6 = moderate sense of going inside, 7-9 = strong sense of going inside, 10 = I went completely inside the virtual world)? After wound care with no VR, each patient was asked the same questions but "during Virtual Reality" was replaced by "without Virtual Reality". After-wound care with no VR, patients were not asked the question about presence.

Such pain rating scales have been shown to be valid through their strong associations with other measures of pain intensity, as well as through their ability to detect treatment effects. (Jensen, 2003 & Jensen et al., 2001) The specific measures used in the current study were designed to assess the cognitive component of pain (amount of time spent thinking about pain), the affective component of pain (unpleasantness), and the sensory component of pain (worst pain). Affective and sensory pain are two separately measurable and sometimes differentially influenced components of the pain experience. (Gracely et al., 1978) Gracely et al., have shown ratio scale measures such as the labeled Graphic Rating Scales used in this study to be highly reliable. In addition, a GRS rating of 'fun' during wound care was measured. (Hoffmann et al., 2008)

Patient 2, a 21-year-old male, was injured when his humvee was hit by a terrorist's rocket propelled grenade in Iraq. The explosion caused 2nd and 3rd degree burns on 15% of his body: lower back, flank, buttox, bilateral hands, bilateral upper arms. A 12-minute segment of wound care to the patient's left and right arms identified from previous days'

procedures as being excessively painful was divided into two equivalent six-minute wound care segments. Pre-medication with one fentanyl lollypop (400 mic) and two percocet tablets by mouth approximately 20 minutes prior to wound care served as the opioid analgesic for this session. During one of the six-minute wound care sessions he received no VR distraction (i.e., standard pre-medication pharmacologies only). During the other six minute wound care session the participant looked into the articulated arm mounted VR goggles and underwent wound care while experiencing immersive, interactive VR (randomized to receive VR first or second). During two brief pauses in the wound care procedure (once after each six minute wound care period), the patient completed three subjective pain ratings using Graphic Rating Scales (GRS) labeled 0 – 10 with respect to the preceding 6 minutes of wound care, using the same measures described above for patient 1.

For both patients, the VR system consisted of a Voodoo Envoy laptop with NVIDIA GForce Go 7900 GTX (512 MB) video card; Intel Core 2 Duo (T7400) CPU @ 2.16 GHz, 2 GB RAM @ 994 MHz. While in High Tech VR, each subject followed a pre-determined path, “gliding” through an icy 3-D virtual canyon (Figure 2). He ‘looked’ around the virtual environment and aimed via a mouse. He pushed a mouse trigger button to shoot virtual snowballs at virtual snowmen, igloos, and penguins (see www.vrpain.com). Each subject saw the sky when he looked up, a canyon wall when he looked to the left or right, a flowing river when he looked down, and heard sound effects (e.g., a splash when a snowball hit the river) mixed with background music by recording artist Paul Simon. Participants looked into a pair of Rockwell Collins SR-80 VR goggles (see www.imprintit.com) with a custom made neoprene blinder on top and sides, which largely blocked his view of the real world. These VR goggles afforded approximately 80° diagonal field of view for each of the rectangular eyepieces with 100% overlap between the right and left eye images. The goggles were held in place near the patient’s eyes by a custom made articulated arm mounting system.

RESULTS

As shown in Figure 3 below, Patient 1 reported less pain when distracted with VR (e.g., “time spent thinking about pain” dropped from “all the time” during no VR to “some of the time” 1.5 (15%) during VR, “pain unpleasantness”

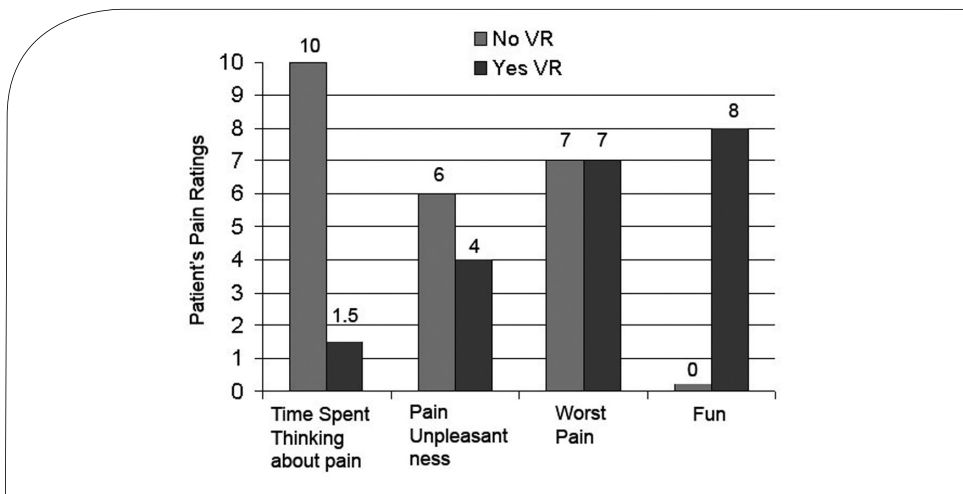


FIGURE 3. Patient 1 reported large reductions in amount of time thinking about pain during VR (shown in blue) compared to no VR (shown in red) during severe burn wound care of burn injury resulting from an Improvised Explosive Device (roadside bomb) attack/explosion.

ratings dropped from "moderate" (6/10) to "mild" (4/10). VR did not reduce Worst pain (0% drop) in Patient 1. Wound care during VR was "pretty fun" (8/10) vs. "no fun at all" (0/10) during no VR and the patient reported having a "moderate sense of going inside the computer-generated world" (6/10).

As shown in Figure 4 below, Patient 2 reported that during his wound care debridement, Time spent thinking about pain was 100% with no VR and 0 with VR, "pain unpleasantness" ratings dropped from "severe" (7/10) with no VR to "none" during VR. Worst pain dropped from "severe" (8/10) with no VR to mild pain (2/10) during VR. And fun increased from zero with no VR to 10 during VR. Patient 2 reported having "a strong sense of going inside the computer-generated world" (8/10). Both patients and their wound care nurses noted that they would prefer VR be available for subsequent dressing changes as they found it to be helpful as an adjunctive modality for pain control. Patient 2 was very determined to continue playing SnowWorld as long as possible. And the wound care nurse of patient 1 spontaneously remarked she was pleasantly surprised to see that when in VR, the patient was not pulling his hand away from her as she worked on his hand, a "protective" behavior he consistently exhibited during daily wound care of his hand with No VR.

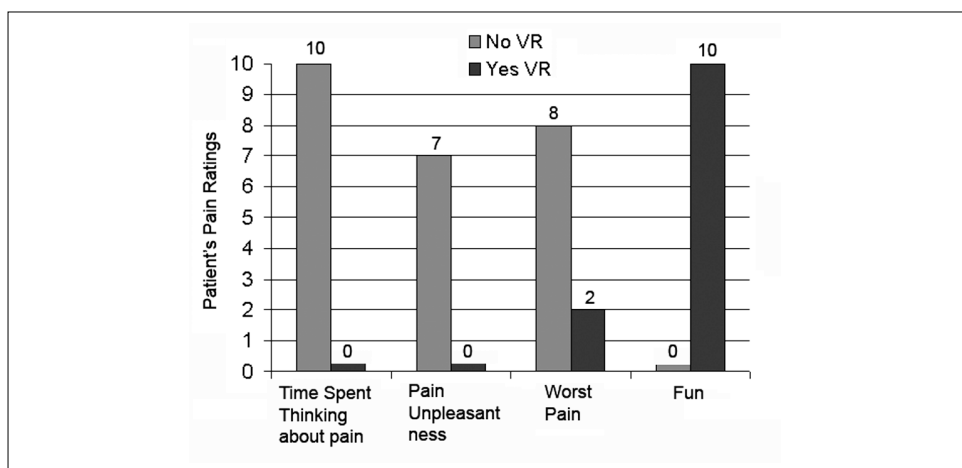


FIGURE 4. Patient 2 reported large reductions in pain during VR (shown in blue) compared to no VR (shown in red) during burn wound care of a severe burn injury resulting from a rocket-propelled grenade attack/explosion.

DISCUSSION

The results of these two case studies demonstrate that immersive VR reduced the reported amount of time patients with a combat-related burn injury spent thinking about their pain and VR reduced pain unpleasantness. VR did not reduce patient one's worst pain rating during his burn wound care. But VR did reduce patient two's worst pain from severe (a rating of 8) down to mild (a rating of 2). Although case studies are scientifically inconclusive and controlled studies are needed, these results provide the first available evidence that VR can reduce severe acute pain during medical procedures (wound care and dressing changes) in patients with combat-related burn injuries. Because excessive acute pain during medical procedures for combat-related injuries remains a widespread medical problem, and our preliminary results support the notion that VR might prove valuable for pain control in combat trauma patients, additional research on this modality with this patient population is warranted.

ACKNOWLEDGMENTS:

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VIRTUAL- REALITY THERAPY

Patients can get relief from pain or overcome their phobias by immersing themselves in computer-generated worlds BY HUNTER G. HOFFMAN



BURN PATIENT participates in a virtual-reality program to relieve the pain of his wound care at Harborview Burn Center in Seattle (*above*). Wearing a headset and manipulating a joystick, the patient maneuvers through the program called SnowWorld (*right*), which was specifically designed to ease the pain of burn victims. Studies show that virtual-reality programs are more effective than ordinary video games in distracting patients from the often excruciating pain of wound care.

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ATTACHMENT 2



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In the science-fiction thriller *The Matrix*, the heroes “plugged in” to a virtual world. While their bodies rested in reclining chairs, their minds fought martial-arts battles, dodged bullets and drove motorcycles in an elaborately constructed software program. This cardinal virtue of virtual reality—the ability to give users the sense that they are “somewhere else”—can be of great value in a medical setting. Researchers are finding that some of the best applications of the software focus on therapy rather than entertainment. In essence, virtual reality can ease pain, both physical and psychological.

For the past several years, I have worked with David R. Patterson, a pain expert at the University of Washington School of Medicine, to determine whether severely burned patients, who often face unbearable pain, can relieve their discomfort by engaging in a virtual-reality program during wound treatment. The results have been so promising that a few hospitals are now preparing to explore the use of virtual reality as a tool for pain control. In other projects, my colleagues and I are using virtual-reality applications to help phobic patients overcome their irrational fear of spiders and to treat post-traumatic stress disorder (PTSD) in survivors of terrorist attacks.

At least two software companies are already leasing virtual-reality programs and equipment to psychologists for phobia treatment in their offices. And the Vir-

tual Reality Medical Center, a chain of clinics in California, has used similar programs to successfully treat more than 300 patients suffering from phobias and anxiety disorders. Although researchers must conduct more studies to gauge the effectiveness of these applications, it seems clear that virtual therapy offers some very real benefits.

SpiderWorld and SnowWorld

FEW EXPERIENCES are more intense than the pain associated with severe burn injuries. After surviving the initial trauma, burn patients must endure a long journey of healing that is often as painful as the original injury itself. Daily wound care—the gentle cleaning and removal of dead tissue to prevent infection—can be so excruciating that even the aggressive use of opioids (morphine-related analgesics)

cannot control the pain. The patient’s healing skin must be stretched to preserve its elasticity, to reduce muscle atrophy and to prevent the need for further skin grafts. At these times, most patients—and especially children—would love to transport their minds somewhere else while doctors and nurses treat their wounds. Working with the staff at Harborview Burn Center in Seattle, Patterson and I set out in 1996 to determine whether immersive virtual-reality techniques could be used to distract patients from their pain. The team members include Sam R. Sharar, Mark Jensen and Rob Sweet of the University of Washington School of Medicine, Gretchen J. Carrougher of Harborview Burn Center and Thomas Furness of the University of Washington Human Interface Technology Laboratory (HITLab).

Pain has a strong psychological component. The same incoming pain signal can be interpreted as more or less painful depending on what the patient is thinking. In addition to influencing the way patients interpret such signals, psychological factors can even influence the amount of pain signals allowed to enter the brain’s cortex. Neurophysiologists Ronald Melzack and Patrick D. Wall developed this “gate control” theory of pain in the 1960s [see “The Tragedy of Needless Pain,” by Ronald Melzack; *Scientific American*, February 1990].

Introducing a distraction—for example, by having the patient listen to music—has long been known to help reduce pain for some people. Because virtual reality is a uniquely effective new form of distraction, it makes an ideal candidate for pain control. To test this notion, we studied two teenage boys who had suffered gasoline burns. The first patient had a severe burn on his leg; the second had deep burns covering one third of his body, including his face, neck, back, arms, hands and legs. Both had received skin-graft surgery and staples to hold the grafts in place.

We performed the study during the removal of the staples from the skin grafts.

Overview/*Virtual-Reality Therapy*

- One of the best ways to alleviate pain is to introduce a distraction. Because virtual reality immerses users in a three-dimensional computer-generated world, it is uniquely suited to distracting patients from their pain.
- Burn patients undergoing wound care report that their pain drops dramatically when they engage in virtual-reality programs. Functional magnetic resonance imaging shows that virtual reality actually reduces the amount of pain-related activity in the brain.
- Virtual-reality programs can also help phobic patients overcome their fear of spiders, heights, flying or public speaking. A specially designed program is now being used to treat post-traumatic stress disorder in survivors of the September 11 attacks.

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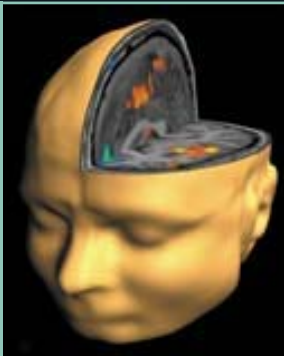
PAIN-RELATED BRAIN ACTIVITY

When healthy volunteers received pain stimuli, functional magnetic resonance imaging showed large increases in activity in several regions of the brain that are known to be involved in the perception of pain (*near right and below*). But when the volunteers engaged in a virtual-reality program during the stimuli, the pain-related activity subsided (*far right and bottom*).

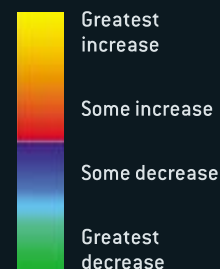
NO VIRTUAL REALITY



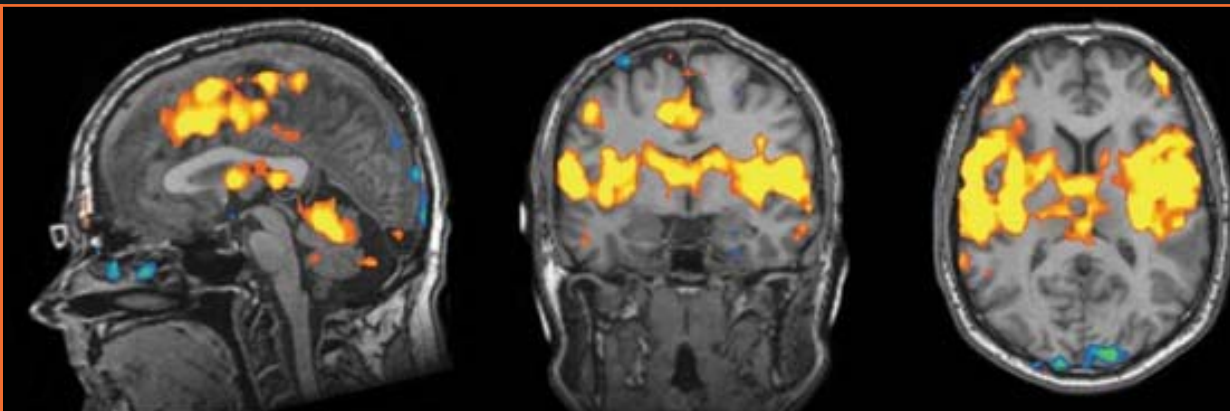
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CHANGES IN BRAIN ACTIVITY IN RESPONSE TO PAIN



NO VIRTUAL REALITY



VIRTUAL REALITY



The boys received their usual opioid medication before treatment. In addition, each teenager spent part of the treatment session immersed in a virtual-reality program and an equal amount of time playing a popular Nintendo video game (either Wave Race 64, a jet-ski racing game, or Mario Kart 64, a race-car game). The virtual-reality program, called Spider-World, had originally been developed as a tool to overcome spider phobias; we used it for this investigation because it

was the most distracting program available at the time and because we knew it would not induce nausea. Wearing a stereoscopic, position-tracked headset that presented three-dimensional computer graphics, the patients experienced the illusion of wandering through a kitchen, complete with countertops, a window and cabinets that could be opened. An image of a tarantula was set inside the virtual kitchen; the illusion was enhanced by suspending a furry spider toy with wiggly

legs above the patient's bed so that he could actually feel the virtual spider.

Both teenagers reported severe to excruciating pain while they were playing the Nintendo games but noted large drops in pain while immersed in Spider-World. (They rated the pain on a zero to 100 scale immediately after each treatment session.) Although Nintendo can hold a healthy player's attention for a long time, the illusion of going inside the two-dimensional video game was found

Virtual reality is not just
changing the way patients
interpret incoming
pain signals; the programs
actually reduce the
amount of pain-related
brain activity.

to be much weaker than the illusion of going into virtual reality. A follow-up study involving 12 patients at Harborview Burn Center confirmed the results: patients using traditional pain control (opioids alone) said the pain was more than twice as severe compared with when they were inside SpiderWorld.

Why is virtual reality so effective in alleviating pain? Human attention has been likened to a spotlight, allowing us to select some information to process and to ignore everything else, because there is a limit to how many sources of information we can handle at one time. While a patient is engaged in a virtual-reality program, the spotlight of his or her attention is no longer focused on the wound and the pain but drawn into the virtual world. Because less attention is available to process incoming pain signals, patients often experience dramatic drops in how much pain they feel and spend much less time thinking about their pain during wound care.

To increase the effectiveness of the virtual therapy, our team created SnowWorld, a program specifically customized for use with burn patients during wound care. Developed with funding from Microsoft co-founder Paul G. Allen and the National Institutes of Health, SnowWorld produces the illusion of flying through an icy canyon with a frigid river and waterfall, as snowflakes drift down [see illustration on pages 58 and 59]. Because patients often report that they are reliving their original burn experience during wound care, we designed a glacial landscape to help put out the fire. As patients glide through the virtual canyon, they can shoot snowballs at snowmen, igloos, robots and penguins standing on narrow ice shelves or floating in the river. When hit by a snowball, the snowmen and igloos disappear in a puff of powder, the penguins flip upside down with a quack, and the robots collapse into a heap of metal.

More recent research has shown that the benefits of virtual-reality therapy are not limited to burn patients. We conducted a study involving 22 healthy volunteers, each of whom had a blood pressure cuff tightly wrapped around one arm for 10 minutes. Every two minutes the subjects rated the pain from the cuff; as expected, the discomfort rose as the session wore on. But during the last two minutes, each of the subjects participated in two brief virtual-reality programs, Spi-

derWorld and ChocolateWorld. (In ChocolateWorld, users see a virtual chocolate bar that is linked through a position sensor to an actual candy bar; as you eat the real chocolate bar, bite marks appear on the virtual bar as well.) The subjects reported that their pain dropped dramatically during the virtual-reality session.

What is more, improving the quality of the virtual-reality system increases the amount of pain reduction. In another study, 39 healthy volunteers received a thermal pain stimulus—delivered by an electrically heated element applied to the right foot, at a preapproved temperature individually tailored to each participant—for 30 seconds. During this stimulus, 20 of the subjects experienced the fully interactive version of SnowWorld with a high-quality headset, sound effects and head tracking. The other 19 subjects saw a stripped-down program with a low-quality, see-through helmet, no sound effects, no head tracking and no ability to shoot snowballs. We found a significant positive correlation between the potency of the illusion—how strongly the subjects felt they were immersed in the virtual world—and the alleviation of their pain.

Seeing Pain in the Brain

OF COURSE, all these studies relied on the subjective evaluation of the pain by the patients. As a stricter test of whether virtual reality reduces pain, I set out with my colleagues at the University of Washington—including Todd L. Richards, Aric R. Bills, Barbara A. Coda and Sam Sharar—to measure pain-related brain activity us-



VIRTUAL-REALITY PROGRAM re-creating a bus bombing is designed to treat post-traumatic stress disorder in survivors of terrorist attacks in Israel and Spain. By gradually exposing the survivors to realistic images



and sounds of a bus bombing (three screen shots are shown here), the program helps them to process and eventually reduce the debilitating emotions associated with the traumatic event.



ing functional magnetic resonance imaging (fMRI). Healthy volunteers underwent a brain scan while receiving brief pain stimulation through an electrically heated element applied to the foot. When the volunteers received the thermal stimuli without the distraction of virtual reality, they reported severe pain intensity and unpleasantness and spent most of the time thinking about their pain. And, as expected, their fMRI scans showed a large increase in pain-related activity in five regions of the brain that are known to be involved in the perception of pain: the insula, the thalamus, the primary and secondary somatosensory cortex, and the affective division of the anterior cingulate cortex [see illustration on page 61].

Creating virtual-reality goggles that could be placed inside the fMRI machine was a challenge. We had to develop a fiber-optic headset constructed of non-ferrous, nonconducting materials that would not be affected by the powerful magnetic fields inside the fMRI tube. But the payoff was gratifying: we found that when the volunteers engaged in SnowWorld during the thermal stimuli, the pain-related activity in their brains decreased significantly (and they also reported large reductions in subjective pain ratings). The fMRI results suggest that virtual reality is not just changing the way patients interpret incoming pain signals; the programs actually reduce the amount of pain-related brain activity.

Encouraged by our results, two large regional burn centers—the William Randolph Hearst Burn Center at New York Weill Cornell Medical Center and Shriners Hospital for Children in Galveston, Tex.—are both making preparations to explore the use of SnowWorld for pain control during wound care for severe burns. Furthermore, the Hearst Burn Center, directed by Roger W. Yurt, is helping to fund the development of a new upgrade,



FEAR OF PUBLIC SPEAKING can be treated using a virtual-reality program developed by Virtually Better, a software company based in Decatur, Ga., that leases its programs to psychologists and psychiatrists. Ken Graap, the company's chief executive, practices a speech in front of a virtual audience, shown on his headset and on the computer monitor.

SuperSnowWorld, which will feature lifelike human avatars that will interact with the patient. SuperSnowWorld will allow two people to enter the same virtual world; for example, a burn patient and his mother would be able to see each other's avatars and work together to defeat monstrous virtual insects and animated sea creatures rising from the icy river. By maximizing the illusion and interactivity, the program will help patients focus their attention on the virtual world during particularly long and painful wound care sessions. Now being built by Ari Hollander, an affiliate of HITLab, SuperSnowWorld will be offered to medical centers free of charge by the Hearst and Harborview burn centers.

Virtual-reality analgesia also has the potential to reduce patient discomfort during other medical procedures. Bruce Thomas and Emily Steele of the University of South Australia have found that vir-

tual reality can alleviate pain in cerebral palsy patients during physical therapy after muscle and tendon surgery. (Aimed at improving the patient's ability to walk, this therapy involves exercises to stretch and strengthen the leg muscles.) Our team at the University of Washington is exploring the clinical use of virtual reality during a painful urological procedure called a rigid cystoscopy. And we have conducted a study showing that virtual reality can even relieve the pain and fear of dental work.

Fighting Fear

ANOTHER THERAPEUTIC application of virtual reality is combating phobias by exposing patients to graphic simulations of their greatest fears. This form of therapy was introduced in the 1990s by Barbara O. Rothbaum of Emory University and Larry F. Hodges, now at the University of North Carolina at Charlotte, for treating fear of heights, fear of flying in airplanes, fear of public speaking, and chronic post-traumatic stress disorder in Vietnam War veterans. Like the pain-control programs, exposure therapy helps to change the way people think, behave and interpret information.

Working with Albert Carlin of HIT-

THE AUTHOR

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Lab and Azucena Garcia-Palacios of Jaume I University in Spain (a HITLab affiliate), our team has shown that virtual-reality exposure therapy is very effective for reducing spider phobia. Our first spider-phobia patient, nicknamed Miss Muffet, had suffered from this anxiety disorder for nearly 20 years and had acquired a number of obsessive-compulsive behaviors. She routinely fumigated her car with smoke and pesticides to get rid of spiders. Every night she sealed all her bedroom windows with duct tape after scanning the room for spiders. She searched for the arachnids wherever she went and avoided walkways where she might find one. After washing her clothes, she immediately sealed them inside a plastic bag to make sure they remained free of spiders. Over the years her condition grew worse. When her fear made her hesitant to leave home, she finally sought therapy.

Like other kinds of exposure therapy, the virtual-reality treatment involves introducing the phobic person to the feared

object or situation a little at a time. Bit by bit the fear decreases, and the patient becomes more comfortable. In our first sessions, the patient sees a virtual tarantula in a virtual kitchen and approaches as close as possible to the arachnid while using a handheld joystick to navigate through the three-dimensional scene. The goal is to come within arm's reach of the virtual spider.

During the following sessions, the participant wears a glove that tracks the position of his or her hand, enabling the software to create an image of a hand—the cyberhand—that can move through the virtual kitchen. The patient maneuvers the cyberhand to touch the virtual spider, which is programmed to respond by making a brief noise and fleeing a few inches. The patient then picks up a virtual vase with the cyberhand; when the patient lets go, the vase remains in midair, but an animated spider with wiggling legs comes out. The spider drifts to the floor of the virtual kitchen, accompanied by a

brief sound effect from the classic horror movie *Psycho*. Participants repeat each task until they report little anxiety. Then they move on to the next challenge. The final therapy sessions add tactile feedback to the virtual experience: a toy spider with an electromagnetic position sensor is suspended in front of the patient, allowing him or her to feel the furry object while touching the virtual spider with the cyberhand.

After only 10 one-hour sessions, Miss Muffet's fear of spiders was greatly reduced, and her obsessive-compulsive behaviors also went away. Her success was unusually dramatic: after treatment, she was able to hold a live tarantula (which crawled partway up her arm) for several minutes with little anxiety. In a subsequent controlled study of 23 patients diagnosed with clinical phobia, 83 percent reported a significant decrease in their fear of spiders. Before treatment, these patients could not go within 10 feet of a caged tarantula without high anxiety; af-



SIDERWORLD is a virtual-reality program designed to help phobic patients overcome their fear of spiders. The patient wears a headset that shows a virtual tarantula (screen shot from program is shown in

background). To provide tactile feedback, the system tracks the positions of a toy spider (suspended by the author, at left) and the patient's hand, allowing her to "touch" the virtual creature.

ter the virtual-reality therapy, most of them could walk right up to the cage and touch its lid with only moderate anxiety. Some patients could even remove the lid.

Similar programs can be incorporated into the treatment of a more serious psychological problem: post-traumatic stress disorder. The symptoms of PTSD include flashbacks of a traumatic event, intense reactions to anything symbolizing or resembling the event, avoidance behaviors, emotional numbing, and irritability. It is a debilitating disorder that affects the patient's social life and job performance and is much more challenging to treat than specific phobias. Cognitive behavioral therapy protocols, such as the prolonged exposure therapy developed by University of Pennsylvania psychologist Edna Foa, have a high success rate for patients with PTSD. The exposure therapy is thought to work by helping patients process and eventually reduce the emotions associated with the memories of the traumatic event. The therapist gradually exposes the patient to stimuli that activate these emotions and teaches the patient how to manage the unwanted responses.

Researchers are now exploring whether virtual-reality programs can be used to standardize the therapy and improve the outcome for patients, especially those who do not respond to traditional methods. JoAnn Difede of Cornell University and I developed a virtual-reality exposure therapy to treat a young woman who was at the World Trade Center during the September 11 attacks and later developed PTSD. During the therapy, the patient put on a virtual-reality helmet that showed virtual jets flying over the towers and crashing into them with animated explosions and sound effects. Although the progress of the therapy was gradual and systematic, the scenes presented by the software in the final sessions were gruesomely realistic, with images of people jumping from the burning buildings and the sounds of sirens and screams. These stimuli can help patients retrieve memories of the event and, with the guidance of a therapist, lower the discomfort of remembering what happened.

Our first patient showed a large and stable reduction in her PTSD symptoms

and depression after the virtual-reality sessions. Other patients traumatized by the tower attacks are now being treated with virtual-reality therapy at Weill Cornell Medical College and New York Presbyterian Hospital. I am also collaborating with a team of researchers led by Patrice L. (Tamar) Weiss of Haifa University in Israel and Garcia-Palacios to create a virtual-reality treatment for survivors of terrorist bombings who develop PTSD.

Virtual Reality by the Hour

BECAUSE DOZENS of studies have established the efficacy of virtual-reality therapy for treating specific phobias, this is one of the first medical applications to make the leap to widespread clinical use. Virtually Better, a Decatur, Ga.-based company that was co-founded by virtual-reality pioneers Hodges and Rothbaum, has produced programs designed to treat an array of anxiety disorders, including fear of heights, fear of flying and fear of public speaking. The company is leasing its software to psychologists and psychiatrists for \$400 a month, allowing therapists to administer the treatments in their own offices. A Spanish firm called PREVI offers similar programs. Instead of reclining on a couch, patients interactively confront their fears by riding in virtual airplanes or by standing in front of virtual audiences.

In contrast, more research is needed to determine whether virtual reality can enhance the treatment of PTSD. Scientists have not yet completed any randomized, controlled studies testing the effectiveness of virtual-reality therapy for treating the disorder. But some of the leading PTSD experts are beginning to explore the virtues of the technology, and the preliminary results are encouraging.

Large clinical trials are also needed to

Another therapeutic application of virtual reality is combating phobias by exposing patients to graphic simulations of their greatest fears.

determine the value of virtual-reality analgesia for burn patients. So far the research has shown that the SnowWorld program poses little risk and few side effects. Because the patients use SnowWorld in addition to traditional opioid medication, the subjects who see no benefit from virtual reality are essentially no worse off than if they did not try it. Virtual reality may eventually help to reduce reliance on opioids and allow more aggressive wound care and physical therapy, which would speed up recovery and cut medical costs. The high-quality virtual-reality systems that we recommend for treating extreme pain are very expensive, but we are optimistic that breakthroughs in display technologies over the next few years will lower the cost of the headsets. Furthermore, patients undergoing less painful procedures, such as dental work, can use cheaper, commercially available systems. (Phobia patients can also use the less expensive headsets.)

The illusions produced by these programs are nowhere near as sophisticated as the world portrayed in the Matrix films. Yet virtual reality has matured enough so that it can be used to help people control their pain and overcome their fears and traumatic memories. And as the technology continues to advance, we can expect even more remarkable applications in the years to come. 

MORE TO EXPLORE

Virtual Reality Exposure Therapy for World Trade Center Post-Traumatic Stress Disorder: A Case Report. JoAnn Difede and Hunter G. Hoffman in *CyberPsychology & Behavior*, Vol. 5, No. 6, pages 529–535; 2002. Available at www.hitl.washington.edu/people/hunter/wtc.pdf

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More information about virtual-reality therapy can be found on the Web at www.hitl.washington.edu/ and www.e-therapy.info

Immersive Virtual Reality: Additional Information for Board of Regents

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