Virtual Reality Helmet Display Quality Influences the Magnitude of Virtual Reality Analgesia

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Abstract: Immersive Virtual Reality (VR) distraction can be used in addition to traditional opioids to reduce procedural pain. The current study explored whether a High-Tech-VR helmet (ie, a 60-degree field-of-view head-mounted display) reduces pain more effectively than a Low-Tech-VR helmet (a 35-degree field-of-view head-mounted display). Using a double-blind between-groups design, 77 healthy volunteers (no patients) aged 18-23 were randomly assigned to 1 of 3 groups. Each subject received a brief baseline thermal pain stimulus, and the same stimulus again minutes later while in SnowWorld using a Low-Tech-VR helmet (Group 1), using a High-Tech-VR helmet (Group 2), or receiving no distraction (Group 3, control group). Each participant provided subjective 0-10 ratings of cognitive, sensory, and affective components of pain, and amount of fun during the pain stimulus. Compared to the Low-Tech-VR helmet group, subjects in the High-Tech-VR helmet group reported 34% more reduction in worst pain ($P < .05$), 46% more reduction in pain unpleasantness ($P = .001$), 29% more reduction in "time spent thinking about pain" ($P < .05$), and 32% more fun during the pain stimulus in VR ($P < .05$). Only 29% of participants in the Low-Tech helmet group, as opposed to 65% of participants in the High-Tech-VR helmet group, showed a clinically significant reduction in pain intensity during virtual reality. These results highlight the importance of using an appropriately designed VR helmet to achieve effective VR analgesia (see www.vrpain.com).
Perspective: Pain during medical procedures (eg, burn wound care) is often excessive. Adjunctive virtual reality distraction can substantially reduce procedural pain. The results of the present study show that a higher quality VR helmet was more effective at reducing pain than a lower quality VR helmet.

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D espite medication with traditional analgesic pharmacologies, excessive acute pain continues to be a significant problem in a variety of clinical settings, especially during medical procedures.[9,31,36,38,39] Economics and other concerns limit the use of general anesthesia (making patients unconscious during medical procedures), increasing reliance on pharmacologic analgesia and/or conscious sedation. Nevertheless, side effects of

opioid analgesia such as nausea, excessive sedation, cognitive dysfunction, constipation, and other concerns limit opioid use for analgesia.[3] In contrast, nonpharmacologic techniques such as distraction typically have few or no side effects and can help reduce pain[11,35] and can be used in addition to traditional opioids.

Researchers have recently begun exploring the use of immersive virtual reality (VR) distraction as an adjunctive, nonpharmacologic analgesic. Using subjective pain ratings during VR compared to control conditions (no VR), patients with severe burns using VR have reported large (eg, 40-50%) reductions in worst pain, pain unpleasantness, and time spent thinking about procedural pain[5,19,23,24,25] and report having more fun and less anxiety during various painful procedures including physical

therapy[23,24] and wound care.[25] Preliminary clinical studies have also shown that VR distraction reduces dental pain,[21] pain during physical therapy rehabilitation after single-event-multilevel surgery for pediatric cerebral palsy,[42] and pain during an endoscopic urological medical procedure with older patients.[44] In an analog laboratory pain study involving functional neuroimaging, VR reduced participants' subjective pain ratings and VR simultaneously reduced pain-related brain activity by more than 50% in each of the 5 brain regions-of-interest (the primary and secondary somatosensory cortex, anterior cingulated cortex, thalamus, and insula).[26]

We theorize that attentional distraction is an important mechanism contributing to VR analgesia. There is a limit to the conscious attentional resources humans have available to process large amounts of incoming information.[30] Conscious attention is required for pain perception.[2,7] We theorize that the more immersive the VR system (due to thoughtful hardware and software design and performance), the more his/her attention will be drawn into the virtual world,[18,19,23,27] leaving less attention available to process nociceptive signals.

In an analog laboratory pain study with healthy volunteers (no patients), researchers[27] recently measured the relative effectiveness of two different "dose levels" of VR distraction on pain ratings in a double-blind laboratory thermal pain study. The High-Tech-VR group used VR hardware (VR helmet, head tracking system, and headphones/sound effects, as well as user interactivity) designed to give participants a strong illusion of going into the 3D computer-generated virtual world, as if it was a place (a sensation known as VR presence). The Low-Tech-VR group used VR hardware designed to elicit a less compelling illusion of VR presence (see-through VR glasses, no head tracking, no headphones/sound effects, and no interactivity). Consistent with an attentional hypothesis, the High-Tech-VR group experienced significantly more analgesia/pain reduction than the Low-Tech-VR group.[27] Because a number of variables were manipulated simultaneously in that previous study, the influence of the quality of the VR helmet alone on analgesic effectiveness could not be isolated. To date, no study has isolated the impact of helmet display quality on amount of VR pain reduction (ie, manipulating only helmet quality). Pilot studies suggest that increasing the size of the eyepieces/display screens in the VR helmet to increase the amount of peripheral vision stimulated (ie, field of view) can increase participants' subjective illusion of going into the virtual world.[34,37] In the present study, we tested the hypothesis that the quality of the VR helmet is an important determinant of analgesic effectiveness of immersive VR. We predicted that VR distraction using the High-Tech-VR (60-degree diagonal field-of-view) helmet would reduce thermal pain more effectively than VR distraction using a Low-Tech-VR (35-degree field-of-view) helmet.

Materials and Methods

Subjects

Seventy-seven healthy undergraduate Psychology students (41% male, 59% female), aged 18 to 23 (mean, 18.67), from the University of Washington participated. Both written and verbal informed consent were obtained using a protocol approved by the University of Washington's Human Subjects Review Committee.

Measures and Procedures

Experimental Thermal Pain Model

Controlled thermal heat pain stimulation ranging from 44 to 48°C was applied using a commercially available Peltier thermode[45] designed to provide noxious heat, noxious cold, and nonnoxious thermal stimulation over a range of 0 to 50°C (see other pain studies using this device).[1,4,8,32,43] The noxious heat stimulus temperature was individually determined for each subject immediately prior to the study, using the psychophysical method of ascending levels as follows. A 30-second heat stimulus (always 44°C for the first stimulus, which all subjects found tolerable) was delivered through a thermode attached to the dorsal surface of the right foot, and the subject was asked to rate the stimulus using a 0-10 graphic rating scale (see below). With the subject's permission, the temperature for the next stimulus was then increased by 1°C (eg, 45°C) and rated, and this sequence was continued until the subject reported a stimulus that was "painful but tolerable." To avoid excessive pain, stimulus increments of less than 1°C were sometimes administered at the researcher's discretion, as subjects reported more intense pain. The experimenter's unannounced goal was to achieve either a pain unpleasantness or a worst pain rating of 7, but a number of subjects chose to stop before achieving a pain rating of 7, and this was permitted. Individualized stimulus temperatures used in the present study ranged from 44 to 48°C (mean of 46.26°C) and were associated with ratings of "worst pain" on a 0-10 scale ranging from 4 to 9 (mean of 6.41). The noxious baseline temperature selected (30-second thermal stimulus without distraction) also served as the pain stimulus temperature during the VR intervention phase of the study protocol (30 seconds of thermal pain during VR).

After each pain stimulus, subjects completed five 0-10 graphic rating scales to assess their sensory experience of pain and VR. 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.[28,29] The specific queries 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 2 separately measurable and sometimes differentially influenced components of the pain experience.[12,15] Gracely et al[15] have shown ratio scale measures such as the labeled

Graphic Rating Scales used in this study to be highly reliable. The use of visual analogue scale pain assessment tools that have 0-10 labels is now recommended over nonlabeled visual analogue scales in clinical trials.[6]

A single rating (to what extent did you feel like you "went into" the virtual world, adapted from Slater et al[41]) was also used in the present study to assess user presence in the virtual world. Hendrix and Barfield[16] showed the reliability of a similar VR presence rating. The measure's ability to detect treatment effects[17,20,27] is preliminary evidence of our VR presence measure's validity. After each pain stimulus, subjects received the following instructions once prior to answering each of 5 separate queries. "Please indicate how you felt during the past 30-s pain stimulus by making a mark anywhere on the line. Your response doesn't have to be a whole number." In the study, the 5 following 10-cm graphic rating scales were administered (a pictorial example of the 10-cm labeled graphic rating scale for "worst pain" is shown): 1) "Rate your WORST PAIN during the most recent pain stimulus (pain intensity). 0 = no pain at all, 1-4 = mild pain, 5-6 = moderate pain, 7-9 = severe pain, 10 = excruciating pain." 2) How much TIME did you spend thinking about your pain during this most recent pain stimulus? (10-cm line with numeric and word descriptors beneath it: 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.) 3) How UNPLEASANT was the most recent pain stimulus? (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). 4) How much FUN did you have during the most recent pain stimulus? (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). 5) While experiencing the virtual world, to what extent did you feel like you WENT INSIDE the virtual 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).

Towards the goal of creating an immersive VR display,[40] we used a High-Tech-VR system designed to 1) shut out physical reality (helmet and headphones that exclude sights and sounds from the real world); 2) provide converging evidence to multiple senses (both computer-generated sights and sounds); 3) provide a surrounding/panoramic view rather than limited narrow field of view; 4) be vivid/high resolution; 5) permit the participant to interact with the virtual world; and 6) use head tracking, which allows subjects to view different portions of the virtual world merely by changing their head position/orientation. In the present study, the only difference between the two groups was that one had a High-Tech helmet and the other group used a less immersive Low-Tech-VR helmet with a narrower field of view, which did not completely block the user's view of the real world.

The distinction between immersion and presence is important, as our study design varies immersiveness as an independent variable and assesses pain reduction and user presence as a dependent variable. According to Slater and Wilbur,[40] immersion is an objective, quantifiable description of the sensory input that a particular VR system delivers to a participant, whereas VR presence is a subjective illusion created in the user's mind, a psychological state of consciousness. Although immersion and presence are distinct concepts, increasing the immersiveness of a VR system often leads to a stronger illusion of presence in virtual reality. A number of studies have shown that increasing the objective immersiveness of a VR system increases participants' subjective illusion of going into the virtual world (presence). For example, increasing the size of the eyepieces in the VR helmet (ie, field of view[37]), adding or improving the quality of sound in VR,[16] and adding electromagnetic head tracking so what the participant sees changes in the virtual environment as they change their head position[16] have all been shown to increase participants' subjective illusion of presence inside the virtual world. Tactile augmentation, adding tactile feedback to virtual objects, can also increase presence,[17] but tactile cues were not used in the present study.

To isolate the influence (if any) of helmet quality on the analgesic effectiveness of High-Tech vs Low-Tech helmets, in the present study, helmet quality was the only factor manipulated.

Experimental Group: High-Tech Virtual Reality Helmet

The VR system consisted of a Dell[46] 530 workstation with dual 2-GHz CPUs, 2 GB RAM, a GeForce 6800 video card running the U.W. Harborview/HITLab's SnowWorld software[47] on the Windows 2000 operating system. A Polhemus™ Fastrak position tracking system was used to monitor the position of the user's head.[48] While in High-Tech-VR, subjects followed a predetermined path, "gliding" through an icy 3-dimensional virtual canyon (SnowWorld). Subjects aimed with their gaze direction (head orientation) and pushed a keyboard button to shoot virtual snowballs at virtual snowmen, igloos, robots, and penguins (Fig 1). This High-Tech-VR helmet condition included head tracking (eg, subjects saw the sky when they looked up, a canyon wall when they looked to the left, a river when they looked down), sound effects (eg, a splash when a snowball hit the river), and animated green-, blue-, or white-colored explosions. Subjects in the High-Tech-VR group wore an Nvis NvisorSX[49] high-resolution helmet which completely blocked the subjects' view of the real world. This helmet has a 60-degree diagonal field of view for each of the round eyepieces, and 1280 × 1024 pixels per eye (×2 eyes = 2,621,440 pixels total).

Control Group, Low-Tech-VR Helmet

The Low-Tech-VR system (hardware and software) was identical to the High-Tech-VR system with 1 exception: a Low-Tech-VR helmet was substituted for the High-Tech-VR helmet. The Low-Tech helmet was a ruggedized Cy-Visor,[50] with 800 × 600 pixels per eye (×2 eyes = 960,00 pixels total), and a diagonal field of view of 35

Figure 1. A screen shot of what subjects see in the 3D virtual world named SnowWorld. Image by Stephen Dagadakis, U.W., copyright Hunter Hoffman, U.W.

degrees for each of the rectangular eyepieces which largely blocked the participant's view of the real world. Although the Cy-Visor has significantly fewer number of pixels in the smaller field-of-view display, the spatial resolution observed by the participant was approximately the same as the NvisorSX when the entire optical system is considered. By simply scaling the number of pixels of the Cy-Visor to the wider field-of-view of 60 degrees while maintaining the same Cy-Visor display resolution gives (60/35 = 1.714) times (800 × 600). The resulting (1371 × 1028) display pixels in a hypothetical scaled-up 60-degree Cy-Visor is slightly greater display resolution than the Nvisor's (1280 × 1024). As expected, qualitative comparisons of display resolution within the central field produced no significant differences. Because both display systems had adjustable brightness, all other visual display characteristics were matched except the field of view.

Control Group, No Distraction

The "no distraction" control group received no distraction and no occlusion.

Procedures and Design

Subjects were randomly assigned to either the "High Tech-VR helmet" group (n = 26), the "Low Tech-VR helmet" group (n = 28), or the "no distraction" group (n = 23). Subjects were not told that there were 2 different VR treatment groups and were thus blinded to the VR intervention. As a result of this blinding procedure, VR helmet quality was manipulated between groups, without the knowledge of the subjects, so both the High-Tech-VR helmet and the Low-Tech-VR helmet groups were under similar contextual demand characteristics. In addition, the research assistant administering the pain ratings was also kept blind to experimental conditions and was not in the room during the VR treatment.

The individualized 30-second thermal pain stimulus

with no distraction (while not wearing a VR helmet) served as the baseline pain rating. When the baseline pain ratings had been completed, subjects sat quietly for 2 minutes and then donned the VR helmet and "went into" VR for a total of 2 minutes. This included a 1.5-minute acclimatization period in VR, after which subjects received their second 30-second pain stimulus while still wearing the treatment group-appropriate VR helmet (or no helmet if they were in the No VR control group). After this experimental thermal pain stimulus, a research assistant not involved with the pain stimulation or VR treatment entered the room and administered subjective pain ratings using the series of 10-point graphic rating scales described above. Thus the researcher interacting with the subject after their VR/thermal pain experience remained blind to the subject's treatment condition.

Data Analysis

Data for each graphic rating scale were analyzed by omnibus analysis of variance (F test), with $\alpha = .05$. Post-hoc t testing was performed when indicated, to determine appropriate treatment group differences.

Results

The temperature used during the baseline "no distraction" stimulus was equivalent for the 3 groups (mean = 46.30°C for the No VR control group; 46.26°C for Low-Tech-VR helmet group; and 46.23°C for the High-Tech-VR helmet group, $F(2, 74) < 1$, not significant). Time spent thinking about pain during baseline was equivalent for the 3 groups (mean = 7.33 (1.44) for the No VR control group; 6.39 (2.67) for the Low-Tech group; and 7.28 (1.70) for the High-Tech group $F(2, 74) = 1.76$, MSE = 7.38, $P = .18$). Pain unpleasantness during baseline was equivalent for the 3 groups (mean = 6.46 (1.21) for the no VR control group; 5.91 (1.59) for the Low-Tech-VR group; 6.37 (1.11) for the High-Tech-VR group, $F(2, 74) = 1.30$, $P = .28$, not significant, MSE = 2.29). Worst pain during baseline was equivalent for the 3 groups (6.47 (.95) for the No VR Group; 6.33 (1.02) for the Low-Tech-VR group; and 6.45 (1.10) for the High-Tech-VR group, $F(2, 74) = 1.42$, $P = .87$, not significant, MSE = .15).

The VR analgesia scores (baseline pain minus pain during VR) were calculated for each individual (maximum possible difference = 10) for each of the 3 pain ratings (ie, worst pain, pain unpleasantness, and time spent thinking about pain). Results of statistical comparisons are shown in Table 1 and Fig 2.

A 30% or greater decrease in pain intensity is generally regarded as being clinically meaningful to patients.[10] Conservatively defining a change score (pain intensity during baseline minus pain intensity during VR) of 3 or more (on a 0-10 scale) as clinically meaningful in the present study, only 29% of participants in the Low-Tech helmet group, as opposed to 65% of participants in the High-Tech-VR helmet group, showed a clinically significant reduction in pain intensity during virtual reality. Similarly, 61% of Low-Tech helmet vs 92% of high-tech

Table 1. Mean VR Analgesia (Baseline Pain Minus Pain During VR, Max Possible Difference = 10)

No VR	Low Tech VR	High Tech VR	Time Spent Thinking About Pain
.61	3.16	4.44	$F(2,74) = 27.33$, $P < .001$, MSE = 92.12
	3.16	4.44	$t(52) = 2.35$, $P < .05$, SE = .55
.61	3.16		$t(49) = 4.77$, $P < .001$, SE = .53
.61		4.44	$t(47) = 8.68$, $P < .001$, SE = .44

No VR	Low Tech VR	High Tech VR	Pain Unpleasantness
.28	1.91	3.55	$F(2,74) = 26.38$, $P < .001$, MSE = 65.56
	1.91	3.55	$t(52) = 3.56$, $P < .005$, SE = .46
.28	1.91		$t(49) = 3.39$, $P < .005$, SE = .48
.28		3.55	$t(47) = 9.02$, $P < .001$, SE = .36

No VR	Low Tech VR	High Tech VR	Worst Pain
.15	1.84	2.79	$F(2,74) = 22.36$, $P < .001$, MSE = 43.15
	1.84	2.79	$t(52) = 2.29$, $P < .05$, SE = .41
.15	1.84		$t(49) = 4.17$, $P < .001$, SE = .40
.15		2.79	$t(47) = 7.87$, $P < .001$, SE = .33

No VR	Low Tech VR	High Tech VR	Amount of Fun
.56	3.36	4.93	$F(2,73) = 27.68$, $P < .001$, MSE = 118
	3.36	4.93	$t(51) = 2.42$, $P < .05$, SE = .65
.56	3.36		$t(48) = 5.20$, $P < .001$, SE = .54
.56		4.93	$t(47) = 8.09$, $P < .001$, SE = .54

helmet participants reported a change score of 3 or more in Time Spent Thinking About Pain, and 36% of low-tech helmet participants vs 73% of high-tech helmet participants reported a change score of 3 or more for pain unpleasantness.

Subjects in the High-Tech-VR group did not report a significantly stronger illusion of "presence" in the virtual environment compared to subjects in the Low-Tech-VR group (mean = 5.08 vs 4.72, respectively, $t(51) < 1$, not significant).
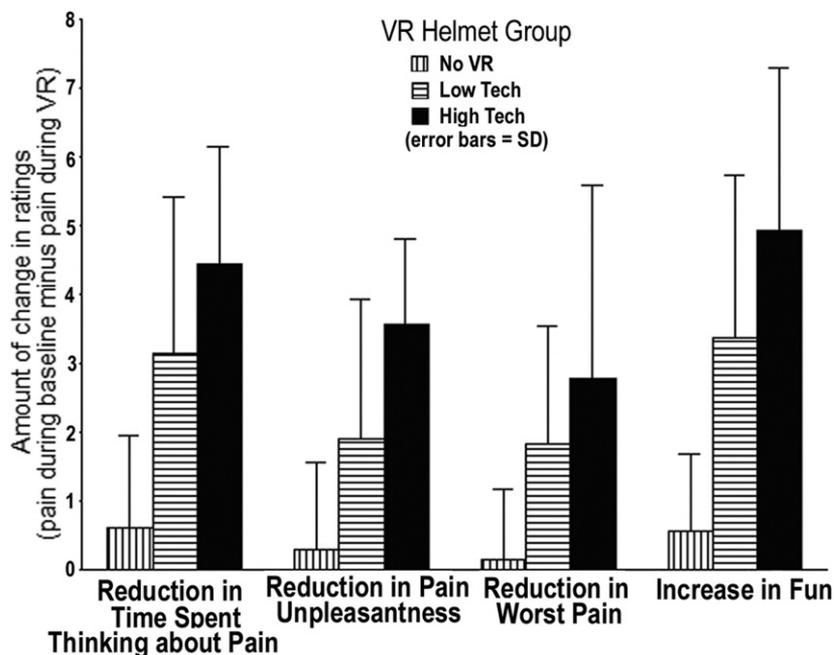

Figure 2. The amount of VR analgesia in the No VR (vertically striped bar) vs the Low-Tech-VR helmet group (horizontal striped bar) vs the High-Tech-VR helmet group (filled bar). VR analgesia is defined as the difference between baseline scores and scores during VR. Bars show means with SD shown as error bars.

Discussion

In the current study, we compared the relative effectiveness of VR distraction using a higher quality VR helmet (wider field-of-view) vs a lower quality VR helmet (narrower field-of-view), on subjective pain ratings during brief thermal pain stimuli. Subjects showed the predicted dose-response relationship: more pain reduction in the "higher distraction dose" High-Tech helmet group than in the "lower distraction dose" Low-Tech helmet group. Compared to the Low-Tech-VR helmet group, the High-Tech-VR helmet group reported 34% more reduction in worst pain, 46% more reduction in pain unpleasantness, 29% more reduction in time spent thinking about pain, and 32% more fun during the pain stimulus in VR. Only 29% of participants in the Low-Tech helmet group, as opposed to 65% of participants in the High-Tech-VR helmet group, showed a clinically significant reduction in pain intensity during virtual reality. These results suggest that a High-Tech-VR helmet is needed to consistently achieve clinically meaningful reductions in pain intensity for the majority of participants.

In the present study, compared to subjects in the Low-Tech-VR helmet group, subjects in the High-Tech-VR helmet group reported a significant increase in how much fun they had during VR, which is consistent with previous reports in subjects with experimental pain[26,27] as well as in burn patients who report having more fun during wound care and physical therapy in High-Tech-VR than with No VR.[25]

The results of the present study are consistent with Hoffman et al's[27] proposal that the concept of immersion in virtual reality can help guide the design of VR systems that increase VR analgesic effectiveness. In the present study, as predicted, and as found by Hoffman et al,[27] manipulating the objective immersiveness of the VR system strongly influenced analgesic effectiveness.

A recent and related study (in preparation) from our lab found a similar pattern of VR analgesia effect when immersiveness was manipulated, without a detectable change in VR presence. Using the same rationale as the present study, we tested whether increasing the objective immersiveness of the VR system by manipulating participants' interactivity with the virtual world would increase the amount of pain reduction during virtual reality (ie, the amount of VR analgesia). One group was allowed to shoot snowballs at snowmen, igloos, robots, and penguins in SnowWorld; another group passively glided through the same SnowWorld without shooting snowballs. Participants allowed to interact with Snow-World showed more pain reduction but not higher presence than those in the passive VR condition. In both the interactivity study and the current study, Slater and Wilbur's[40] principles of immersion were helpful for modifying factors that increased analgesic effectiveness in virtual reality, despite the fact that pain ratings were more sensitive to the manipulation than were the single-item presence ratings.

Such assessments of user presence during painful stimuli may only detect a difference in presence when several immersion factors are manipulated simultaneously (high display quality, head tracking on, sound effects on, interactivity on vs low display quality, head tracking off, sound effects off, no interactivity) as demonstrated previously.[27]

Independent of the relationship between presence and analgesia, our current data are not inconsistent with attentional distraction as a mechanism of VR analgesia. Future research should directly explore the relationship between the amount of attention distracted by VR (ie, the amount of reduction in performance on an attention demanding task) and the amount of pain reduction achieved by such distraction. If VR analgesia works via an attentional mechanism, we would predict that VR systems that are more attention grabbing (as measured via a divided attention task) will be more effective at reducing pain than a VR system that is less attention grabbing.[22] A divided attention task may prove more valuable and more objective than subjective presence ratings for quantifying the amount of attention drawn into virtual reality and for helping to differentiate the elements of the most effective VR analgesia systems.

One weakness of the current study is that VR treatment time (2 minutes) and pain stimulation duration (30 seconds) were brief. However, in controlled clinical studies, VR therapy for procedural pain has recently been extended for durations of greater than 10 minutes. Clinical studies are needed to determine whether the quality of the VR helmet shows such a large impact on clinical patients (ie, whether the results from the present laboratory study generalize to clinical pain).

One critical issue raised by the current study is the important balance between the functional quality and the associated cost of VR system components. The results of the present study show that increasing the quality of the VR helmet visual display can substantially enhance the effectiveness of virtual reality as a nonpharmacologic analgesic. However, such High-Tech-VR helmets are currently expensive (the 1280VR, a new helmet with similar specifications to the one used in the present study, costs under $16,000 at www.imprintit.com) and are relatively heavy (<2 lbs), compared with lighter weight consumer models that are less expensive (the ruggedized CyVisor used in the present study is $2,000 at www.virtualresearch.com). New display technologies are slated to emerge in the next 2 or 3 years that will reduce the costs and improve the quality and weight of High-Tech-VR helmets.[18] Numerous factors are relevant to deciding which helmet to incorporate into a clinical VR analgesia system, including the anticipated severity of pain, the efficacy of VR analgesia, the efficacy of other concurrent analgesic techniques (eg, opioids), the frequency of VR system use, and the cost of VR system acquisition and maintenance. At this early point in VR analgesia development and application, most of these factors cannot be quantified, although research such as the current study is a useful step in this process. SnowWorld is available for eligible medical centers for pain control free of charge (www.vrpain.com). A new upgrade called SuperSnow-World will also be free. Seven U.S. Medical centers are currently beginning to explore VR analgesia with SnowWorld

(Harborview Burn Center in Seattle; New York Burn Center; Shriner's Children Burn Center in Galveston; Johns Hopkins Burn Center; Brooke Army Medical Center in Texas; Tripler Army Medical Center in Honolulu; and the University of Wisconsin Burn Center). Each of these centers have chosen to use High-Tech-VR helmets (equal or better quality than the high-tech helmet used in the present study) under the rationale of providing the most effective VR analgesia system available for this most challenging clinical pain setting, to maximize the quality of care for their patients, and to give the VR distraction approach the most fair test (ie, assessing whether VR analgesia could ever become part of the standard of care in the future). One additional factor to consider is the extent to which the use of such nonpharmacologic analgesic techniques may facilitate certain aspects of medical care, and hence, result in cost savings. Although such costs savings have yet to be shown for VR analgesia, recent reports document costs savings with hypnotic analgesia in procedural pain settings[33] and suggest that adjunctive use of nonpharmacologic analgesic techniques may offer economic benefits that, at least in part, help offset the costs associated with such techniques.

The relevance of the current investigation to clinical pain management is also noteworthy. It is widely accepted that for problematic pain management settings (eg, procedural pain, pediatric pain, chronic pain), a multimodal analgesic approach is warranted (ie, several pain control techniques used simultaneously). Although not yet widely available, VR analgesia has demonstrated efficacy in various settings, including cutaneous burns,[19,23,24,25] postoperative physical therapy,[42] dental pain,[21] pain during a noninvasive endoscopic urological procedure to reduce the size of an enlarged prostate,[44] and cancer pain[13,14] and, furthermore, combines well with concurrent opioid use. Acute, procedural pain settings seem to be particularly well-suited to the application of VR, either alone or as an adjunct to pharmacologic analgesia, because complete analgesia relief is rarely possible during most medical procedures, and side effects from virtual reality analgesia are minimal/nonproblematic for 10- to 20-minute medical procedures (and probably longer), even when a higher quality (high-dose) VR helmet is used. Future research should explore whether the amount of pain reduction achieved with VR analgesia can be further increased, how it can be effectively combined with other analgesic techniques, and how it can be applied most cost effectively. The present study suggests that, with additional technology development/maturation, there is much room for further improving the analgesic effectiveness of immersive virtual reality distraction.

Acknowledgments

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