Active and Passive Distraction Using a Head-Mounted Display Helmet: Effects on Cold Pressor Pain in Children

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Objective: The current study tested the effectiveness of interactive versus passive distraction that was delivered via a virtual reality type head-mounted display helmet for children experiencing cold pressor pain. ***Design:*** Forty children, aged 5 to 13 years, underwent 1 or 2 baseline cold pressor trials followed by interactive distraction and passive distraction trials in counterbalanced order. ***Main Outcome Measures:*** Pain threshold and pain tolerance. ***Results:*** Children who experienced either passive or interactive distraction demonstrated significant improvements in both pain tolerance and pain threshold relative to their baseline scores. In contrast, children who underwent a second cold pressor trial without distraction showed no significant improvements in pain tolerance or threshold. ***Conclusion:*** Although both distraction conditions were effective, the interactive distraction condition was significantly more effective. Implications for the treatment of children's distress during painful medical procedures are discussed.

Keywords: distraction, pain, children, medical procedures

Although distraction is emerging as a front-line intervention for children undergoing acute painful medical procedures (Dahlquist, 1999a; Powers, 1999), a close examination of the literature reveals inconsistent methodology and conflicting outcomes. Moreover, there has been surprisingly little study of the mechanisms that account for the effectiveness of distraction with children. The present study incorporates some of the technology used in virtual reality (VR) interventions (i.e., a head-mounted display [HMD] helmet) to enhance the delivery of distraction, and in so doing tests one of the mechanisms that has been proposed to make distraction more effective—whether the distraction activity is active versus passive.

A number of studies support the effectiveness of distraction as a treatment for children experiencing acute medical pain. For example, music, distracting conversation, distracting breathing techniques (e.g., blowing bubbles or party blowers), toys, and cartoons have been associated with reductions in distress during venipunctures, bone marrow aspirations, lumbar punctures, burn treatment, cystourethrograms, and routine immunizations (Dahlquist, 1992; Powers, 1999; Zelikovsky, Rodrigue, Gidycz, & Davis, 2000). However, not all outcomes have been positive. For example, Arts et al. (1994) found music to be no better than a placebo; Jacobsen at al. (1990) found no relation between distracting conversation and child distress during chemotherapy; Cassidy et al. (2002) found no differences between children who watched TV during an injection and children who saw only a blank TV; Landolt, Marti, Widmer, and Meull (2002) failed to find any benefit from cartoon movie distraction for children undergoing burn debridement; and Manne, Bakeman, Jacobsen, Gorfinkle, & Redd (1994) reported problems with children refusing to use the party blower. However, little is known regarding why some distraction strategies fail (Dahlquist & Pendley, 2005).

According to McCaul & Malott (1984), distraction interventions are presumed to work because: (a) pain perception is "a controlled, not automatic process" (p. 518); attention must be directed toward the painful stimulus for it to cause distress, and (b) attentional capacity is limited. The more attention demanded by the distracting task, theoretically, the less attentional capacity available for processing painful stimuli. However, the distraction process may not be that straightforward (McCaul, Monson, & Maki, 1992). Theoretical models in the attention literature (i.e., multiple-resource theory) propose that individuals have multiple attentional pools or resources that function relatively independent, such that engaging in a task involving one modality will not deplete the individual's attention resources in other sensory modalities (Wickens, 2002). Multiple-resource theory would therefore suggest that watching cartoons or listening to music are likely to be inadequate pain distractors because they only involve auditory and

visual attention resources, leaving the tactile and kinesthetic sensations associated with acute pain unaffected.

Electronic games, on the other hand, are multisensory. In addition to visual and auditory sensations, tactile and kinesthetic senses are involved as the child plays with the game. Thus, electronic games may offer the potential to block more of the sensory domains associated with acute pain stimuli. Preliminary findings using electronic games as distractors are promising. For example, Dahlquist and colleagues (Dahlquist, Busby, et al., 2002; Dahlquist, Pendley, Landthrip, Jones, & Steuber, 2002; Pringle et al., 2001) used distraction via handheld electronic games to reduce overt behavioral distress in preschool and elementary-school aged cancer patients undergoing intramuscular injections and subcutaneous port access. The large effect size obtained by Dahlquist, Pendley et al. ($f = .41$) and the fact that improvements were maintained over the 8-week intervention suggest that electronic games may be highly effective distractors for children undergoing painful medical procedures.

Researchers also have argued that distraction activities that are active should be more effective than distraction that is passive (e.g., Dahlquist, 1999a, 1999b; Mason, Johnson, & Woolley, 1999). Tasks that engage the child in manipulating the environment and/or in problem-solving should utilize more attentional resources than passive tasks. Moreover, tasks involving active problem-solving may be more likely to interfere with catastrophizing and other pain-exacerbating maladaptive thought processes (Haythornwaite, Lawrence, & Fauerbach, 2001).

Within the broader distraction literature, we are aware of only two pediatric studies that have compared passive distraction with more active distraction (MacLaren & Cohen, 2005; Mason et al., 1999). In both studies, cartoon viewing served as the passive distractor. Mason et al. found that active distraction (parent–child interaction involving reading a short story) was more effective in reducing pain and distress behaviors than either passive distraction (the cartoon) or a control condition. However, MacLaren and Cohen found that children were more distracted and less distressed when engaged in a passive distraction (e.g., watching a cartoon) than when they played with an interactive toy. Children who played with the interactive toy were more distracted than children in a standard nondistraction condition, but the distress levels between the groups were equal.

However, neither of these studies provides a clear test of active versus passive distraction. The cartoons, stories, and interactive toys differed on multiple dimensions in addition to whether they were active versus passive. Thus, one cannot determine if the active/passive aspect of the distraction activity, or the many other differences between the distraction activities, actually accounted for the outcomes. A more tightly controlled test of the relative utility of active versus passive distraction for acute pain in children is needed.

Additional support for the premise that interactive distraction should be superior to passive distraction comes from the rapidly developing literature on human interaction with computer technology-generated environments (which are called virtual reality [VR] in commercial applications). VR applications typically use HMDs and headphones to present a 3-dimensional (3D) virtual environment and to facilitate the suppression of extraneous (nonvirtual environment related) sensory information by physically muting real-world sounds and restricting the user's peripheral vision. As individuals interact with virtual environments, they often are able to suppress conflicting sensory information from the real environment and from the VR hardware itself (Schubert, Friedmann, & Regenbrecht, 2001), resulting in a sense of being "in" the virtual environment, rather than looking at it from the outside. This psychological process is called *presence* (Nash, Edwards, Thompson, & Barfield, 2000; Schubert et al., 2001).

According to Nash et al. (2000), the more the virtual environment responds to the individual in a lawful, meaningful manner, the greater the sense of presence. Thus, virtual environments that change in response to the individual (i.e., real-time computer graphics that change in response to the manipulation of a joy stick or the individual's head turning, or respond to the individual's manipulation of objects in the virtual environment) are more likely to elicit presence. More vivid and realistic stimuli in the virtual world, as well as a first person perspective also are thought to provide a greater sense of presence, although unrealistic (e.g., cartoon characters) and third person (e.g., race car games) perspectives also can induce presence (Schubert et al., 2001; Schuemie, van der Straaten, Krijn, & van der Mast, 2001).

Despite the apparent potential for VR applications to be powerful distractors, there have been relatively few studies of VR distraction for acute pain. Preliminary investigations by Hoffman and colleagues (Hoffman, Doctor, Patterson, Carrougher, & Furness, 2000; Hoffman, Patterson, & Carrougher, 2000; Hoffman, Patterson, Carrougher, & Sharar, 2001; Hoffman, Patterson, et al., 2004) suggested that positive benefits in pain reduction in young adults and older adolescents undergoing burn debridement can be elicited within 3 minutes of VR engagement and can be sustained over multiple burn treatments. Steele et al. (2003) demonstrated reductions in self-reported pain during VR distraction (a HMD with a tracking device that controlled the movement of a character in a 3D game plus a hand-held trigger device that fired a gun) with a 16-year-old boy with cerebral palsy undergoing painful physical therapy. VR distraction also appeared to modulate adult brain activity in response to thermal pain (Hoffman, Richards, et al., 2004).

However, few VR interventions have been tested with children. Wint, Eshelman, Steele, and Guzzetta (2002) found a trend for lower self-reported pain during lumbar punctures in adolescents who viewed a 3D movie through a VR visor than in adolescents who received standard care. However, their intervention was less than optimal; it required no interaction with the virtual environment.

A series of studies using a 3D interactive distraction intervention (a 360° Virtual Gorilla environment (Allison, Willis, Bowman, Wineman, & Hodges, 1997) presented via a VR HMD helmet and a joystick) yielded more promising findings. Children with cancer (aged 7 to 19) demonstrated lower levels of distress during subcutaneous port access during the interactive VR distraction condition than did children in a no-distraction control condition (Gershon, Zimand, Lemos, Rothbaum, & Hodges, 2003; Gershon, Zimand, Pickering, Rothbaum, & Hodges, 2004; Wolitzky, Fivush, Zimand, Hodges, & Rothbaum, 2005)

Taken together, the distraction and VR literatures suggest that distraction that is multisensory and interactive is most likely to be effective in allocating attention away from pain sensations, although empirical tests of this premise are lacking. Moreover, VR literature suggests that the use of a HMD helmet that blocks or

mutes external visual and auditory sensations may help direct attention away from pain stimuli.

The current study tested the effectiveness of distraction that was enhanced by the use of a VR-type HMD helmet for children experiencing cold pressor pain. Although the ultimate goal of our research was to investigate the effectiveness of technology-assisted distraction with a clinical population, such as children undergoing painful medical procedures, we elected to study experimental pain, rather than clinical pain, in the present study in order to avoid the many uncontrolled factors that influence discomfort in a clinical setting. For example, in the clinical setting, even when participants receive the same procedure (such as an injection), the actual pain stimulus may vary depending on the depth of the needle, the volume of liquid infused, and the rate of infusion. In contrast, a laboratory pain study allows researchers to standardize the intensity of the pain stimulus (Edens & Gil, 1995). In the current study, all participants experienced cold-pressor pain in water maintained at the same temperature.

Laboratory studies also allow researchers to manipulate the variables of interest, while holding other environmental variables constant. Thus, the conditions under which participants received each experimental condition can be more closely controlled than in the clinic. Experimental protocols also allow for clear, consistent, operationalization of the pain response (i.e., in the present study the duration of exposure to the cold pressor before the first report of pain or before pain becomes intolerable and the child removes his/her hand from the cold water). Finally, many laboratory pain stimuli are safe and practical to repeat in a single session, thus allowing for efficient within-subject designs without the problems of varying inter-trial duration and participant attrition that can plague longitudinal clinical interventions (Edens & Gil, 1995; Gracely, 1994). Thus, laboratory-based efficacy studies allow for the refinement of intervention procedures under "ideal" conditions before pursuing effectiveness testing in the clinical setting.

Cold pressor pain is particularly well-suited to children because ice water is familiar and not particularly threatening, because it is safe, and because the child controls the termination of the pain stimulus. (See Edens & Gil, 1995; Fanurik, Zeltzer, Roberts, & Blount, 1993; Miller, Barr, & Young, 1994, for a more extensive discussion of cold pressor laboratory pain studies with children.) Moreover, because cold-induced discomfort diminishes rapidly when the hand is removed from the cold water, it is possible to conduct multiple trials with a single participant. By treating each participant as his/her own control, one can thus avoid the problems associated with interparticipant variability in baseline pain tolerance and pain threshold.

The present study tested the relative effectiveness of interactive versus passive distraction. Using a more tightly controlled design than previous studies, the visual and auditory nature of the distraction stimuli tested in each distraction condition were held constant, whereas only the child's ability to interact with the distraction stimuli was manipulated. Children were expected to demonstrate greater improvements in cold pressor pain threshold and pain tolerance during both the interactive and the passive distraction conditions than during the no-distraction control condition. Improvements were expected to be greatest in the interactive distraction condition.

Method

Participants

Participants were recruited from a suburban community and from a university summer day camp via flyers. Forty-six children and their parents agreed to participate in this study. Three children were unable to participate due to scheduling difficulties. Three additional children were excluded from analyses because their pain tolerance exceeded the 4-minute study limit. Of the final sample of 40 children, 28 (65%) were female. Participant ages ranged from 5 to 13 years, with a mean of 10.12 years ($SD = 1.93$). Twenty-six participants (65%) were White, 10 (25%) were African American, 2 (5%) were Middle Eastern, 1 (2.5%) was Asian, and 1 (2.5%) was biracial.

Design

Children were randomly assigned to one of three conditions: interactive distraction ($n = 13$), passive distraction ($n = 14$), or a no distraction control condition ($n = 13$, see Table 1). All participants underwent a baseline cold pressor trial during which pain tolerance and pain threshold were measured. During Trial 2, participants in the interactive distraction condition used a joystick to play a videogame displayed through a 3D VR head mounted display helmet with integrated headphones. Participants in the passive distraction condition also wore the HMD helmet in Trial 2, but instead of playing the videogame, they watched prerecorded footage generated by someone else playing the same videogame segment used in the interactive distractions condition on their display screen. The game starting points were identical in both conditions. Thus, the visual and auditory stimuli presented through the HMD in both conditions were identical. Only the child's ability to manipulate the virtual environment varied across the two distraction conditions. To control for the effects of repeated exposure and possible habituation to the cold pressor, control participants underwent a second cold pressor trial with no distraction provided.

To compare the relative benefits of interactive versus passive distraction in a completely within-subjects design, and thereby increase power, up to two more cold pressor trials were conducted. In cold pressor Trial 3, experimental participants received the distraction intervention they did not receive in Trial 2. In Trials 3 and 4, control participants received the two experimental interventions in counterbalanced order. Thus, all participants participated in both experimental conditions. Participants' performance during their last baseline trial (Trial 1 for participants originally assigned to an experimental condition; Trial 2 for participants originally assigned to the control condition) was then compared with their performance during interactive distraction and during passive distraction.

Materials and Equipment

Cold-pressor apparatus. The cold-pressor apparatus that was used in the present study is similar to those used in previous studies of cold-pressor pain (e.g., Farthing, Venturino, Brown, & Lazar, 1997; Forys & Dahlquist, 2007). A plastic ice cooler (48 × 30 × 30 cm.) was filled with water and divided into two sections by a plastic screen. Ice cubes and three PolarPack® Foam Bricks (Mid-Lands Chemical Company, Inc. Omaha, NE) were placed in

Table 1
Experimental Design

Experimental group	*n*	Cold pressor trial			
		1	2	3	4
Interactive distraction	13	Baseline[a,b]	Interactive distraction[a,b]	Passive distraction[b]	
Passive distraction	14	Baseline[a,b]	Passive Distraction[a,b]	Interactive Distraction[b]	
Control (Order 1)	7	Baseline[a]	Baseline[a,b]	Interactive Distraction[b]	Passive Distraction[b]
Control (Order 2)	6	Baseline[a]	Baseline[a,b]	Passive Distraction[b]	Interactive Distraction[b]
Total	40				

[a] Trials used for the between-subjects analyses. [b] Trials used for the within-subjects analyses.

the section that was farthest from the participant. The foam bricks, which are commonly used to transport medications that must be maintained at cold temperatures for long periods of time, utilize a unique vacuum forming process that ensures an exact release of thermal energy with every use. The cooling ability of each brick is long lasting. A nylon cradle was used to hold the participant's arm in the ice-free section of the water. This cradle allowed the participant to relax his/her arm as well as ensured that the hand remained fully immersed in the water. It was adjusted so the water line fell at or slightly above the participant's wrist.

A waterproof thermometer was attached to the inside of the cooler and used to monitor water temperature. The water temperature was maintained at 5°C. Warmer water temperatures have been reported to cause problems with ceiling effects. For example, 93% of 10- to 14-year-old participants demonstrated ceiling effects (tolerated the full 4 minutes) at a water temperature of 10°C (Goodman & McGrath, 2003). Similar problems with ceiling effects have been reported by other investigators (e.g., Miller et al., 1994; Piira, Taplin, Goodenough, & von Baeyer, 2002).

Stopwatch. An Emerson stopwatch (Model #136, Redmond Group of Companies, Mississauga, Ontario, Canada) was used to measure pain threshold and pain tolerance times to the tenth of a second.

Thermal feedback system. A thermal feedback system, manufactured by Bio-Feedback Systems, Inc. (Boulder, CO) (Model DT–100; Power ID–91), was used to measure hand temperature at baseline and between each trial.

Videogame equipment. Pilot testing indicated that the Sony Playstation 2® (Sony, Oradell, NJ) *Finding Nemo®* "Jellyfish Race" game was appropriate for children in the age range of this study. The game provides a first person perspective as the participant controls "Marlin," who chases "Dory," while trying not to get stung by the jellyfish. The Sony Playstation 2 controller was mounted on a base and attached to a table so that children could manipulate the controller with one hand while the other hand was in the cold water. (A one-handed controller also was desirable because of its potential generalizability to medical procedures, such as intravenous injections, which leave only one hand free.)

HMD helmet. An adjustable HMD with integrated headphones was used in both distraction conditions. The VFX3D Interactive Personal Display System manufactured by Interactive Imaging Systems, Incorporated, Rochester, NY) was connected to the Sony

Playstation 2® through a Sony RDR–GX7 DVD recorder (Sony, Oradell, NJ). On connection, either the child's own videogame performance (active distraction condition) or the prerecorded videogame footage (passive distraction condition) could be viewed through the HMD. The stereoscopic 360,000 pixel color display was projected through the goggles, which were adjustable to the individual's optimal interocular distance to reduce eye strain. Auditory effects of the game were delivered via headphones built into the HMD. Smaller children or children with very short hair occasionally preferred to wear a soft stocking cap under the helmet for comfort.

Procedure

This study was approved by the University of Maryland, Baltimore County's Institutional Review Board. Informed consent was obtained from the parent and assent was obtained from child participants ages 7 or older. Participants were assigned to experimental group by stratified randomization. Groups were matched on age (within 1 year) and gender.

The experiment was conducted in a 16 ft. × 12 ft. carpeted laboratory room that was maintained at a temperature between 22 and 23 °C. The child participant and two graduate or undergraduate student experimenters were present. The following procedures were followed for each cold pressor trial. The child was seated with the nondominant arm next to the cold-pressor apparatus. The temperature sensor was taped to the index finger of the child's nondominant hand. After a 1 minute adaptation period, the child's finger temperature was measured.

Because small changes in water temperature have been found to significantly affect pain tolerance (Mitchell, MacDonald, & Brodie, 2004), care was taken to ensure that the water temperature remained constant by monitoring the water temperature before and after each trial and by circulating the water by hand in between trials. (Although a circulating water bath is ideal for maintaining a constant water temperature, financial constraints prohibited purchasing such a device.) The above procedures in combination with the coolant bricks adequately maintained a temperature of 5 °C (+/– 1 °C). Ice did not need to be added between trials.

Before each trial the experimenter told the child that the water would be cold and that they would notice that after a while their hand would start to feel uncomfortable or hurt. The child was

instructed to say, "It hurts now" when his/her hand began to feel uncomfortable or hurt, and to remove the hand from the water when it became too uncomfortable or hurt too much. The participant was asked to repeat the instructions before each trial to make sure he/she understood that the trial could be terminated at any time without any negative repercussions.

The child's nondominant hand was placed in the cooler to wrist level as the elbow rested on the cloth cradle. Timing began as soon as the participant's hand was submerged to wrist level and ended when the hand was removed. The time at which the child said, "It hurts now" was used as the measure of pain threshold. The total time the hand was submerged was used as the measure of pain tolerance. At the end of the trial, the child's hand was placed in a warm water bath (32 °C) for approximately 5 minutes, and warmed to within 1 °C of baseline temperature. Posttrial finger temperature was recorded.

Baseline. The participant was informed that the experimenter would need to test how well his/her body likes cold temperatures before playing the video game by placing his/her hand in cold water. The experimenter read the instructions described above to the child. The experimenter then placed the child's hand in the cold pressor apparatus. Children in the control condition underwent two baseline trials. Children initially assigned to the two VR distraction conditions underwent a single baseline trial.

Interactive distraction condition. The participant was told that he/she would be playing *Finding Nemo*® while wearing a VR helmet and using a mounted controller, while his/her nondominant hand was placed in the cold water. A surgical cap was placed on the child's head for hygienic purposes. The experimenter told the participant that he/she would see the video game through the viewer in the helmet and hear the game through the earphones in the helmet. The experimenter modeled the correct use of the controller and described the game for the participant. The experimenter then ensured the child understood how to operate it by allowing him/her to play the game for 30 s. The participant was then told that he/she would be allowed to play the game for about 10 s before having his/her hand placed in the water, and that the game would be ended when the participant removed his/her hand from the water. The VR helmet was then placed on the child's head and the game was commenced. After 10 s of play, the participant's nondominant hand was placed in the cooler. All other procedures were the same as baseline.

Passive distraction condition. The participant was told that he/she would be watching someone else play *Finding Nemo*® on a prerecorded DVD while wearing a VR helmet, and while his/her nondominant hand was placed in the cold water. The participant was told that they would see the video game through the viewer in the helmet and hear the game through the earphones in the helmet. The game was then described to the participant. The participant was then told that he/she would be allowed to watch the game for about 10 seconds before having his/her hand placed in the water, and that the game would stop when the participant removed his/her hand from the water. The VR helmet was placed on the child's head and the prerecorded game play (DVD) was commenced. After 10 seconds of watching the game, the participant's nondominant hand was placed in the water. All other procedures were the same as baseline.

A brief qualitative questionnaire was administered at the end of the study to assess the child's experience of the distraction tasks.

After all procedures were completed, the child was then allowed to pick a prize from a bag of trinkets valued under $2.00 a piece.

Measures

Pain threshold was defined as the number of seconds of immersion in the cold pressor until the child reported pain. Pain tolerance was defined as the total number of seconds the child kept his/her hand immersed in the cold water.

At the end of the study procedures, participants were asked two exploratory qualitative questions about their awareness of stimuli outside of the virtual environment. The questions were: "Other than the videogame, what else did you see while playing the game?" "Other than the videogame, what other noises did you hear while playing the game?"

Results

Preliminary Analyses

Baseline pain threshold scores ranged from 2 to 69 s, with an overall mean of 19 s ($SD = 15.27$). Baseline pain tolerance scores ranged from 7 to 79 s, with an overall mean of 28 s ($SD = 17.54$).

One-way analyses of variance (ANOVAs) revealed no significant differences between experimental groups (control, passive distraction, interactive distraction) in participant age, baseline pain threshold, or baseline pain tolerance (all $ps > .45$).

Distraction Versus No Distraction

Two separate 3×2 (experimental condition by trial) ANOVAs were conducted on pain threshold and pain tolerance scores obtained at baseline (Trial 1) and during the first experimental trial (Trial 2). Results revealed a significant trial by condition interaction for pain threshold $F(2, 37) = 4.09, p = .025, f = .50$, and for pain tolerance $F(2, 37) = 4.02, p = .026, f = .47$.

Post hoc comparisons revealed that, when compared with their baseline scores, passive distraction participants showed a significant increase in pain threshold during Trial 2 ($M = 19.70, SD = 3.95$ vs. $M = 27.08, SD = 5.34, p = .02$), as did interactive distraction participants ($M = 14.73, SD = 4.10$ vs. $M = 28.86, SD = 5.55, p < .001$). Interactive distraction participants also demonstrated a significant increase in pain tolerance ($M = 28.71, SD = 4.99$ vs. $M = 70.35, SD = 13.17$). However, the average increase in pain tolerance during Trial 2 for the passive distraction participants was not significant ($M = 27.97, SD = 4.81$ vs. $M = 37.51, SD = 12.69, p = .35$).

Control participants showed no evidence of habituation to the cold pressor tasks. Their pain threshold scores showed no change from Trial 1 to Trial 2 ($M = 21.93, SD = 4.10$ vs. $M = 22.61, SD = 5.54, p > .99$). Similarly, their pain tolerance scores showed no change from Trial 1 to Trial 2 ($M = 27. 37, SD = 4.99$ vs. $M = 27.37, SD = 13.17, p > .99$).

Relative Effectiveness of Passive Versus Interactive Distraction: Within-Subjects Analysis

Order effects. Prior to conducting within-subject analyses, independent *t* tests were conducted to determine whether the order in which children participated in the passive and active VR distrac-

tion conditions affected their scores. No order effects were found. Neither pain threshold nor pain tolerance scores differed as a result of order of participation in the experimental conditions (all *p*s > .26). Therefore, data were collapsed across the two orders of presentation for the subsequent within-subjects analyses.

Within-subjects analyses. Separate within-subjects ANOVAs were conducted on the entire sample's pain threshold scores and pain tolerance scores across the three experimental conditions (the participant's last baseline trial, passive distraction trial, and interactive distraction trial) to examine the relative effects of passive and interactive distraction with greater power. Results revealed significant effects for experimental condition for pain threshold $F(2, 78) = 10.23$, $p < .001$, $f^2 = .27$, and for pain tolerance $F(2, 78) = 12.90$, $p < .001$, $f^2 = .33$.

As predicted, post hoc comparisons indicated that children demonstrated the lowest pain thresholds during baseline (no distraction), significantly higher pain thresholds during passive distraction, and the highest pain thresholds during the interactive distraction (all *p*s ≤ .01). The patterns were even more dramatic for pain tolerance. Children demonstrated the poorest pain tolerance during baseline, significantly greater pain tolerance during passive distraction, and the greatest pain tolerance during interactive distraction (all *p*s < .01; see Figure 1).

Qualitative analysis. Thirty participants (75%) reported that they did not see anything while playing the videogame; 31 participants (77%) reported that they did not hear anything while playing the videogame. The remaining 23 to 25% of participants reported seeing their shoes, the floor, the wall, the television, the door, and part of a table and reported hearing talking and a "movie" in another room.

Discussion

The technology-assisted distraction intervention appeared to be very effective for this sample of 5- to 13-year-old children. Rela-

tive to their own baselines, children demonstrated higher pain thresholds and greater pain tolerance during both passive and interactive distraction. These findings cannot be attributed to mere habituation to the cold pressor task, because the children who underwent repeated cold pressor trials without distraction showed no improvements in either pain threshold or pain tolerance across trials.

Although both distraction conditions were effective, interactive distraction was superior to passive distraction. Children demonstrated significantly higher pain thresholds during interactive distraction than during passive distraction. Even more striking, however, were the differential effects for pain tolerance. On average, children tolerated the cold pressor nearly twice as long during interactive distraction than during passive distraction. To our knowledge, this is the first study to use a controlled experimental design to demonstrate that interactive distraction can increase pain thresholds and pain tolerance in children.

Several possible explanations for why interactive distraction worked better than passive distraction should be considered in future research. First, the process of interacting with the videogame may have blocked additional modalities of sensory input that passive distraction did not affect, i.e., tactile and kinesthetic sensations. Children received tactile stimulation as they manipulated the joystick. In addition, they had to utilize kinesthetic feedback to use the joystick to direct the avatar's movements. Thus, the interactive distraction task involved two sensory attentional pathways that the passive distraction task did not affect.

The interactive distraction task also differed from the passive distraction task in that it required the child to actively problem-solve while playing the game. For example, the children had to make quick decisions about which direction to move and how to avoid approaching jellyfish. Thus, the interactive distraction task included an active cognitive processing component. In the adult pain literature, "internal" distraction tasks that involve effortful
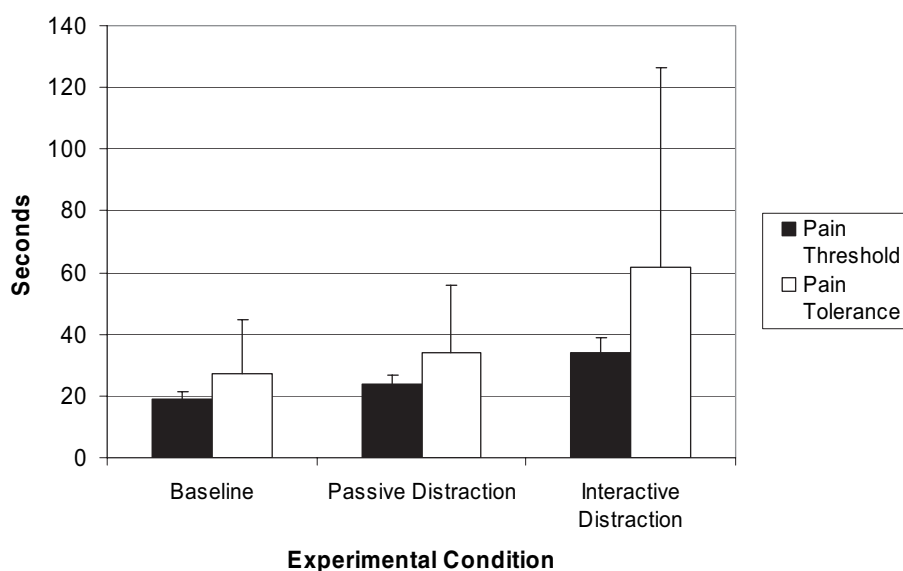

Figure 1. Estimated means and standard deviations for pain threshold and pain tolerance scores across experimental conditions (within-subjects analyses; *n* = 40).

cognitive processes, such as computation or detailed imagery, but do not block competing sensory information, have been found in some studies to be as effective as "external" sensory blocking interventions (McCaul & Malott, 1984). Although internal distractors are not typically used with children because of justifiable concerns about their developmental readiness to use such unstructured self-control strategies (Piira, Hayes, & Goodenough, 2002), it is possible that children can use internal pain control strategies if they are given a compelling enough prompt or structure to use them (e.g., a highly engaging game).

Further study is needed to tease apart the mechanisms by which interactive distraction affects children's pain experiences. The present design did not allow for an examination of the role of the HMD helmet. It is possible that the sensory blocking of the helmet provides a crucial enhancement of distraction effectiveness for children. Preliminary findings from Gershon et al. (2003) and Wolitzky et al. (2005) suggested that the helmet may enhance the effects of distraction. Studies also are needed to test whether the addition of active problem-solving to a sensory blocking intervention can enhance the pain management effectiveness of distraction for children.

Future research also should consider alternative explanations for the effectiveness of the interactive distraction condition. For example, it is possible that participants were motivated to keep their hand in the water to keep playing the game, and it is this access to a positive activity (i.e., game playing), rather than the distracting nature of the positive activity itself, that accounts for the greater benefit of interactive distraction.

Limitations

Although the effects of interactive distraction on the cold pressor pain stimulus used in the present study were impressive, laboratory pain differs from clinical pain in many important ways. Our participants knew that their experience of the cold pressor pain was completely under their control; they could stop the pain at any time by removing their hands from the water. The duration of the pain experience was relatively brief. And, perhaps most important, the children did not have a history of pain or frightening experiences associated with this pain stimulus. One cannot assume that interactive distraction would be equally effective with highly anxious children or in clinical situations in which children have no control over the duration of the pain they experience or must endure pain for longer than a few minutes.

The results of the present study also are limited by the relatively restricted age range of the current sample. It is not known how children younger than 5 years old would respond to the distraction interventions utilized in this study. Because young children tend to demonstrate the greatest distress during acute clinical pain, further investigation of the applicability of this methodology to younger children is warranted.

Finally, the cold pressor apparatus used in the present study lacked a circulating mechanism. Although the cold pressor appeared to maintain a consistent water temperature, it is still possible that some local warming of the water around the child's hand occurred. Local warming could be particularly problematic if children assigned to one of the experimental conditions had warmer hands and therefore warmed the surrounding water to a greater degree than did children assigned to another experimental

condition. In the present study, this potential problem was mitigated by the within-subjects design in which each subject served as his/her own control. Thus, even if a slight degree of local warming did occur, the impact on the present findings would be minimal.

Future Directions

Although the generalizability of the present findings remains to be tested, several aspects of the participants' reactions to interactive distraction suggest that it has the potential to be a practical and cost-effective clinical intervention. First and foremost, children enjoyed the distraction activity. Even after experiencing the cold pressor pain, a number of children asked if they could do the study again. The participants also learned to use the videogame and adapted to the HMD equipment very quickly (within 1 minute). The interactive distraction task appeared to effectively block participants' awareness of the environment. The majority of participants reported being unaware of visual and auditory stimuli outside of the interactive distraction task. Moreover, in contrast to other cognitive-behavioral interventions, the interactive distraction intervention required no specialized skills or professional training on the part of the adult administering the intervention, other than the basic skills involved in setting up the equipment. Thus, it could be used in a variety of medical settings by a wide range of personnel. Finally, the physical arrangement of the equipment that we employed (i.e., the one-handed controller) is compatible with a variety of common, acutely uncomfortable medical procedures. For example, a child could interact with the virtual environment with one hand while receiving chemotherapy to a subcutaneous port, while an intravenous line was being started or blood was being drawn, or while a central line was being flushed.

The results of the present study also suggest that although some sort of distraction is better than no distraction, interactive distraction is much more likely to provide effective acute pain management for children than is passive distraction. Further research is needed to determine the degree to which other aspects of virtual reality technology (such as fully immersive 3D virtual environments) or other cognitive problem-solving activities could be employed to further enhance pain management over and above what can be achieved through current methods of interactive distraction.

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