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Effectiveness of virtual reality distraction during a painful medical procedure in pediatric oncology patients

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Abstract
The effectiveness of virtual reality (VR) as a behavioral intervention designed to decrease distress during port access procedure was examined in 20 7- to 14-year-old pediatric oncology patients. Children were randomized to either engage in an immersive VR environment during the procedure or to a no VR control condition. Children's distress was assessed through subjective self-ratings and objective physiological and behavioral ratings. Narrative accounts of the experience were used as a measure of how well the child coped with the procedure. VR was effective in reducing children's distress on all measures. Implications of these findings for intervention are discussed.

Keywords: *Virtual reality, pediatric oncology patients, physiological and behavioral ratings*

Introduction

Children with cancer must undergo many and often painful medical procedures throughout the course of their illness. It is therefore imperative to investigate methods to reduce the distress associated with such procedures. Several studies have shown distraction to be a successful intervention for children undergoing invasive medical procedures.

In a study designed to decrease burned children's pain behavior during hydrotherapy, Kelley, Jarvie, Middlebrook, McNeer and Drabman (1984) evaluated the effectiveness of cartoon viewing during the painful procedure. Using a within-subjects design, the

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researchers found that the children's pain behavior was significantly reduced during the cartoon viewing, as opposed to the control condition with no cartoon viewing. In an experiment by Manne, Redd, Jacobsen, Gorfinkle and Schorr (1990), researchers designed an intervention to decrease anxiety for children with cancer undergoing venipuncture. The intervention included parent coaching, distraction, and positive reinforcement. For the distraction, the child was coached by the parent to blow into a party blower, as paced by the parent's slow counting. This not only distracted the children, but regulated breathing as well. Children's distress was significantly decreased by the behavioral intervention. In another experiment, children were taught distraction techniques such as counting and interactive play. Children who engaged in these distracting activities showed less behavioral distress than those who did not (Powers, Blount, Bachanas, Cotter & Swan, 1993).

Overall, distraction during a painful medical procedure has been shown to be highly effective in alleviating children's distress. Very recently, a technological advancement called virtual reality (VR) has been studied as a possibly more effective distracter than those previously studied and used in the medical setting. VR has an advantage over distraction techniques such as cartoon viewing or traditional video games because the body tracking, head-mounted displays, and other sensory input devices create a more immersive, three-dimensional, and interactive setting for the user. The head-mounted display reduces the visibility the user has to other people and distractions around the medical exam room. Research has shown that VR significantly reduces pain behavior in burn wound care (Hoffman, Doctor, Patterson, Carrougher & Furness, 2000; Hoffman, Patterson, Carrougher & Sharar, 2001), and in port access procedures for pediatric oncology patients (Gershon et al., 2001). The weakness of virtually all of these studies of behavioral interventions designed to reduce pain and distress during invasive medical procedures is an extremely small sample size. Furthermore, these studies do not necessarily look at the effects of VR specifically on children. The Hoffman et al. (2000) article is a case study; the Hoffman et al. (2001) study has a sample size of seven, ages ranging from 9 to 32 years old, and uses a within subjects design; the Gershon et al. (2001) study not only has a small sample size but its sample ranges in age from 7 to 19 years old, including older adolescents. There are many possible reasons for these sample limitations, such as the unavailability of subjects and unpredictable nature of a person's chronic illness. Thus, more research is needed to investigate the effectiveness of VR as an intervention for medical procedures. Additionally, more research is needed on its effects specifically in pediatric populations.

In this study, the effectiveness of VR was examined in a group of pediatric cancer patients undergoing a port access procedure, consisting of ''accessing'' a permanent catheter implanted in the chest by piercing the skin. Children's anxiety, pain, and distress were assessed before and during the procedure. We predicted that children who received the VR intervention would be less distressed during the procedure than those who did not receive the intervention. In addition, an exploratory measure of coping, a narrative account of what happened at the clinic, was also included. Most developmental research on relations between stress and memory focus on amount and accuracy of recall and, in general, finds that stress leads to better memory of the central actions of the event (see Fivush, 1998 and Pezdek & Taylor, 2001, for reviews). More recent research has focused instead on the content of children's recall of stressful events, with particular emphasis on internal state language referencing thoughts and emotions concerning the event (Fivush & Baker-Ward, in press). This research perspective stems from findings in the adult literature that narratives rich in cognitive processing and emotion language are related to better psychological and physical outcome (Pennebaker, 1997; Smyth, 1998).

If the ability to construct a more causally coherent and emotionally expressive narrative is linked to better outcome, then it might also be the case that lower distress would allow children to better process the incoming information in a way that would allow them to focus on their internal states, thus constructing a more internally focused narrative that would aid them in subsequent coping. Recent research indicates that children who are more stressed following a natural disaster include less detail and less internal state language in their narratives and, in turn, inclusion of less internal state language predicts higher posttraumatic stress symptoms above and beyond initial stress levels (Sales, Fivush, Parker & Bahrick, in press). Thus in this study, we predicted that children who experienced the VR intervention would be less stressed by the procedure and would therefore be able to report their experience in more detail and include more information about their thoughts and emotions.

Method

Participants

Twenty-three children between the ages of 7 and 14 receiving treatment for cancer and undergoing a port access procedure that day were recruited from a children's hospital in a major metropolitan city. Families were approached in the exam room, and parents and children gave written informed consent, as approved by the university's Institutional Review Board. One parent did not agree to participate. Two additional participants withdrew because the children became too ill to participate. Of the remaining 20 children, 12 were male, and 8 female. Based on demographic information provided by the parents, 55% of the participants were African-American, 40% White, and 5% Asian. Children varied in time since diagnosis but 13 had been diagnosed in the previous 6 months, an additional 2 within the year, 2 in the past 2 years, and 3 in the past 3 years. Children also varied in the number of previously experienced port access procedures (range from 0 to more than 10) (see Table I for means). Children received two movie tickets as compensation for participating in the study.

Apparatus

A VR system designed to be an educational supplement for children visiting the gorilla habitat at Zoo Atlanta (Allison, Willis, Bowman, Wineman & Hodges, 1997), in which the child explores a virtual gorilla habitat, was used in the experimental condition. This particular VR environment was selected out of convenience, and because the environment was age-appropriate. The VR system consists of a computer connected to a joystick and head-mounted display. The head-mounted display covers the head and eyes, and allows the children to move the picture on the screen by moving their heads. For example, the children can look up at the sky or down at the ground. The child moves through the environment with the joystick, and wears headphones to hear noises such as a waterfall in the habitat and gorillas growling. The children can approach or withdraw from the gorillas, or simply wander around the immersive environment. All the children greatly enjoyed the VR environment as indicated by comments after the experience. An external monitor displays what the child is viewing in the head-mounted display.

Table I. Means (and standard deviations) for all measures by condition.

Measure	Condition			t	p-value
	VR	No VR	Mean		
Demographic variables					
Age	11.20 (2.25)	9.80 (2.30)	10.50 (2.33)	$t(18) = 1.37$	$p = 0.19$
Mos. since diagnosis	5.10 (7.36)	12.80 (14.90)	8.95 (12.10)	$t(18) = 1.47$	$p = 0.16$
No. prev. procedures	7.30 (2.94)	7.80 (4.16)	7.55 (3.50)	$t(18) = 0.31$	$p = 0.76$
Pre-procedure					
How-I-Feel	29.10 (6.79)	34.00 (8.54)	31.55 (97.92)	$t(18) = 0.57$	$p = 0.58$
Pulse-before	99.20 (19.42)	100.10 (17.43)	99.65 (17.96)	$t(18) = 0.11$	$p = 0.91$
Distress-before	19.00 (21.57)	37.35 (43.13)	28.28 (34.50)	$t(18) = 1.20$	$p = 0.24$
During procedure					
Pulse-during*	95.80 (19.3)	117.60 (25.70)	106.70 (24.80)	$t(18) = 2.14$	$p < 0.05$
CHEOPS**	4.90 (0.99)	8.30 (2.41)	6.60 (2.50)	$t(18) = 4.13$	$p < 0.01$
Distress-during	12.00 (16.36)	34.45 (41.80)	23.23 (32.97)	$t(18) = 3.03$	$p = 0.10$
Pulse-after	93.30 (18.38)	107.80 (21.35)	100.55 (20.77)	$t(18) = 1.63$	$p = 0.12$
Narratives					
Actions*	7.10 (3.28)	4.10 (2.81)	5.60 (3.35)	$t(18) = 2.20$	$p < 0.05$
Elaborations*	4.40 (4.03)	1.20 (1.03)	2.80 (3.30)	$t(18) = 2.43$	$p < 0.05$
Thoughts/Emos.	2.30 (2.06)	1.00 (0.81)	1.65 (1.60)	$t(18) = 1.90$	$p < 0.08$

* Significance at $p < 0.05$.
** Significance at $p < 0.01$.
Note: Mos. = Months; Emos. = Emotions; No. prev. = Number of previous.

Measures

How-I-Feel questionnaire (Spielberger, Edwards, Montouri & Lushane, 1970). Instructions for this standardized measure of anxiety were revised such that children answered 20 questions on a 3-point scale concerning how anxious they felt specifically about getting their port accessed.

Pulse. The pulse rate was taken before, during and after the procedure using a pulse-oxygen monitor (BCI International, Waukesha, WI).

Visual Analogue Scale for pain and anxiety (VAS, Varni, Walco & Katz, 1989). The parent, child, and nurse rated the child's pain and anxiety on two separate 10-centimeter horizontal lines supplemented by descriptions of differing degrees of pain and anxiety, respectively. For the children, the ruler also shows facial expressions that match the scaled levels of pain and anxiety. Ratings were made before the procedure and again immediately after based on the child's pain and anxiety levels during the procedure. The scale is scored from 0 (none) to 100 (maximum pain or anxiety).

The children's hospital of eastern ontario pain scale (CHEOPS, McGrath et al., 1985). The first author observed the child during the procedure to evaluate pain behavior. The behavioral observation consists of six behavioral categories scored from 0 (no pain) to 3 (severe pain) at one minute intervals throughout the procedure. The six behavioral categories are crying (with 4 specific behaviors coded: no cry, moan, cry, and scream), facial expression (with 3 specific behaviors coded: composed, grimace, and smiling), verbalization (with 5 specific behaviors: none, other complaint, pain complaint, both complaint, and positive),

torso posture (with 6 specific behaviors coded: neutral, shifting, tense, shivering, upright, and restrained), touch (with 5 specific behaviors coded: not touching, reach, touch, grab, and restrained), and leg movement (with 5 specific behaviors coded: neutral, squirm/kick, drawn up/tense, standing, and restrained). The first author was trained by the fourth author to a criterion of 90% agreement before the study began. The fourth author has established reliability on this scale in a previous study (Gershon et al., 2001).

Procedure

All data were collected by the first author. After consent was obtained, one half of the children were randomly assigned to either the experimental condition receiving VR during the port access procedure ($n = 10$; 5 males, 5 females), or the no VR treatment ($n = 10$; 7 males, 3 females) as a control condition. The researcher then read the How-I-Feel Questionnaire to the child in order for the child to complete the questionnaire. Simultaneously, the parent completed a demographic information form. The pulse monitor was then connected to the child's finger.

When the nurse entered, the parent, child, and nurse each rated the child's anxiety level and predicted pain using the VAS, and the first pulse measure was taken. If the child was in the experimental condition, the researcher set up the VR equipment and demonstrated its use. The child was then allowed to play in the gorilla environment. Set-up and training the child to use the VR equipment took less than 5 min. As the port was accessed the researcher took a pulse reading, while scoring the child's behavior on the CHEOPS. When the procedure was over, the researcher again asked the child, parent, and nurse to rate the child's pain and anxiety during the procedure on the VAS and another pulse measure was taken. Children in the control condition were allowed to play with the VR for a few minutes after the procedure and all ratings for entertainment purposes. Nothing was recorded or observed at this time. The nurse and parent then left the room and the researcher conducted the narrative interview with the child.

Children were prompted by the request, ''I know this has been a difficult procedure and you've done really well. I want you to tell me about your experience. I want you to think about everything that happened since you came into the clinic today. Tell me all your thoughts and feelings and everything that happened.'' Interviews lasted about 5 min, were tape recorded and transcribed verbatim. From these transcripts, raters determined the number of actions recalled (e.g., ''The nurse took my temperature.''), the number of thoughts or feelings mentioned (e.g., ''I thought it was really going to hurt'' or ''I was happy when it was over.''), and total number of elaborations, defined as giving additional detail about an already mentioned action, thought, or emotion. Actions were a measure of the amount of information provided, thoughts and emotions captured the extent to which children were able to discuss their internal reactions, and elaborations captured how detailed children's reports were (see Sales et al., 2002, for complete descriptions and theoretical rationales for these categories). Two raters blind to condition individually coded each narrative; percent agreement across all 20 narratives for actions was 84%, for thoughts and emotions mentioned, 84%, and for elaborations, 84%. It should be noted that children provided relevant information in response to these probes (e.g., reporting medical assessments of temperature and weight, recalling what happened during the port access procedure, etc.) and did not report irrelevant information (e.g., what they did before they came to the clinic, what color shirt they had on, etc.). This is in accord with a great deal of research on narrative accounts in children of this age (see Fivush, 1998, for a review).

Results

Data reduction

For the VAS ratings, parents, children, and the nurse all rated the child's pain and anxiety on a 0–100 scale before and during the procedure. There were extremely high correlations between ratings of pain and anxiety within each rater as well as extremely high correlation among the three raters (77% of the 66 correlations computed among raters and ratings were significant at $p < 0.05$). Thus, we created a composite measure of distress before and during the procedure. Distress-before was calculated as the mean of the child's self-report of anxiety and predicted pain before the procedure. Distress-during was determined by the mean of the child's retrospective self-report of pain and anxiety during the procedure. Children's self-reports were selected because they are the most direct measure of the children's subjective experience.

Effects of VR

Means and standard deviations for all measures by condition are shown in Table I. In order to examine the effects of VR, three separate MANOVA's with experimental *versus* control group as the independent variable were computed, one on the pre-procedure anxiety, pain and distress measures, one on the pain and distress measures during the procedure, and one on the narrative variables. Preliminary *t*-tests on age, time since diagnosis and number of previous procedures showed no differences between conditions (see Table I). Still, because of the wide variability, age and number of previous procedures were entered as covariates in all analyses (time since diagnosis was skewed and therefore could not be used as a covariate but note that the majority of children had been diagnosed recently, within the previous 6 months). To foreshadow, these variables were not significant in any of the analyses. All significant effects ($p < 0.05$) were followed up with univariate analyses. All inferential test information is included in Table I.

Importantly, there were no significant effects or interactions on the pre-procedure variables. Children in the two groups did not differ in level of anxiety, or in ratings of distress, or pulse rate before the procedure. However, during the procedure, there were significant differences between groups on the CHEOPS and pulse, as well as a trend for pulse after, and a trend for the retrospective distress rating of the procedure, indicating children in the VR condition did not experience as much pain and anxiety, and marginally tended to be less distressed than controls. Children in the VR condition also recalled significantly more actions in their narratives, elaborated more, and tended to mention more thoughts and emotions, than children in the control group. Importantly, children's narratives focused on what happened during the clinic visit; no child in the VR condition talked in detail about the VR environment. Thus, differences in length and elaboration are not a function of discussion of the VR intervention itself.

Discussion

This study assessed children's anxiety and distress concerning a specific invasive medical procedure, and the effectiveness of VR, an immersive distracter, in alleviating children's distress during the procedure. Consistent with the findings of other studies of distraction (Gershon et al., 2001; Hoffman et al., 2000, 2001), VR was effective in decreasing distress and pain behavior during this procedure. Although there were no differences between the experimental and control groups before the procedure on any variable, children

experiencing VR exhibited significantly less pain and anxiety during the procedure, as assessed with both behavioral measures (the CHEOPS) and physiological measures (pulse rate), and had a marginally significant tendency to display less distress following the procedure on both physiological (pulse rate) and self-report (distress ratings) measures.

Additionally, the exploration of narrative as a way of assessing distress and coping provided intriguing results. Children who received VR were able to recall more details about the clinic visit and comment on their thoughts and emotions more than children who did not receive VR. These findings suggest that lowering distress in children leads to a more complete and more psychologically imbued narrative. Children who are less distressed may be better able to cognitively and emotionally process what is happening and thus better able to subsequently report it. Given previous research demonstrating relations between narratives rich in cognitive processing and emotional language and subsequent psychological and physical well-being (Pennebaker, 1997; Smyth, 1998), it seems possible that these children who are better able to construct more psychologically imbued narratives will cope more effectively over time. This is an interesting question for future research.

While our findings do show strong support for the use of VR as a distracter during medical procedures, there are limitations to our findings. First, the study examined a small sample that varied in age and number of previous procedures. Although statistical correction indicated age and previous experience did not influence the overall effectiveness of VR, a replication with a larger sample that can examine these variables more systematically is warranted. Further, because of logistical constraints, only one coder rated children's behavior during the procedure. Thus, biases may have been introduced during the behavioral assessment. However, the coder was trained to a high criterion of reliability and therefore this possibility is unlikely. Still, future studies should use multiple blind coders. Finally, it is worth noting that the standard deviation for the distress measure is relatively large, suggesting there may be moderating variables accounting distress levels. Future research should examine potential moderators of distress levels both before and during the procedure.

The results suggest that VR may be a highly effective intervention for children undergoing painful and distressing medical procedures. If future research with larger samples and younger children supports these initial findings, the medical community should consider the use of such devices for all children. Additionally, children's narratives about stressful medical procedures may provide clinicians with important information about how children are coping with the anxiety and distress that may be inevitable in these situations. Finally, future research should compare the effectiveness of VR to other distracters. Due to the expensive nature of some VR equipment compared to previously used distraction techniques, the costs and benefits of different types of distraction interventions can only be determined after stringent testing of the relative effectiveness of various interventions.

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