A Pilot and Feasibility Study of Virtual Reality as a Distraction for Children With Cancer

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ABSTRACT

Objective: To pilot and test the feasibility of a novel technology to reduce anxiety and pain associated with an invasive medical procedure in children with cancer. Method: Children with cancer (ages 7–19) whose treatment protocols required access of their subcutaneous venous port device (port access) were randomly assigned to a virtual reality distraction intervention, a non–virtual reality distraction, or treatment as usual without a distraction. The researchers obtained assessments of the child's pain and anxiety from the parent, child, and unblinded nurses. Pulse rate was monitored throughout the procedure, and behavioral indices of distress were recorded, as observed by the researchers. Results: Reductions in pain and anxiety were found for children who used the virtual reality distraction in comparison with the no distraction condition as evidenced by lower pulse rate and reports of pain by nurses. No significant differences were found for the non–virtual reality condition versus the no distraction condition on pulse rate. Conclusions: These findings suggest that virtual reality may be a useful tool for distraction during painful medical procedures, but further studies are needed to test potential efficacy and feasibility during other, more distressing medical procedures with larger sample sizes. J. Am. Acad. Child Adolesc. Psychiatry, 2004;43(10):1243–1249. Key Words: virtual reality, childhood cancer, distraction.

Patients with childhood cancers must undergo numerous invasive medical procedures in their treatment. Although they are necessary for survival, anxiety and distress about these painful and invasive procedures can make it difficult to endure the recommended regimens. Over the past 15 years, increased efforts have been made to alleviate the anxiety and pain to increase adherence (Ellis and Spanos, 1994; Varni et al., 1995). In the pediatric pain literature, studies have focused on developmentally appropriate interventions (Blount et al., 1994; Powers et al., 1993) including coping strategies as suggested by the U.S. Department of Health and Human Services (1992) such as imagery, breathing, relaxation, social support, and positive thinking. Another relatively simple coping strategy is distraction. The basic theoretical principle for distraction is that attention is diverted away from a noxious stimulus and is focused instead on a more pleasant one (McCaul and Malott, 1984).

A recent technological advance that has the potential to be an engaging distraction is virtual reality (VR). VR is a relatively new medium of human–computer interactions whereby a human becomes an active participant in a virtual world (Gershon et al., 2000; Zimand et al., 2002). The human user experiences both visual and auditory stimuli that help “immerse” the individual into the computer-generated reality and create a sense of presence within the environment (Regenbrecht et al., 1998; Rizzo et al., 1998). The more immersed an individual becomes, the more that person feels like a
part of the world (Wiederhold et al., 1998). The immersion process occurs through a head-mounted display (HMD) that consists of two display screens. This visual system within the HMD allows for three-dimensional interaction between the individual and the computer (Vincelli, 1999). In addition, there are stereo earphones and a head tracker system. The tracker moves the individual in the virtual world in correspondence with the head movements made by the individual in the real world. The combination of this hardware and software allows the individual to feel a sense of presence and/or immersion by having the environment change in real time with the user’s movements, which makes the user feel like an active participant within this virtual world (Rothbaum et al., 1997).

Several studies have demonstrated the beneficial effects of VR distraction in medical settings. Hoffman et al. (2000) reported two case studies of adolescents whose anxiety was reduced during burn wound dressing change when VR distraction was compared with video game distraction. Another report indicated that VR was somewhat successful in relieving children’s anxiety associated with chemotherapy (Schneider and Workman, 1999). This study followed 11 children during treatment but lacked a randomized, controlled design. A case study also demonstrated that VR reduced anticipatory anxiety over time for a pediatric cancer patient (Gershon et al., 2003). A recent study examined the use of a three-dimensional computer-based environment for children on a pediatric hemodialysis unit (Bers et al., 2003). The focus of this study, however, was not on distraction but rather on coping with chronic illness. Although the use of VR for pain management is relatively new, it has been used successfully to treat numerous phobias such as fear of heights and flying (Rothbaum et al., 1995a, b, 1996, 2000).

The aim of this pilot study was to determine whether an immersive VR distraction technique is feasible and beneficial for children undergoing medical procedures. We expect that if such an intervention could be used successfully, it might alleviate or minimize unnecessary anxiety about the procedure. To examine this question, children with cancer who needed a port access were randomly assigned to either a VR distraction, a non-VR distraction (NonVR), and a control condition with treatment as usual with no distraction.

METHOD

Sample Selection

Children were included in this study if they met the following criteria. Children had to be between the ages of 7 and 19 with a diagnosis of childhood cancer who presented at an outpatient oncology unit in a southeast metropolitan area with a parent. These children had to be visiting the oncology unit to receive a port access as a component of their cancer treatment. This invasive medical procedure involves a port (a previously implanted catheter) that is used for frequent intravenous medications such as chemotherapy and blood draws. The access refers to piercing the skin with a needle to reach the port catheter. Although the port access procedure is relatively quick, it can be distressing due to the needle insertion into the implanted port. It should be noted that the port access is not a treatment for cancer itself but a procedure that is an important part of the treatment process. Children were excluded from the study if they could not speak English or were not with their legal guardian.

The random assignment was conducted by computer generation of a list of three numbers to assign successive patients who volunteered for the study to one of three treatment conditions. Because one of the researchers moved (J.G.), data collection was stopped before obtaining the anticipated number of subjects, leading to unequal numbers in the groups. Children were randomly assigned to one of the three treatment conditions: 22 subjects were assigned to VR distraction, 22 to a no distraction control group, and 15 were assigned to the NonVR distraction condition. The Human Investigations Committee at Emory University approved the study.

Interventions

Apparatus. Both the VR and NonVR distraction groups used the Virtual Gorilla program, created as an educational tool for children visiting the gorilla habitat at Zoo Atlanta (Allison et al., 1997). In this virtual environment, the user takes on the persona of an adolescent gorilla in a gorilla habitat and can interact with the other gorillas. In the VR condition, a head-mounted display with stereo earphones transmits the image onto screens in front of the child’s eyes. In the NonVR condition, the subject played with the Virtual Gorilla program displayed on the computer monitor without the head-mounted display. In both conditions, the subject used a computer joystick to maneuver around the environment.

Procedure. After a pediatric oncology nurse referred a child, the researcher explained the study and its rationale. If the parents and child agreed to participate, the parents were given the informed consent form, demographics form, and the Visual Analogue Scales (VASs). The child and the nurse were also provided with the VASs. In addition, a pretreatment pulse rate was obtained from the child.

All participants were then provided an opportunity to practice and learn how to use the Virtual Gorilla program. As described by Allison et al. (1997), children were told that they would enter a gorilla habitat as the youngest gorilla and interact with a group of older male and female gorillas. It was explained that they would start off behind a glass shield and that by using the joystick, they could move forward, backward, left, and right. They were told that they could walk around once they passed through the glass and explore the gorilla habitat. In addition, because he or she was the youngest member of the group, the other gorillas would react to him or her differently. For example, if the subject approached the gorilla in a threatening way (e.g., staring for too long, getting too close), the other gorilla might become upset. He or she would know...
that the gorilla was annoyed because it would start making threatening noises and move toward the young gorilla. In addition, there were flags above each gorilla’s head indicating their level of annoyance. In this program, green flags meant that the gorilla was happy, yellow meant somewhat annoyed, and red meant very annoyed. If the gorilla remained very annoyed for too long, the subject was sent to "time out." Essentially, this meant starting over again behind the protective glass.

After practicing for approximately 5 minutes, patients were prepared for port access. They removed their shirts to allow the nurse to see and feel for the port. VR subjects then put on the head-mounted display, NonVR subjects played with the program without a headset but used the computer monitor and earphones, and control subjects did nothing and received the standard treatment without distraction. For the control subjects, the computer was not in the room during the port access procedure. This condition represented how the treatments are typically conducted without VR distraction.

The medical procedure of port access consists of cleaning the area where the EMLA cream (a topical anesthetic used by all participants) had been applied to numb the skin. The area was thoroughly cleaned and prepared before the needle was inserted to access the port. During the access, the child’s pulse was monitored and recorded. In addition, the researcher recorded the Children’s Hospital of Eastern Ontario Pain Scale (CHEOPS) target behaviors. The whole procedure lasted approximately 5 to 10 minutes, depending on the complexity of the child’s port. After the port was accessed, the procedure was completed. At this stage, the child’s pulse was again recorded. Then the child, parent, and nurse all rated pain and anxiety levels during the procedure.

Measures

The VAS (Varni et al., 1989) was a slide rule device that contained a 10-cm horizontal line on the front and back. On the front, the line had contrasting pictures and words of pain (Varni/Thompson VAS, Children’s Hospital and Health Center, San Diego, CA), and the back had pictures and words representing anxiety (Varni/King Emotional Distress Scale, Children’s Hospital and Health Center, San Diego, CA). The raters (child, nurse, and available parent) were able to slide an arrow along this scale to indicate level of pain and anxiety experienced by the participant. Several different nurses helped with the study. The measurements were made at two intervals during the study: before the port access procedure and after it was completed. Ratings made after the port access procedure asked raters to indicate the perceived levels of pain and anxiety experienced by the subject during the procedure. Logistically, it was impossible to obtain ratings at the moment of the access; therefore, retrospective scores were used. The VAS is a preferred assessment methodology because it avoids problems with language descriptors, particularly for children (Gift, 1989). This self-report measure has been used extensively in adult pain assessment and has been used successfully in pediatric research (Jay, 1988; McGrath et al., 1986).

The CHEOPS (McGrath et al., 1985) is a behavioral observation scale originally designed for postoperative pain assessment with reported strong interrater reliability and high correlation between the CHEOPS and VAS measures of pain. It examines six target behaviors that are broken down into smaller behaviors. Each behavior is assigned a score, ranging from 0 to 3, with 0 indicating a behavior that is the antithesis of pain and 3, a behavior indicative of severe pain. The target behaviors are crying (no cry, moan, cry, scream), facial expression (composed, grimace, smiling), verbalization (none, other complaint, pain complaint, both complaint, positive), torso posture (neutral, shifting, tense, shivering, upright, restrained), touch (not touching, reach, touch, grab, restrained), and leg movement (neutral, squirm/kick, drawn up/stance, standing, restrained). Interrater reliability on this measure was found to be high ($\kappa = 0.89$) among a random sample of 10 subjects who were observed by two of the authors (J.G. and M.P.).

Pulse Rate. To obtain a physiological measure of arousal, the child’s pulse rate was monitored before starting the port access procedure before the nurse came into the room. A second measure of the pulse rate was taken at the moment the port was accessed by the nurse. Finally, once the nurse had completed the procedure, the pulse rate was taken a third time. The researcher running the particular subject through the protocol collected the ratings (J.G. or M.P.) using a pulse-oxygen monitor (BCI international, Waukesha, WI) for all subjects regardless of treatment condition. A pulse-oxygen monitor was one of the least intrusive of the physiological measures available.

Statistical Analysis

Due to the nature of this pilot work and the sample size, only limited statistical analyses were performed. Demographic information was analyzed with descriptive statistics including $t$ tests for continuous variables and $\chi^2$ for discrete variables. In addition, analysis of variance tests were used to examine treatment efficacy between the three conditions (VR, NonVR, and control) with post hoc analyses (least squares difference) based on significant omnibus results. Effect size estimates (eta-square $[\eta^2]$) were reported to indicate the proportion of variance that was accounted for by an effect. SPSS V9.0 software was used for all statistical analyses.

RESULTS

Sample Characteristics

Fifty-nine children participated in the study ranging in age from 7 to 19 years, with a mean age of 12.7. The children received treatment for a wide range of cancer diagnoses including various forms of leukemia, lymphoma, and solid mass tumors. Chemotherapy protocols varied for each child depending on the diagnosis. The sample demographics included 51% males and the ethnic breakdown of the children was as follows: 64% white, 20% African American, 6% Latino, 3% Native American, and 7% listed as other. All other demographic variables measured (family status, years of parental education, employment status) were similar across groups. Thirty-four percent of families indicated that their combined income exceeded $50,000, and 36% indicated they made between $20,000 and $50,000. The income of rest of the families was below $20,000 or they did not answer this question.
Efficacy of Distraction Conditions

**Pulse Rate.** Significant differences on pulse rate emerged during the port access procedure (Fig. 1, Table 1). Children in the VR distraction condition had a significantly lower pulse rate than children in the control condition ($p < .05$) at this time point based on an analysis of variance. No significant group differences were found before or after the port access procedure. The pulse rate in the NonVR distraction condition did not significantly differ from either of the other two conditions at any time point. Effect size estimates ($\eta^2$) were also reported. According to Cohen (1988), when $\eta^2 \geq 0.06$, the result is considered a medium effect, whereas $\eta^2 \geq 0.15$ is classified as large in magnitude. Thus, the effect size estimate for the VR distraction condition compared with the control condition represented a medium effect.

**VAS.** As expected, no significant differences on pain or anxiety emerged among the groups before the port access procedure. During the procedure, a significant difference emerged for nurse ratings of pain during the procedure ($p < .05$) based on multivariate analysis of variance. Nurses rated children in the VR and NonVR distraction conditions as experiencing less pain than those in the control group. No other significant results emerged from the VAS data. In general, all scores on the VAS were relatively low, ranging from 0 to approximately 30. Because the scale ranges from 0 to 100, these lower scores might suggest that the port access procedure was not very distressing for these subjects, except from the nurses’ perspective.

**CHEOPS.** The final dependent measure of distress to test the efficacy of the intervention was the observational scale completed by the researchers during the port access. Nonverbal indices of distress as measured by the CHEOPS also indicated that subjects in the no distraction condition exhibited significantly more muscle tension in their torso compared with those in the VR distraction condition and more leg tension compared with both the VR and NonVR distraction conditions ($p < .05$). A significant correlation was found between pulse rate during the procedure and the total CHEOPS score $r(59) = 0.30$, $p < .05$, suggesting that the nonverbal indices of distress were related to physiological arousal. No significant differences were found for the overall CHEOPS score, and the scores on this measure tended to be quite low in general.

**Covariates**

**Age.** The age range of subjects in the study was quite large, spanning a wide variety of developmental stages and cognitive capacities. As a result, it was hypothesized that younger subjects in the study (≤12.7 years) would have more difficulty using coping mechanisms to deal with anticipatory anxiety and pain. This age (12.7 years) was chosen because it was the mean age of the study subjects and approximated the age when the researchers hypothesize that subjects would derive less benefit from the distraction. Therefore, it was predicted that any intervention that facilitated this process should be more efficacious for these younger subjects.

The data set was analyzed by conducting a multivariate analysis of covariance with age as a covariate. The analysis of covariance data from the pulse rate found that age was a significant covariate for pulse ratings, both before and during the medical procedure. As a result, adjusted means were calculated for these scores controlling for age. Although no significant differences were found between pulse rates before the medical procedure, a significant difference remained between the VR and NonVR distraction conditions during the port access procedure even after controlling for age. Thus, although pulse differences before port access might be explained by age differences, the differences in pulse rates of the children during the medical procedures cannot be accounted for by this variable. On other dependent measures, age was not a significant covariate and did not account for any significant findings on those variables.

The pulse data were also broken down by treatment and age. Age was split at 12 years to approximate the
mean age of the sample. Figure 2 shows the mean scores for subjects in the study based on their ages and treatment condition.

These results further demonstrate that age appeared to be a factor for the VR distraction group and to some extent the NonVR distraction group but not for the control group. Significant differences by age group were found before and during the medical procedure for the VR treatment group. A significant difference was also found between the younger and older NonVR distraction subjects during the procedure.

DISCUSSION

This pilot study examined the benefit of VR distraction compared with NonVR distraction and no distraction during a port access procedure for pediatric cancer patients. Overall results suggest potential benefit from using VR as a distraction during painful medical procedures as indicated by reduced physiological arousal, lower ratings of pain by the nurse, and reduced behavioral indices of distress. Thus, on multiple dependent variables, the VR distraction appeared to decrease the distress experienced by these children with cancer during the port access procedure.

The most significant indication of reduced distress during VR distraction emerged from the pulse data. Although pulse can be affected by a multitude of factors, these data appear to represent the most objective measure of physiological arousal in the study. Children in the VR distraction condition had a significantly lower pulse rate than controls during the procedure, and this difference remained lower after the procedure was completed. Future research efforts should include additional physiological measures (e.g., galvanic skin response, electromyography).

Few significant differences emerged on the ratings of pain and anxiety by subjects, parents, nurses, and experimenters. These ratings were more subject to interpretation, inference, and bias than the pulse data. The lack of findings on these measures may result from a lack of severity in the port access procedure. Among the many invasive interventions that these children must experience, the port access procedure is relatively mild. The subjects who did experience distress with this procedure tended to be the younger children in the study. In fact, the results confirmed that the younger subjects did experience more distress with this procedure than older subjects. Thus, an intervention for the port access procedure in the future should probably focus on younger children.

Limitations

Several limitations warrant further discussion. Although there were significant differences between the treatment conditions, these results were not overwhelming. This might be accounted for by a lack of

<table>
<thead>
<tr>
<th>VR</th>
<th>NonVR</th>
<th>Control</th>
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<tr>
<td>Mean pulse before port access</td>
<td>92.6 (16.6)</td>
<td>99.3 (22.2)</td>
</tr>
<tr>
<td>Mean pulse during port access</td>
<td>96.3 (14.8)*</td>
<td>103.8 (19.9)</td>
</tr>
<tr>
<td>Mean pulse after port access</td>
<td>91.7 (13.5)</td>
<td>96.6 (16.1)</td>
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*Note: $\eta^2$ = effect size; VR = virtual reality.

* $p < .05$ between virtual reality and control based on post hoc analyses.
power due to the relatively small sample size or that the port access procedure may not be very distressing for these children. Although differences were found on the VAS, the ratings were generally in the 20 to 30 range of 100, again suggesting that some subjects did not feel particularly anxious about the procedure. Because subjects used a topical anesthetic (EMLA) during the procedure, this may have also limited the distress experienced by the subjects.

One potential factor may have contributed to the fact that the results did not overwhelmingly suggest enormous decreases in distress in the participants. The port access procedure may not have been that distressing for these children. Although some participants demonstrated obvious distress (e.g., crying and screaming), others showed no overt reaction to this procedure. Because this pilot study was also a feasibility study, one of the primary purposes was to determine whether such a technology could be used with a medical procedure. These results seem to indicate that a VR distraction intervention might be more useful for more moderately distressing procedures such as a lumbar puncture or bone marrow aspiration. Due to the expense of a VR system, further large-scale studies are needed to determine the cost benefit and feasibility for such a system with other medical procedures.

Another potential limitation was the fact that treatment conditions were not completely blind. Raters were aware of the treatment conditions based on the protocol that was used during the port access procedure. This lack of blinding may have contributed to some bias and ratings, and, therefore, results should be interpreted with caution.

Finally, because all participants were provided an opportunity to practice with the VR program before the port access procedure, this practice may have represented an intervention in itself. Such an intervention could have potentially lowered the overall effects by providing some distraction for all treatment groups. In future studies, participants in the control group should not use the equipment before the port access procedure, thus representing the standard treatment as usual and minimizing potential distractions.

Clinical Implications

This pilot study demonstrated the feasibility of using an immersive VR distraction technique to reduce distress for invasive medical procedures in physically ill children. The ability to focus an individual on an imaginary world and potentially lower the distress associated with invasive medical procedures suggests that this technology has potential for use in medical psychology. Although these preliminary results suggest that the VR may have alleviated distress in some of the subjects, more distressing procedures might produce more significant results. Future research efforts need to consider the use of larger sample sizes and the development of appropriate software for younger children. In addition, research should address the feasibility of VR for use in more distressing medical oncology procedures, and, potentially, for other populations of patients who undergo other noxious procedures.

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REFERENCES


