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Effectiveness of Virtual Reality for Pediatric Pain Distraction during IV Placement

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ABSTRACT

The objective of this study was to test the efficacy and suitability of virtual reality (VR) as a pain distraction for pediatric intravenous (IV) placement. Twenty children (12 boys, 8 girls) requiring IV placement for a magnetic resonance imaging/computed tomography (MRI/CT) scan were randomly assigned to two conditions: (1) VR distraction using *Street Luge* (5DT), presented via a head-mounted display, or (2) standard of care (topical anesthetic) with no distraction. Children, their parents, and nurses completed self-report questionnaires that assessed numerous health-related outcomes. Responses from the Faces Pain Scale–Revised indicated a fourfold increase in affective pain within the control condition; by contrast, no significant differences were detected within the VR condition. Significant associations between multiple measures of anticipatory anxiety, affective pain, IV pain intensity, and measures of past procedural pain provided support for the complex interplay of a multimodal assessment of pain perception. There was also a sufficient amount of evidence supporting the efficacy of *Street Luge* as a pediatric pain distraction tool during IV placement: an adequate level of presence, no simulator sickness, and significantly more child-, parent-, and nurse-reported satisfaction with pain management. VR pain distraction was positively endorsed by all reporters and is a promising tool for decreasing pain, and anxiety in children undergoing acute medical interventions. However, further research with larger sample sizes and other routine medical procedures is warranted.

INTRODUCTION

WHILE MOST MEDICAL PROCEDURES provoke anxiety and distress, needle insertion continues to be the most frightening and bothersome medical procedure for children.[1] Nonetheless, venipuncture is routinely requested for procedures in pediatric medical centers. In a study of 7–17-year-olds undergoing venipuncture, 52% of the children reported mild to severe pain.[2] Given the subjective experience of children who must undergo this procedure, it is not surprising that researchers have explored ways of distracting children from pain associated with venipuncture.

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Attention plays an important role in the perception of painful stimuli. The subjective experience of pain requires a person to attend to and process painful sensory inputs[3]; consequently, a large number of studies have targeted a variety of methods of distraction.[4] Virtual reality (VR) has been identified as a potentially effective tool for pain distraction due to its immersing nature, which demands substantial attentional resources.[5] The multi-sensory nature of the virtual environment (VE) draws participants' attention away from "real world" visual, auditory, and tactile stimuli, and into the "virtual world." In addition, the presentation of a VE using a head-mounted display (HMD) prevents visual perception of the stimuli in the real world and may further provide advantages over other forms of distraction. For example, children receiving immunizations while being distracted by a cartoon only watched the cartoon for an average of two-thirds of the procedure despite nurse reminders and posted signs drawing attention to the television.[6] Furthermore, precise control of the child's perceptual environment in an HMD increases experimental control and, thus, the internal validity of such a study. Empirical studies to date support the theoretical foundation intimating promise for VR as a particularly effective non-pharmacological method of pain management for both children and adults.[7]

Intravenous (IV) placement, a particularly painful type of venipuncture, is an essential procedure for imaging studies in pediatric patients, particularly for sedation and the administration of contrast for computed tomography (CT) scans. This study's primary aim was to compare a new VR pain distraction scenario with standard of care for reducing pain with IV placement. Secondary aims focused on the relationship between child, parent, and nurse pre- and post-assessments of pain, anxiety, generalized distress surrounding IV placement, and satisfaction with pain management.

METHODS

Subjects

The current investigation recruited 20 children (12 boys, 8 girls) ages 8–12 (M = 10.2) and their parents from the Childrens Hospital Los Angeles (CHLA) Department of Radiology. Eligible participants were awaiting outpatient magnetic resonance imaging (MRI) or CT scans that required IV placement. The study sample was reflective of the hospital's patient population with regard to ethnicity and medical status (Table 1). Children with known or reported cognitive disabilities, taking pain medication, or children who did not pass the cognitive and physical screening were excluded.

Procedure

Children and their families were approached in the radiology waiting room to determine interest in study participation. Interested families accompanied a trained research assistant to a private room to review the informed assent/consent forms. Following assent/consent, the research assistant administered the screening measures to determine the child's cognitive functioning (Test of Nonverbal Intelligence[8]) and active range of motion, ensuring the child's capability of navigating through the VE.

Following the screening tasks, children and their parents completed baseline measures administered by the research assistant. Next, the child was stratified according to age (7–9 or 10–12) and gender (boy or girl), and then randomized to one of two conditions: (1) standard of care (control), which included a topical anesthesia spray prior to IV placement, or (2) standard of care plus VR. Children in the VR distraction group began interacting with the VE at 5 min prior to the IV placement, continued play throughout, and interacted with the VR for 5 subsequent min. Children in the control group were given an opportunity to play with the VR for 3 min following the completion of their IV placement.

Participants completed self-report surveys at three separate intervals: approximately 30 min before the IV, immediately before the IV, and following IV placement. The battery of instruments included the Visual Analog Scales (VAS) to assess pre-existing pain, IV pain intensity, past IV pain intensity, and anticipatory anxiety[9] about the current procedure; the Wong-Baker FACES Pain Rating Scale[10] and the Faces Pain Scale–Revised[11] to assess affective pain (worry and bother related to pain); the Childhood Anxiety Sensitivity Index[12] to measure the child's anxiety sensitivity (vulnerability to stressful situations) prior to the procedure; the Child Simulator Sickness Questionnaire[13] to determine whether the child feels sick as a result of the intervention; the Child Presence Questionnaire to assess the child's engagement with the intervention; a demographic questionnaire; and satisfaction questionnaires (Likert-format surveys assessing behavioral distress reduction and overall satisfaction) for the child, parent, and IV nurse. The current study was reviewed and approved by the hospital-based Institutional Review Board (IRB).

TABLE 1. DEMOGRAPHICS

	VR mean (SD) (n = 10)	*Control mean (SD) (n = 10)*	*F*
Age	10.40 (1.58)	10.00 (1.33)	0.38^{NS}
Gender			
Male	6	6	
Female	4	4	
Medical conditions			
Yes	6	6	
No	4	4	
Current pain medications			
Yes	0	0	
No	10	10	
Previous imaging study			
Yes	10	8	
No	0	2	
Computer in home			
Yes	6	8	
No	4	2	
Ethnicity			
Caucasian	5	4	
Latino/a	4	3	
African American	1	1	
Asian/Pacific Islander	0	1	
Multi-racial	0	1	
IV in last 12 months	15.33 (20.01)	6.60 (9.01)	1.56^{NS}
IV in lifetime	82.67 (89.88)	143.00 (225.84)	0.55^{NS}
Hours playing video games	4.10 (3.21)	4.60 (2.68)	0.14^{NS}

NS, non-significant.

Virtual environment

The virtual environment, *Street Luge,* by Fifth Dimension Technologies (5DT), featured a fast-moving reality-based world in which the player races downhill lying on top of a big skateboard. The VE was presented via the 5DT HMD 800, a high-performance professional HMD that provides active matrix LCDs with full SVGA (800 × 600 × 3[rgb]) pixel resolution. An InterSense Inertia Cube2 with a 3-degrees-of-freedom (DOF) tracker was attached. The player navigated through the VE with a Logitech rumble pad that provided tactile feedback and music via headphones, thus supplying a multi-sensory immersive experience. The HMD was connected to a Dell laptop (<www.dell.com>), Inspiron 8500 with 2.6-GHz processing speed and 1 GB of RAM, operating on Microsoft Windows XP and a NVIDIA GeForce4 4200 Go video card.

RESULTS

The Faces Pain Scale–Revised revealed that children in the control condition experienced a significant fourfold increase in affective pain following the IV placement ($t = -3.25$*); by contrast, no significant change was detected within the VR condition for affective pain ($t = -1.00^{NS}$; Table 2). No significant differences were reported between the treatment groups on all measures of affective pain and anticipatory anxiety for children and their parents. Child responses on both of the affective pain measures were highly correlated ($r = 0.96$**; Table 3). All measures of IV pain intensity reported by the child, parent and nurse were similar across conditions and time. However, there was a nurse-reported trend suggesting greater IV pain intensity in the control group compared to VR ($p = 0.08$).

TABLE 2. CHILD-REPORTED AFFECTIVE PAIN WITHIN TREATMENT GROUPS

	Treatment condition	*Pre mean (SD)*	*Post mean (SD)*	*t*
Faces Pain Scale–Revised	VR	0.80 (1.93)	1.80 (2.40)	−1.00^{NS}
	Control	0.60 (0.97)	2.40 (1.84)	−3.25*
Wong-Baker FACES Pain Rating Scale	VR	0 (0)	2.00 (2.31)	−2.74*
	Control	0.20 (0.63)	2.00 (2.11)	−2.86*

*$p < 0.05$.
NS, non-significant.

Pearson correlations revealed significant associations among child self-reported measures (Table 3). Child participants' IV pain intensity was significantly associated with both measures of affective pain: the Faces Pain Scale–Revised ($r = 0.82$**) and the Wong-Baker FACES Pain Rating Scale ($r = 0.76$*). The child's anticipatory anxiety regarding the IV placement positively correlated with the child's general anticipatory anxiety ($r = 0.86$**). Additionally, pain experienced by the child during past IV placements was positively associated with the child's anticipatory anxiety concerning the current IV placement ($r = 0.68$*). Children receiving VR distraction throughout were significantly more satisfied with their pain management than children in the control condition (F (1, 18) = 12.17**; Table 4). No associations were detected between child self-reports and parent or nurse reports.

Notably, none of the children reported simulator sickness following VR exposure. Children in the VR condition demonstrated a sufficient level of presence/immersion (M = 16.7; range 0–24) with the intervention. Child participants in the VR condition reported similar anxiety sensitivity (F (1, 19) = 0.06^{NS}) on the CASI instrument (M = 29.6) when compared with those in the control condition (M = 29.0). Mean scores for both conditions were comparable to that of a pediatric clinical sample consisting of children with diagnosed anxiety disorders (M = 28.1).[12]

While parent reports of state-based anxiety were subclinical prior to and after the IV procedure, slight increases in their self-reported anxiety were noted. Parent reports also demonstrated significant differences between treatment groups for the following constructs: how much they believed the intervention reduced their child's pain (F (1, 18) = 9.54**); how much they believed the intervention reduced their child's fear (F (1, 18) = 6.67*); whether they wanted the same intervention for their child for future IV placements (F (1, 18) = 23.82**); and if they believed that their child was more cooperative (F (1, 18) = 13.04**).

DISCUSSION

Children requiring IV placement often endure a stressful and acutely aversive experience. The current study demonstrates that children, parents, and nurses alike find VR via HMD, in particular the *Street Luge* scenario, to be an effective and welcomed pain distraction during acute venipuncture. Children in the VR group further evidenced sufficient child presence, no VR simulator sickness, less affective pain changes across the medical proce-

TABLE 3. PEARSON CORRELATIONS OF CHILD-REPORT ITEMS (VR CONDITION)

	Faces revised	*IV pain intensity*	*General AA*	*Imaging AA*
WB faces	0.96**	0.76*	0.05	−0.52
IV pain intensity	0.82**		0.20	−0.38
IV AA	0.35	0.43	0.86**	0.59
Past pain	−0.31	−0.21	0.52	0.68*

*$p < 0.05$; **$p < 0.01$.

TABLE 4. SATISFACTION WITH CHILD'S PAIN MANAGEMENT

Reporter	*VR mean (SD)*	*Control mean (SD)*	*F*
Child	8.60 (2.55)	4.11 (3.06)	12.17**
Parent	9.10 (1.29)	7.11 (3.22)	3.26^{NS}
Nurse	6.80 (2.78)	6.50 (3.17)	0.05^{NS}

*$p < 0.05$; **$p < 0.01$.
Scale of 1 to 10 (1 = not at all; 5 = moderately; 10 = extremely).
NS, non-significant.

dure, and higher satisfaction with their pain management compared to the control group.

These results clearly emphasize the benefits of VR distraction and suggest its ability to attenuate routinely aversive procedures. A key finding, given its modest sample size, revealed that children undergoing IV placement without distraction reported a fourfold increase in affective pain compared to children in the immersive VR condition. This finding highlights the complex interplay of pain and anxiety and illuminates children's stress surrounding routine medical procedures. Conversely, children in the VR group were calm, less anxious and more cooperative during the intervention, thereby indicating a reduction in overall pain and distress.

It is important to note that the majority of participants (80% in each condition) received a topical cooling spray prior to the IV placement, which may have attributed to the low IV pain intensity responses across both groups. However, with a topical anesthesia, children were still reporting clinically significant levels of anxiety and varied levels of affective pain. This data supports the complex nature of pain perception and highlights that a child's psychological state (i.e., anxiety) can drive pain perception similar to actual or imagined tissue damage.

As expected, measures of affective pain were highly correlated with IV pain intensity. Additionally, measures of anticipatory anxiety (general, IV placement, imaging) were highly correlated with each other and the child's perception of past procedural pain. Measuring a child's sense of anticipatory anxiety regarding the invasive (IV placement) and the non-invasive medical (imaging) procedure enabled us to examine other contributing factors to the child's psychological state. These relationships further corroborate the malignant effect of routine medical procedures on a child's wellbeing. Our data supported that children were anxious about the medical procedures regardless of their invasiveness and that past procedural-based pain was associated with anticipatory anxiety related to the imaging procedure. Helping children to quell their procedural and anticipatory anxiety will contribute to greater comfort and less overall anxiety. In future studies with larger sample sizes, subtle nuances differentiating anticipatory, procedural, and state anxiety, from affective pain, pain intensity, and past pain memories, may provide useful information for maximizing pain distraction.

Children in the VR treatment condition were twice as satisfied with their pain management and reported that they would like to use VR during their next invasive medical procedure. Parental satisfaction with VR was evident across many other domains including the belief that VR reduced their child's pain and anxiety and increased cooperation during the procedure. The following parental quotes capture the essence of VR as pain distraction: "A good idea and concept. Keep up the good work. Getting the child's thoughts away from what is actually happening seems to be a good idea." "Thank you for helping ease my child's fears."

CONCLUSION

Future directions in the application of VR for acute medical interventions would include larger samples and the inclusion of other pain indicators (i.e., researcher-reported observation, videotaping, and physiological measures) to capture a multimodal assessment of pain perception. While this study investigated a new VR pain distraction scenario, more immersive, and gender- and age-appropriate scenarios may emerge as we gain more knowledge about matching children to VR scenarios.

This study has demonstrated both the feasibility and utility of VR pain distraction for IV Placement

in an outpatient radiology department. Significant findings suggest that children, parents, and nurses are satisfied with the use of VR for pain distraction as compared to the standard of care. Findings also indicate that multiple indices are better than any single indicator when evaluating pain responsivity. Data suggest that an evaluation of affective pain, anxiety, and overall satisfaction of pain management contribute to an effective intervention, rather than examining pain intensity alone. Additionally, results revealed that any single intervention (i.e., topical anesthesia) for venipuncture is insufficient for impacting overall pain perception. In sum, these findings clearly indicate the efficacy of virtual reality as a useful tool for pain distraction.

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