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Original Articles

Effects of Virtual Reality During Pediatric Vaccinations

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Objective:
The purpose of this study was to examine the effectiveness of virtual reality (VR) distraction offered by a child life specialist on minimizing pain in children receiving a vaccination.
Method:
It was hypothesized that children who received child life-led VR distraction would report less pain and display fewer pain behaviors during a vaccination than those in a control group. Ninety children between the ages of 4 and 12 were randomly assigned to either a VR distraction group or a control group. The VR distraction group engaged with a VR device facilitated by a child life specialist during the vaccination, and the control group received standard care.
Results:
Children self-reported their experienced pain using a facial analogue scale. Caregivers and a research observer assessed the child's pain and pain behaviors using a facial analogue scale and a behavioral observation tool. Although children did not self-report less pain, there was a significant difference in children's pain behaviors displayed during the vaccinations, with children in the child life-led VR distraction group displaying significantly less pain as noted by caregiver and researcher observation.
Conclusion:
In conclusion, VR distraction led by a child life specialist was found to decrease pain behaviors displayed by children; therefore, this type of distraction may be a helpful intervention for children who are receiving a vaccination.
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Decades of research have shown that one of children's top healthcare fears is needles (Broome & Hellier, 1987; Hart & Bossert, 1994; McMurtry et al., 2015; Taddio et al., 2009, 2012). Vaccinations are the most common needle procedure children experience (McMurtry et al., 2015; Taddio et al., 2009). In fact, it is estimated that children who are up-to-date on their vaccinations will experience at least 30 needle injections by the age of 18, simply from recommended vaccinations (Center for Disease Control and Prevention, 2022). Many children encounter pain during vaccinations, and pain is positively related to needle fear (McMurtry et al., 2015; Taddio et al., 2009, 2012). According to McMurtry and colleagues (2015), due to perpetuating factors, as children's fear of pain increases, so does their fear of needles. For example, children who are distressed by the possibility of experiencing pain focus their worry on the threatening parts of the procedure (e.g., their feelings at the time of injection). This causes them to remember more pain and distress about the vaccination, reinforcing the fear of needles (McMurtry et al., 2015).

Research has shown that fear of needles may impact children's response to healthcare visits and future consumerism of healthcare (McMurtry et al., 2015). Children with fear of needles are more likely to report increased pain (McMurtry et al., 2011), fear healthcare professionals (McMurtry et al., 2015), and display non-compliance during needle procedures (Taddio et al., 2012, 2014). Fear of needles can have long-term impacts such as avoidance of healthcare procedures, including vaccinations (Taddio et al., 2012; Wright et al., 2009) and dental procedures (Armfield & Milgrom, 2011).

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It is estimated that 10% of the population will avoid vaccinations due to needle fear, thus healthcare guidelines have begun to address needle fear and pain related to vaccinations (Taddio et al., 2009, 2010). Evidence-based guidelines for minimizing pain and distress during pediatric vaccinations include applying topical anesthetics at the site of injection, using comfort positioning (e.g., positioning upright rather than lying down), administering more painful injections last when there are multiple vaccinations, offering breastfeeding or sucrose to infants, and utilizing distraction techniques (Harrison et al., 2013; Taddio et al., 2010). According to McMurtry and colleagues (2015), "Consistent application of effective pain management strategies for childhood vaccinations not only serves to reduce acute pain and suffering at the time of vaccination but may also substantially reduce the development of high levels of needle fear and/or phobia" (p. S8-S9).

There is a growing movement to include distraction activities as part of standard care for children experiencing vaccinations and other needle procedures (Harrison et al., 2013; Taddio et al., 2010). Distraction techniques are defined as strategic efforts to engage an individual's attention away from the negative stimuli of a healthcare procedure to a more neutral stimulus (Burns-Nader et al., 2017). Certified Child Life Specialists (CCLSs) are members of the healthcare team who have the expertise, training, and time to offer distraction activities as an intervention to support children during procedures (Boles et al., 2020). CCLSs use their assessment of patients' development and psychosocial needs to tailor distraction activities to the individual needs of the child (Boles et al., 2020; Romito et al., 2021). Examples of distraction techniques used by CCLSs include playing a game on a computer tablet, listening to music, watching a moving, or engaging in a virtual reality game, to name a few. Distraction techniques offered by CCLSs have been found to decrease pain and distress for children experiencing healthcare procedures (Boles, 2018; Burns-Nader et al., 2017; Canbulat et al., 2014; Koller & Goldman, 2012; Ortiz et al., 2017).

One type of distraction technique that can be offered by child life specialists during pediatric procedures is virtual reality (VR). VR distraction involves the immersion of individuals into a simulation gaming program or a computer-generated world (Burns-Nader, 2019; Huffman, 2004). It is thought that the immersion of one's cognition and senses into the VR program impacts one's perception of pain and fear and possibly decreases pain-related activity in the brain (Hoffman et al., 2011; Huffman, 2004). According to the gate control theory, during VR, the brain is busy processing the immersive components of the VR, which limits one's ability to perceive pain and fear (Hoffman et al., 2011).

There is growing evidence of the benefits of VR distraction for minimizing pain and distress in children undergoing painful procedures, including wound care (Hua et al., 2015), catheterization placement (Gold et al., 2021), blood draws (Gerceker et al., 2020), and venipuncture (Erdogan & Ozdemir, 2021). These studies find that children who participate in VR distraction report and display significantly less distress and fear compared to children who do not receive VR distraction (Erdogan & Ozdemir, 2021; Gerceker et al., 2020; Gold et al., 2021; Hua et al., 2015). Although some studies have identified the benefits of VR distraction during needle procedures, little is known about the effects of VR distraction in children undergoing vaccinations. Specifically, there are no studies that examine VR distraction provided by a child life specialist during vaccinations. Additional research is needed to examine the use of VR distraction during vaccinations to minimize pain and distress.

Addressing pain and distress during vaccinations has the potential to decrease the development of fear of needles in pediatric patients (McMurtry et al., 2015). Several studies have examined the effectiveness of VR distraction in reducing pain, fear, and anxiety during needle procedures and found positive benefits (Czech et al., 2021). However, to date, there is little to no evidence of studies examining the use of child life-led VR distraction during vaccinations. The purpose of this study is to examine the effectiveness of child life-led VR distraction in minimizing pain and pain behaviors in children receiving a vaccination. It was hypothesized that children who received VR distraction by a child life specialist would report less pain and display fewer pain behaviors during a vaccination than a control group.

Method

Participants

The study included 90 children, between the ages of 4 and 12 (M = 7.3, SD = 2.61), who were receiving a vaccination at a pediatric clinic. A majority of the participants were male (53.4%, $n = 47$), and most of the participants identified as African American (46.0%, $n = 40$). Full descriptive statistics are available in Table 1.

Location

The study took place at a pediatric clinic located in a university medical facility in a small city within the Southeast part of the United States. The pediatric clinic provides care for children up to 16 years of age, including immunizations, illness treatment, well child visits, developmental screenings, hearing and vision screenings, and minor injury treatments. The pediatric clinic is staffed with 5 doctors, a nurse practitioner, and a team of nurses, and it serves as a site for medical students' training. Although the pediatric clinic does not employ a CCLS, the staff of the clinic have previous experience with child life and welcome opportunities to collaborate in research and education activities with the first author who is a CCLS.

Procedures

Following institution review board approval, the research team recruited participants from the pediatric clinic. The nurses of the clinic informed the research team of potential participants who met eligibility criteria. Participants were eligible if they were receiving at least one vaccination, were within the age requirement (between 4 and 12 years of age) and spoke English. The age range of eligibility

Table 1. Demographic Characteristics

Variable	Number (n)	Percentage (%)
Age		
4	19	21.6
5	11	12.5
6	6	6.8
7	9	10.2
8	11	12.5
9	6	6.8
10	9	10.2
11	10	11.4
12	7	8.0
Sex		
Male	47	53.4
Female	41	46.6
Ethnicity		
Caucasian	29	33.3
African American	40	46.0
Asian	1	1.1
Hispanic	9	10.3
Other	8	9.2

was selected because it includes the ages at which children are most vulnerable to developing fear of needles (Bienvenu & Eaton, 1998; McMurtry et al., 2015). Children with neurodiversity or other developmental conditions that impacted their ability to participate in study activities were excluded. The research team would approach eligible participants and their caregivers and obtain informed consent and assent. Participants were randomly assigned to either the VR intervention group (n = 39) or the control group (n = 51). Group randomization was conducted via an online software, randomizer.org. The difference in participant size between groups is because the study had to be closed due to the COVID-19 pandemic. Recruitment of additional participants was ongoing until the pandemic closed the clinic to outside personnel (i.e., researchers).

While waiting in the room, caregivers were asked to complete a demographic questionnaire. The intervention took place in patient rooms after the child had been triaged. The nurses informed the research team when it was time for the vaccination. The CCLS would then introduce the child to their assigned intervention. During the vaccination, caregivers were nearby with the nursing staff in the closest proximity to the child. Standard to the clinic, comfort positions (i.e., position the child in a comfort hold or position by the caregiver) or topical numbing agents were not utilized. When it was time for the vaccination, the child received their assigned intervention (VR distraction or control) by a CCLS. The research team included two CCLSs who rotated based on a schedule determined by the clinic and availability of study personnel. Both CCLSs were trained in study protocols.

Immediately following the vaccination, the child self-reported their pain using a facial analogue scale to the CCLS. One of four research observers was present, and the research observer and the child's caregiver rated the child's pain using a facial analogue scale. The CCLS and research observer strategically asked the child and caregiver for their response in a way that did not allow for the other party's awareness of the response (i.e., the caregiver could not see the child's response). The research observer also reported on the child behaviors of pain during the vaccination using an observation scale. Before the study began, the team of research observers were trained on study protocol and the BOPS observation scale and inter-rater agreement was established.

Interventions

VR Distraction Group. Participants who were assigned to the VR intervention group were provided VR distraction by a CCLS. The VR device used was a Samsung Gear VR Innovator headset with a Samsung Galaxy mobile phone, which fit into the headset to deliver sound and images (Samsung Electronics). The VR device is equipped with eye tracking which allows for the users to navigate simulated environments and engage in play and does not require any other controllers (i.e., hand controller). This specific VR system has been shown to be feasible for use with patients in a medical setting (Mosadeghi et al., 2016). No additional child life services were provided (e.g., education).

Upon entry into the room, the CCLS established rapport with the patient and family and explained the VR device and game. Once the headset was on, the CCLS prompted children to begin playing a VR game that offered visual and auditory immersion. The game (Bear Blast by AppliedVR) took participants through colorful and engaging landscapes that contained teddy bears that needed to be knocked down by a cannon. Participants' eye gazes controlled where the cannons fired. The game is developmentally appropriate for the age range of participants and allows for flexibility to meet children's individualized needs and development (e.g., look around, try to beat a top score). While the child was playing the game, the CCLS would support engagement of the distraction based on the child's response and behaviors. How the CCLS conversed or engaged with the participants was individualized from participant to participant as CCLSs provide individualized care based on the developmental and psychosocial needs of patients (Boles et al., 2020). The VR headset was cleaned with alcohol-based wipes between participants.

Control group. Participants in the control group received the standard care typically offered at the clinic during vaccinations. The pediatric clinic does not employ a CCLS, and the presence of a CCLS in the clinic was for the purpose of research. Therefore, the control group did not include other psychosocial supports like education or other types of distraction activities because they are not typical standards of care in the clinic. The CCLS explained their role was to be present during the vaccination, and afterwards to ask the child a question about their vaccination.

The CCLS would engage in conversations with the nurse and child to help normalize their presence in the room.

Measures

Background/Demographic Questionnaire

This questionnaire gathered information about the children including the child's age, ethnicity, and gender.

FACES Pain Rating Scale (FACES; Wong & Baker, 1988)

The FACES scale is a reliable and valid facial analogue scale for assessing the self-reported pain of children, ages 3 and up (Wong & Baker, 1988). After the vaccination, the research observer showed the child participants a scale of faces that ranged from a very smiling face that represented no hurt, very happy (0) to a very tearful face that represented hurts as worse as you can imagine (5). The research assistant explained the scale to the participant (i.e., provided a verbal description for each face), then asked, "Point to the face that shows how much hurt you had during the vaccination?" Children were asked to point to the face so that the caregivers and observer were unaware of their response.

FACES Pain Scale-Revised (FPS-R; Hicks et al., 2001)

The FPS-R is a valid and reliable facial analogue scale for assessing pain (Hicks et al., 2001). After the vaccination, the caregiver and research observer were shown the scale that includes 6 faces ranging from no hurt (0) to very much pain (10). They were asked to circle the face best representing the child's pain during the vaccination.

Behavioral Observation Pain Scale (BOPS; Hesselgard et al., 2007)

The BOPS is a valid and reliable tool for using observations to assess children's pain (Hesselgard et al., 2007). In the current study, it was used by the research observer to assess the child's level of pain during the vaccination. The BOPS assessed pain using three evidence-based variables that are indictive of pain in children: facial expression, vocalization, and body positioning. During the vaccination, the research observer scored each variable on a scale ranging from 0 to 2, with each of the three possible scores having a description of behaviors. For example, the variable of facial expression was scored a 0 if the child displayed a neutral/positive facial expression, scored a 1 if the child had a negative or concerned facial expression, and scored a 2 if the child had a grimace or distorted face. Possible composite scores ranged from 0 to 6, with higher scores indicating more pain, and any score above 2 suggesting the child was in pain (Hesselgard et al., 2007).

Results

There were no significant differences found between groups on descriptive variables, indicating the VR group and the control group were similar. A Shapiro-Wilk test of normality was conducted and found child's self-report of pain ($p < .01$), observer report of pain ($p < .01$), observer report of pain behaviors (BOPS) ($p < .01$), and caregiver report of pain ($p < .01$) were not normally distributed. Therefore, to test the hypotheses set forth in this study, Mann Whitney U tests were conducted.

Table 2. Summary of Differences between VR Distraction and Control on Mann-Whitney U Tests

Variable	VR Distraction (n=39)	Control (n=51)	
	Mean rank	Mean rank	z-value
Self-Reported Pain	43.12	47.32	-.80
Caregiver Pain	35.83	52.15	-3.07*
Observer Pain	35.56	52.36	-3.13*
Observer BOPS	34.26	54.10	-3.67*
Body positioning	38.42	50.91	-2.57*
Verbalization	32.5	55.44	-4.49*
Facial Expression	37.81	51.38	-2.64*

*indicates significance at the p< .01

Children and Caregiver Reports of Pain

When children self-reported the pain during the vaccination, there was not a significant difference in pain scores between the two groups. Caregivers reported on their child's level of pain displayed during the vaccination using the FPS-R. Caregivers of children in the VR group reported their children displayed significantly lower pain during the vaccination than caregivers in the control group. See Table 2 for a summary of the results.

Observer Reported Pain

A research observer also reported on pain behaviors using the FPS-R and BOPS. The research observers reported that participants in the VR group displayed significantly less pain than participants in the control group. The research observers also found a significant difference in pain behaviors between groups using the BOPS, with those in the VR group displaying fewer pain behaviors overall and within each of the individual variables of the BOPS (body positioning, verbalization, and facial expression). See Table 2.

Discussion

The purpose of this study was to examine the effectiveness of child life-led VR distraction in minimizing pain in pediatric patients undergoing vaccinations. It was expected that children who received VR distraction during the vaccinations would report less pain and display fewer pain behaviors than children who did not receive VR distraction. Pain was assessed through self-reports and behavioral observations. This hypothesis was partially supported. Children who received child life-led VR distraction during the vaccinations displayed significantly less pain behaviors than children who did not receive VR distraction. However, there was not a significant difference in self-reported pain by the children between groups.

Research has shown that it can be difficult to find effective distraction activities for minimizing pain during pediatric vaccinations (Burns-Nader et al., 2016; Goldstein et al., 2019). The current findings suggest VR does appear to help distract pediatric patients as the VR group did display fewer pain behaviors during vaccinations. VR distraction has an immersive component that allows children to be virtually transported from the healthcare setting to a more neutral environment and actively engage with that environment through the headset or a hand-held controller. This immersive ability decreases the brain's ability to process pain as more of the individual's attention is focused on the VR activity (Hoffman et al., 2011).

A lack of significant difference in self-reported pain provided conflicting results. However, it is important to note that children's report of pain is often related to their initial fear of pain (Gatchel et al., 2007). Therefore, if children were fearing pain during the vaccination, they may have reported higher pain afterwards (McMurtry et al., 2015). Future research should collect information about children's fear of pain in addition to their self-reported pain during the vaccination. Also, the caregiver and research observer observations were conducted at the time of the vaccination while the self-report measure was conducted after the procedure. The subscales of the BOPS (i.e., verbalization, body position, and facial expression) provide evidence that during the vaccinations, children in the control group were not displaying pain as indicated by evidence-based behaviors used to evaluate pain.

Children experience many vaccinations during their visits to the pediatrician (Center for Disease Control and Prevention, 2022). The findings of the current study indicate that VR distraction led by a CCLS may be an effective tool to offer pediatric patients receiving vaccinations to distract children from the procedure and minimize pain behaviors. Pediatric offices and clinics should consider the possible positive outcomes for supporting patients receiving an immunization with child life-led VR distraction.

Limitations

There are a few limitations to this study. The first limitation to note was the potential for observer bias. Due to the nature of the study, participant group assignment was not blinded. It was obvious to the research observers which participants were in the VR distraction group because they had on the VR headset. Therefore, the research observers' knowledge of the participants' group assignment could have influenced scoring. The generalizability of the findings is another potential limitation. This study examined vaccinations administered at a pediatric clinic. Future studies should examine if VR distraction by a CCLS is effective in other areas or with other needle procedures. In addition, the VR device used for this study was one in which interaction with the game utilized eye movement, allowing the child to maintain stillness at the site of the vaccination. These findings may not generalize to other VR systems that use hand controls or other tools for assisting in movement in the game. In addition, a CCLS offered and supported the VR distraction. The support of the CCLS likely influenced the effectiveness of the VR distraction. Therefore, the findings may not generalize to VR distraction without child life support. Finally, the VR device limited the view of the participants' face, as it covered their eyes and forehead. This may have impacted the research observer's ability to assess pain using facial expression. The assessment scales for pain and pain behaviors have not been validated for use with a VR device.

Implications

The findings demonstrated that VR distraction led by a CCLS decreased the pain behaviors that children displayed during vaccinations. These findings suggest that pediatric clinics should consider offering VR distraction led by a CCLS to pediatric patients receiving a vaccination. It is unknown if VR distraction offered by a caregiver or someone other than a CCLS would have the same outcomes. Therefore, future research is needed to examine the effectiveness of VR distraction without CCLS support. In addition, future studies should continue to examine the outcomes of other types of CCLS distraction and supports during pediatric vaccinations.

Conclusion

As pediatric facilities are utilizing evidence-based protocols for pain management during needle-related procedures, the importance of examining the effectiveness of distraction activities to minimize pain and distress during pediatric vaccinations is of importance. This study found VR distraction offered by a CCLS was effective in decreasing pain behaviors in children undergoing vaccinations. Therefore, pediatric healthcare providers should consider offering VR distraction by a CCLS to children receiving vaccinations.

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