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The Impact of Immersive Virtual Reality on Procedural Pain in Children and Adolescents

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THE IMPACT OF IMMERSIVE VIRTUAL REALITY ON PROCEDURAL PAIN IN CHILDREN AND ADOLESCENTS

by

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ABSTRACT

Children commonly undergo uncomfortable and often times painful procedures, including those that may not be perceived as painful to adults (Çelikol, Büyük, & Yıldızlar, 2019). It is important to note when a child's pain is poorly managed, it causes adverse effects related to their well-being and reduces their ability to cope effectively with pain in the future (Gates et al., 2020). Virtual reality (VR) has been used in a multimodal approached to manage acute pain in adults, but there is little research related to its use in treating procedural pain in children and adolescents. This thesis reviewed the published research on the use of immersive VR on procedural pain in children and adolescents. A total of nine studies were analyzed and included in this literature review and all of them included VR as a distraction intervention during a procedure for children or adolescents. The procedures included three venipunctures, one intravenous injection, one venous cannulation, one dental filling or tooth extraction, one nasal endoscopy, one vascular access, and one burn dressing change. All studies measured and compared the reported pain levels of the participants using VR as well as participants who did not use VR. The results obtained from the nine studies provided evidence to support the use of immersive VR in children and adolescents while they undergo a painful procedure. To more accurately generalize the results of these studies and confidently say immersive VR can be used to decrease procedural pain, there is a need for more research containing larger sample sizes, standardized pain measurement, and increased variety of procedures. The databases searched for this literature review includes CINAHL Plus with Full Text, Medline, Cochrane Central Register of Controlled Trials, and APA PsycINFO. The key search terms included "virtual reality" and "procedure" and "pain" and "childhood or adolescent."

DEDICATIONS

To everyone who supported me, I could not have done it without you. I want to especially thank my parents for their love and support in everything I do, not just my thesis, and Nathan for encouraging me to keep going even when I wanted to give up.

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INTRODUCTION

A child who is admitted to the hospital experiences stress and anxiety related to the separation from their family and support system and the pain which occurs during medical procedures performed throughout their stay. The level of anxiety and stress a child has can influence the perceived amount of pain felt during medical procedures (Piskorz & Czub, 2017). The more anxiety a patient has, the more pain they may perceive, and the less anxiety they have, the less pain they perceive. When a child's pain is poorly managed, it causes adverse effects related to their well-being and reduces their ability to cope effectively with pain in the future (Gates et al., 2020). Acute pain can be managed by a multimodal approach that involves pharmacologic and nonpharmacologic methods. Acute procedural pain is frequently managed with nonpharmacologic cognitive-behavioral strategies, including distraction, guided imagery, and hypnosis (Howard, 2003). The basis for distraction therapy is an individual has a limited amount of attention; if that attention can be redirected from painful stimuli resulting from a medical procedure to a nonpainful stimulus, it will decrease the pain perception of the patient (Walker et al., 2014; Koller & Goldman, 2012; Wint et al., 2002).

Since the early 2000s, virtual reality (VR) has emerged as an immersive distraction tool that has shown much promise for decreasing pain and anxiety with few to no side effects (Walker et al., 2014; Koller & Goldman, 2012). While the exact mechanism of how VR works in the brain is still unknown, its impact on pain is often understood using the "gate theory" of attention. In this theory, it is hypothesized that VR can effectively reduce pain perception due to its ability to redirect attention to the virtual environment instead of the pain (Jones et al., 2018). Additionally, the fun and immersive nature of VR helps lessen anxiety related to the procedure.

VR can be delivered using a variety of technologies, including mobile devices such as tablets and smartphones, as well as computers, televisions, and head-mounted displays. The head-mounted displays allow for a higher immersion into VR and are simply connected to a computer, TV, or other electronic devices (Iannicelli et al., 2019).

BACKGROUND AND SIGNIFICANCE

Procedural Pain

There is a high amount of anticipation of pain when children and adolescents require a medical procedure. Treatment of procedural pain varies based on the duration of the procedure, expected pain, level of anticipation and anxiety, the patient's understanding of what is going to happen, the patients' pain history, and their style and ability to cope with pain. The pain management approach should be multimodal and tailored to the needs of specific patients. It may include a mix of interventions such as different levels of sedation or anesthesia, in addition to guided imagery, distraction, relaxation, massage, or heat compresses (Committee on Psychosocial Aspects of Child and Family Health & Task Force on Pain in Infants, Children, and Adolescents, 2001). Whatever the choice(s), it should be appropriate for the patient and the procedure.

Virtual Reality (VR)

VR has a wide array of uses. It was used in the 1990s for military exercises, then as technology advanced, its potential in the medical field as a therapeutic tool was seen. This experience has been used as a substitute for exposure therapy in soldiers who had Post-traumatic stress disorder, to treat social disorders and phobias, and for training exercises because of its ability to bridge the gap between conceptual and hands-on practice (Iannicelli et al., 2019). In the past, it was difficult to conduct studies and trials using VR due to the cost of the devices, limited software development, and availability of needed hardware. However, as the technology continues to develop, the head-mounted display has been created, which is reasonably priced, easy to use for a variety of ages, and easily accessible by the public. This shift has allowed

research to move from small-scale laboratory studies to any person who has access to a smartphone or gaming console. These changes have paved the way for VR to play a role in pediatric health care (Gold & Mahrer, 2018).

According to Cipresso et al., (2018) there are three different types of VR systems that provide the user with a range of immersion levels. VR systems that rely on desktops to display the images of the virtual world environment are considered non-immersive systems; these are the simplest of the VR systems and often the cheapest. VR systems are immersive when they use components such as head mounted displays to provide a completely simulated experience. These head-mounted displays can provide an enhanced three-dimensional perspective of the virtual environment when the user moves their head in conjunction with audio and tactile instruments. Semi-immersive systems, being the in-between of the two previous, have a monitor, which utilizes a perspective projection coupled with the user's head position, allowing it to show a solid, three-dimensional scene. In immersive VR, the head-mounted display allows the participant to use head movements to look around the virtual environment. Participants experience the new virtual world as if they are a part of it, which is a component that makes VR a very effective distraction method (Piskorz & Czub, 2017).

PURPOSE

The purpose of this literature review was to analyze published research related to the use of virtual reality on acutely painful procedures in children and adolescents.

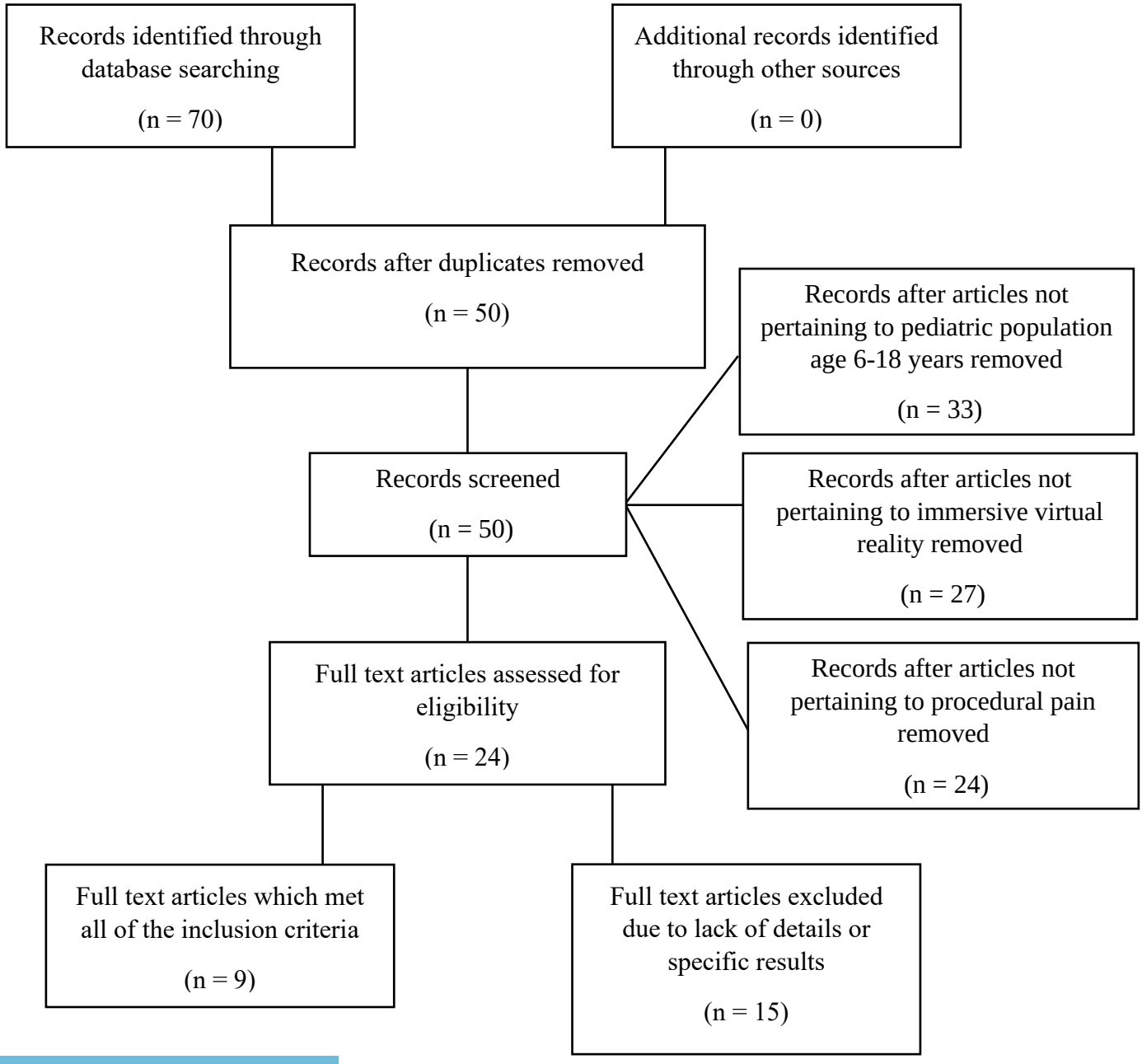
METHODS

A literature review was conducted to search for research that studied the use of virtual reality as a distraction to reduce procedural pain in pediatric patients ranging from the ages of 7-18 years old. The databases chosen for this review included CINAHL Plus with Full Text, Medline, Cochrane Central Register of Controlled Trials, and PsycINFO. The key search terms were "virtual reality AND procedure AND pain AND childhood or adolescent NOT systematic review or meta-analysis." The search results were limited to peer-reviewed/scholarly journals published between 2010 and 2020. The inclusion criteria included research written/published in English. Research was excluded if they did not relate to procedural pain, immersive virtual reality utilizing a head mount display, and pain management within the childhood or adolescent population.

Figure 1: Prism Flow Diagram

Key Search Terms: virtual reality, AND procedure, AND pain, AND childhood or adolescents

Limiters: NOT systematic review or meta-analysis or physical therapy, English language, peer-reviewed and scholarly journals published between 2010-2020.



FINDINGS

Nine studies exploring immersive VR and its effects on procedural pain in the pediatric population were reviewed and their evidence analyzed. While each of the studies varied in their methods of collecting data, the procedures being performed, and the virtual reality devices used, they resulted in similar findings. A few of the same pain scales were used in the different studies, but no same scale was used throughout them all, and in some studies, more than just pain was being measured. The majority of the studies had similar results with variations in the degree of difference between the pain levels of the control and experimental group, showing VR's promising effects on procedural pain.

Chen et al. (2019) conducted a randomized control study on the effects of virtual reality on one hundred thirty-six patients undergoing an intravenous injection. The purpose of this study was to determine if virtual reality could be used as a distraction intervention on school-aged children to reduce fear and pain they experience while undergoing intravenous injections. Using the block randomization method, the participants were divided into experimental and control groups, each consisting of sixty-eight participants. The experimental group used the head mounted display Xiaozhai V4 and an iPhone which had four age-appropriate virtual environments. A Wong-Baker Faces Pain Rating Scale (WBFPS) ranging from 0-10 (0 being no pain and 10 being excruciating pain) and Children's Fear Scale (CFS) ranging from 0-4 (0 being no fear and 4 being extreme fear) were used to rate pain and fear. The VR intervention began when the nurse determined the site for the injection and stopped three minutes after. Then, five minutes later the WBFPS and CFS was used by the participants, primary caregivers and nurses to measure pain and fear felt during the procedure. In the control group, the WBFPS and CFS were

used eight minutes after the torniquet was worn. A p value of < 0.05 was considered statistically significant. Pain scored by children using VR was 3.35 ± 2.38 as compared to 4.35 ± 2.95 in the control group, ($p = 0.031$). Pain scored by primary caregivers for children in the VR group was 3.26 ± 2.37 and 4.29 ± 2.70 in the control group, ($p = 0.02$). Pain scored by the nurse in the VR group was 3.29 ± 2.01 and 4.29 ± 2.52 in the control group, ($p = 0.012$). Fear score by children in the VR group was 1.32 ± 1.19 and 1.78 ± 1.40 in the control group, ($p = 0.043$). Fear score by primary caregivers in the VR group was 1.35 ± 1.23 and 2.03 ± 1.36 in the control group, ($p = 0.003$). Fear score by nurses in the VR group was 1.56 ± 1.20 and 2.15 ± 1.24 in the control group, ($p = 0.006$). The results showed utilizing VR in the emergency department with school-aged children while they undergo intravenous injections can effectively reduce the degree of pain and fear experienced by the child and the amount observed by their primary caretakers and nurses.

Piskorz and Czub (2017) conducted a group quasi-experiment consisting of a nineteen-person experimental group who used VR and a nineteen-person control group with no VR to determine if VR use during venipuncture could effectively minimize stress and pain levels in pediatric patients. All data collection for the experimental group was completed before the control group for two reasons. First, so no child was presented with the VR game, was interesting in using it, but then not be allowed to use it because they were assigned to the control group, and second to avoid the control group consisting of only children who chose not to use VR during their venipuncture. The authors of the study designed a game based on the Multiple Object Tracking (MOT) paradigm and displayed it through an Oculus Rift DK2 head mounted display. Participants in the VR group completed a 10-to-15-minute training the same day or one

day prior to their blood-draw procedure in order to become acquainted with the VR system and learn how to play the game. Children who were a part of the control group had standard blood-draw procedure and did not have any distraction. The children's ages were measured in years, and after the procedure, participants of both groups measured their level of pain and stress by marking a horizontal line on a continuous, 10-cm Visual Analogue Scale (VAS) (0 being no pain/stress and 10 being severe pain/stress), which was then coded in millimeters, giving it a range of 0-100. Pain intensity reported was 59% lower in the VR group when compared to the control group, and stress levels were 73.4% lower in the VR group when compared to the control group.

Walther-Larsen et al. (2019) conducted a randomized and observer-blinded clinical trial consisting of sixty-four patients ages 7 to 16 years old who were scheduled for a venous cannulation. The twenty-eight participants in the control group received standard care for venous cannulation which included positioning, a topical numbing cream, and distraction using a smartphone led by a nurse who is specialized in pediatric pain. The thirty-one participants in the intervention group also had positioning and topical numbing cream, but their distraction differed in that it was provided by VR while they played the game *Seagull Splash*, a custom VR game created for the procedure. Participants of the intervention group held a control in the opposite hand the procedure was on and wore Samsung Galaxy S6 mobile-based Gear VR goggles to play the game. The primary outcomes measured by this study were patient satisfaction and pain levels and secondary outcomes included length of time to complete the procedure and any adverse effects. Participant satisfaction and if they would use VR again was measured using a 0 to 100 scale and a VAS score of 0 to 100 was used to assess pain. On a scale of 0 to 100 for pain, a

difference of 20 was considered clinically relevant. The VAS score of the VR group was higher with 27 of 100 vs 15 of 100 in the control group ($p = 0.23$). Mean procedure time in minutes for the VR group was 1.75 and for the control group was 2.0 ($p = 0.58$). So, while the results of this study found no significant difference between pain scores in the two groups, there was high patient satisfaction in those who used the VR intervention.

Atzori, Hoffman, et al. (2018) conducted a within-subject study to evaluate VR's effectiveness as a distraction intervention on fifteen children and adolescents undergoing venipunctures. The study utilized a VR helmet and the Personal 3D Viewer Sony: HMZ T-2, which was supported by a laptop to play Snow world, the VR environment designed specifically to provide distraction during painful procedures. All participants had two venipunctures done on two different days. One venipuncture with "Yes VR" (experimental group) and one with "No VR" (control group). Patients were randomly assigned to one of the two groups and when they returned for their second venipuncture, it was done with whichever distraction wasn't used the first time. When in the "No VR" condition, patients received standard care, which was a non-medical conversation with the nurse performing their venipuncture to provide distraction. In the "Yes VR" condition, before the nurse arrived, participants had 5 minutes to wear the headset and become accustomed to the VR system, and the headset wasn't removed until after the procedure. Once the venipuncture was completed, the patient completed a self-report questionnaire. For both conditions, pain was evaluated based on "time spent thinking about pain", "pain unpleasantness", and "worst pain." The study also measured fun and nausea experienced during the procedure. The quality of the VR was only explored in the "Yes VR" group. The mean pain scores for "time spent thinking about pain" was 3.23 ± 2.98 in the "No VR" condition and 1.33 ±

1.05 in the “Yes VR” condition, (p <0.05). The mean pain score for “pain unpleasantness” was 3.27 ± 3.43 in the “No VR” condition and 0.93 ± 1.16 in the “Yes VR” condition (p < 0.01). The mean pain score for “worst pain” was 3.60 ± 3.00 in the “No VR” condition and 2.00 ± 1.20 in the “Yes VR” condition, (p < 0.05). Mean pain levels during the venipuncture were significantly lower in the “Yes VR” condition compared to mean pain levels of the “No VR” condition. There was a statistically significant increase of fun reported in the “Yes VR” condition when compared to fun levels in the “No VR” condition, and no significant difference in nausea levels between the two conditions.

Aydın and Ozyazıcıo (2019) conducted a randomized control trial to investigate using VR to reduce pain associated with venipunctures in 120 children aged 9 to 12 years. The patients were randomized into either the experimental group (n=60) or the control group (n=60). The study used a VR headset for participants of the experimental group to be able to visualize the “Aquatic VR” application while undergoing their blood draw. No interventions were used on the participants in the control group. In both groups, after their venipuncture procedure, the Visual Analogue Scale (VAS) and the Wong-Baker Faces Pain Scale (WBFPS) were used to measure pain levels. In this study, the value of p < .05 was accepted as statistically significant. Using the WBFPS, the experimental group’s pain scores were 1.68 ± 1.51 and 2.02 ± 1.96 in the control group, (p = 0.01). Using the VAS, the experimental group’s pain score was 3.07 ± 2.86 and 3.23 ± 3.05 in the control group, (p = 0.05).

Atzori, Grotto et al. (2018) conducted a study with the aim to analyze how effective immersive VR can be when used as a distraction intervention for children and adolescents when they have painful dental procedures. The five children and adolescents who took part in this

study were between the ages of 7 and 17 years old and had to have two separate dental visits where they needed dental fillings or teeth extractions (comparable procedures). Each participant was randomly assigned to either the "Yes VR" condition or the "No VR" condition, when they came back for their second visit, they were assigned to whichever condition they were not a part of the first time. A questionnaire was used to evaluate pain, fun, and nausea experienced during the procedure. For both conditions, patients were asked to score their "time spent thinking about pain", "pain unpleasantness", "worst pain", and "fun" on a scale from 0 to 10 to evaluate the cognitive, affective, and sensory components of the pain experienced. The "Yes VR" condition showed significantly lower levels in ratings of "worst pain" and "pain unpleasantness" with a reduction of 42% and 75% respectively when compared to the "No VR" condition, however, no statistical significance was found in "time spent thinking about pain" between the two conditions. "Yes VR" also reported a 61% increase over the "No VR" condition in "fun" experienced during their dental procedure.

Liu et al. (2020) conducted a study in fifty-three children undergoing flexible or rigid nasal endoscopy. Participants were randomly assigned to either the control group (n=23) or the experimental group (n=30). All patients received topical analgesia which is standard for nasal endoscopy procedures but those in the experimental group also had virtual reality goggles and a handheld control so they could interact with a virtual environment as a form of distraction during their procedure. After the procedure, pain and anxiety was rated by the participant using the Wong-Baker FACES pain scale and the Subjective Units of Distress Scale (SUDS). The physician who performed the nasal endoscopy also filled out a Childhood Emotional Manifestation Scale (CEMS) to provide an objective measurement of the distress the child felt

during the procedure. Patient's self-report of the Wong-Baker FACES scale was 0.80 ± 1.06 in the experimental group vs. 2.26 ± 2.38 in the control group, (p = .018). Patients self-report of anxiety on the SUDS scale was 9.50 ± 12.48 in the experimental group vs 38.48 ±29.83 in the control group, (p = 0.0002). The participants procedural satisfaction was 6.40 ± 0.77 in the experimental group vs. 4.74 ± 1.74 in the control group, (p = 0.0002). The CEMS score for the experimental group was 5.15 ± 0.46 vs. 9.64 ± 5.66 in the control group, (p = 0.0001). There was significantly less pain during the procedure in the children and adolescents in the experimental group who used immersive VR to distract them while having their nasal endoscopy; the SUDS scores of the patients in this group were also significantly lower than those in the control group. The results of the CEMS score in the experimental group were significantly lower than the control group. These results support the hypothesis that VR can be used to decrease pain and anxiety in children and adolescents when they must undergo a nasal endoscopy procedure.

Caruso et al. (2019) conducted a prospective randomized controlled trial study to determine if VR being used with children and adolescents having vascular access procedures would lead to a pain reduction. This study analyzed data from 259 patients between the ages of 7 and 18 who were randomly assigned to either the VR group (n=132) or the control group (n=127). Participants in the control group received standard coping care including nonprocedural talk and coaching, watching television or a movie, and certified child life specialists (CCLS) consultation when available and those in the VR group used a Samsung GearVR headset and mobile device to experience a VR environment during their venous access procedure. The primary outcome of pain was measured by having participants rate their pain immediately before and after their procedure using the Faces Pain Scale-Revised (FPS-R). Secondary outcomes measured were

patients fear using the Child Fear Scale (CFS), procedural compliance using a modified Induction Compliance Checklist (mICC), satisfaction using satisfaction surveys, and adverse effects. There was no statistical significance in the difference in changes in procedural pain scores (increased, unchanged, or decreased) between the VR group and control group ($p = 0.62$). When comparing postprocedural pain between the two group, there also was no statistically significant difference ($p = 0.59$). Changes in fear scores between the VR and control groups, ($p = 0.015$) shows a statistically significant difference between the groups. Fear before and after the procedure was measured and there was a 48.3% decrease in the VR group versus only a 26.1% decrease in the control group. No evidence in this study supported that VR has the ability to reduce pain during venous access for children and adolescents, however, it does support a statistically significant decrease in fear.

Kipping et al. (2011) conducted a prospective randomized control trial to assess VR effectiveness of reducing acute pain during burn wound care in adolescents and if it can realistically be used in a hospital. Forty-one adolescents ages 11 to 17 were randomly divided into the experimental group (n = 20) and the control group (n = 21). Those in the experimental group used a VR headset and joystick to navigate an age-appropriate VR game of their choice. Those in the control group were given the option to choose another form of distraction such as watching TV, listening to music, reading or listening to a story, or having no distraction at all. Participants were undergoing their first conscious burn dressing change and both of the groups had the same wound care procedures and medication protocol. The participants used a VAS score ranging from 0-10 (0 = no pain, 10 = pain as bad as it could possibly be) to rate their pain and the nurses used the Faces, Legs, Activity, Cry, Consolability scale (FLACC) to measure the

observed pain of the adolescents during their burn dressing change. The results of this study showed no statistically significant difference between the VR group and the control group on the VAS, heart rate and oxygen saturation levels, or nausea levels. The FLACC rating by nurses in the procedure showed a statistically significant difference in the pain levels of participants during the removal of their dressings, with those in the VR group showing less pain, and only 15% of the patients in the VR group required rescue doses of Entonox compared to 43% in the control group. So, while this study had no consistent statistically significant difference between the two groups and their pain levels, there was a trend of mean pain scores being lower in the VR group.

DISCUSSION

Even though there were differences in procedures performed and eligibility criteria within the different studies, they all consisted of a population of children and adolescents who were 7 to 18 years old and undergoing a procedure commonly known to be painful for children and adolescents. While the studies differed in the equipment and VR applications used, they all provided an immerse virtual reality experience for the participants. The VR applications consisted of Seagull Splash, Aquarium VR, SnowWorld, SpaceBurgers™, Ocean Rift, Pebbles the Penguin, Space Pups, Chicken Little™, and Need for Speed™. Some studies used only a head mounted display such as the ones conducted by Chen et al. (2019), Piskorz and Czub (2017), Aydın and Ozyazıcıo (2019), and Caruso et al. (2019) whereas Walther-Larsen et al. (2019), Atzori, Hoffman et al. (2018), Atzori, Grotto et al. (2018), Liu et al. (2020), and Kipping, Rodger, Miller, and Kimble (2011), required the participants to also use a handheld controller or mouse in addition to the VR headset or goggles to interact with the virtual environment.

The scales and tools to measure pain varied throughout the studies. The most common pain rating scale used was the Visual Analog Scale (VAS) with a range of 0-10 or 0 -100 (0= no pain) and (10 or 100= worst pain). Both Piskorz and Czub (2017) and Walther-Larsen et al. (2019) relied solely on the VAS, however, most of the studies used more than one pain rating scale to gather their results. Kipping et al. (2011) used the physiological measurements of heart rate and oxygen saturation levels along with the VAS score to measure pain. Chen et al. (2019) used a 0-10 Wong-Baker Faces Pain Rating Scale (WBFPS) and a 0-4 Children's Fear Scale (CFS) whereas Liu et al. (2020) used a 0-10 WBFPS and a 0 to 100 rating Subjective Units of Distress (SUDS) anxiety score. Atzori, Hoffman et al. (2018) and Atzori, Grotto et al. (2018)

used a questionnaire that had the participants rate “time spent thinking about pain”, “pain unpleasantness”, and “worst pain.” It would be easier to determine the average reduction in pain if all of the studies used the same primary pain measurement scale, and then if they wanted to use more than one, they could add in secondary pain scales.

The nine studies included in this analysis had a wide variety in sample sizes that ranged from five to 259 patients and the procedures the patients were undergoing in the different studies included intravenous injections, venous cannulation, venipunctures, dental fillings or tooth extractions, nasal endoscopy, and burn dressing changes. When comparing results between studies, there was little consistency due to the variety of sample sizes and procedures. Results of six out of nine studies showed a statistically significant decrease in the pain levels reported by participants. Results of the study conducted by Kipping et al. (2011) showed no statistical significance of the pain reported by the participants, however, there was a statistical difference in the pain observed by the nurse during dressing removals. The study conducted by Caruso et al. (2019) showed no statistically significant difference in pain levels, however, they allowed the control groups to use other nonpharmacological interventions which makes it difficult to assess if the results were because VR wasn’t an effective intervention or if it was because the VR and the nonpharmacological control interventions were just both effective. Despite the differences and limitations of each of the studies, the majority of them showed a lower pain level in the children and adolescence using the VR. None of the studies reported significant adverse effects or issues being able to perform the procedure due to the VR, showing its potential to be used along with other analgesic interventions.

The study done by Kipping et al. (2011) had the nurses measure the participants pain score by using the FLACC scale. This pain scale scores pain intensity by a mix of behavioral (facial expressions, crying/not crying, and body movements) and physiological (heart rate, oxygen saturation, and blood pressure) factors. It rates the face, legs, activity, consolability, and cry on a scale of 0-2, which allowing for a maximum score of 10. FLACC was designed to be used for infants/children ages 2 months to 7 years (Crellin et al., 2015). Since the study conducted consisted of adolescents ages 7 to 11 years old, their choice to use the FLACC scale is not an appropriate tool to measure the participant's pain.

There is not enough evidence to conclude VR will definitely reduce pain in children and adolescents for all procedures, it is recommended that more research be done to further investigate its uses. More studies to collect data on specific procedures is necessary to be able to definitively decide what procedures VR is ideal for and be effectively used.

LIMITATIONS

Even though VR had positive effects on procedural pain, this literature review had limitations. There were not many studies that pertained to immersive VR effects on procedural pain in the pediatric population. VR's uses in pediatric pain is still a fairly new topic so there were limited articles containing consistency in the methodology, sample size, scales used to measure pain, and procedures performed. Only nine articles were analyzed and included in this literature review.

While the nine studies did all use VR goggles or a headset to provide an immersive VR experience, they differed in the applications played during the procedures, which could make a difference in the outcomes based on how engaging the game was to the players. The games were similar in they required little to no movement by the player, thus not interrupting the procedure being performed. However, to better assess how effective VR is in decreasing procedural pain, the same application should be used so all participants receive the same VR environment, which would allow a higher level of consistency between the studies when data are compared.

Another factor that varied throughout the nine studies was the scale(s) used to measure pain levels in the children and adolescents. Having a consistent scale used would make it more accurate to determine the average decrease in pain for the participants of the studies. Not all of the studies looked at stress and anxiety along with the pain. Both stress and anxiety are important to take into consideration when assessing the pain levels of children and adolescents during their procedure.

The majority of the procedures in the studies consisted of needle use such as intravenous injections, venous cannulation, or venipunctures. More research using VR needs to be conducted regarding other common pediatric procedures to determine if it consistently decreases pain.

Even considering the limitations, the results of the nine studies showed improvement in pain scores in children and adolescents who used VR when compared to those who did not. Since the pain levels of the children and adolescents who used virtual reality were lower than those who did not in all the studies, the data supports VR's ability to positively impact its users during procedures.

NURSING IMPLICATIONS

The results of the combined studies are directly related to nurses and the work they do. The procedures used in these studies such as intravenous injections, venous cannulations, and venipunctures, are procedures the nurse commonly performs in their everyday practice. These procedures and others such as burn dressing changes, nasal endoscopy, and dental work, are known to cause children pain, anxiety, and stress. So, it is important that nurses are educated in interventions which can decrease the pain and anxiety levels in children and adolescents during their procedures.

When a patient undergoes any sort of procedure, it is often the nurse who suggests and provides distraction. These distraction techniques commonly include music, guided imagery, breathing, and more. However, VR is a newer technology not available everywhere nor commonly used, especially within the pediatric population. So, it is crucial facilities who have access to VR educate nurses to let them know it is an available resource. Nurses also must be educated on how to use the VR systems because it is important to understand how to set up and operate the VR. It is also important to make sure nurses can educate their patients on how to use VR.

Of the nine studies, there were a few that measured symptoms of motion sickness experienced, such as headache, dizziness, or nausea due to using the VR headset. Even though very few users experienced any negative side effects, it is still important all nurses using a VR intervention are aware of them and how to best treat the side effects if they do occur.

RESEARCH IMPLICATIONS

Since the use of immersive VR on procedural pain in children and adolescents is a relatively new intervention, there is still a need for more research to be done. These nine studies provide a good framework of support that immersive VR has promising results in decreasing pain and anxiety levels in children and adolescents during medical procedures. However, it is necessary to further investigate VR's uses by doing more research with larger sample sizes, procedures of different types, and using a consistent pain scale to further support VR's use during procedures for children and adolescents. There needs to be focus specifically on different procedures to determine if using VR as a distraction technique is effective with more procedures, or if it is limited only to specific ones. By knowing what procedures are most positively affected by VR, we will more confidently be able to recommend its application.

Future research studies could focus on what types of VR applications are most effective. Finding the types of virtual environments children and adolescents prefer and engage with most could help decrease pain levels even more. For example, finding out if children and adolescents enjoy educational applications about sea life, the forest, or even space, or would they rather play games would help researchers learn the types of VR environments to test in their studies.

In new research studies conducted, researchers should examine if VR could be effectively used on children or adolescents who have a developmental delay or have issues communicating or expressing how they feel. The majority of the studies looked at in this review excluded participants who had a mental or physical developmental delay. So, there is little to no data to support VR use in children and adolescents who have a developmental delay and need to undergo a painful procedure.

CONCLUSION

Children and adolescents often undergo painful procedures, and their pain is frequently managed with nonpharmacologic cognitive-behavioral strategies, including distraction, guided imagery, and hypnosis (Howard, 2003). Immersive VR, a newly emerging distraction technique, has the potential to not only positively impact patients' pain and anxiety levels, but also make the procedure easier to perform. The results of the research studies included in this literature review have strongly supported the idea that immersive VR can be effectively used to decrease pain levels in children and adolescents. Due to the fact using immersive VR in the pediatric population is still a relatively new idea, more research needs to be conducted before it can be confidently recommended to be used as an intervention in procedural pain management for children and adolescents.

APPENDIX: TAB

Table 1: Table of Evidence

Articles	Participants and Study Design	Intervention Detail	Outcomes Measures	Results (Key Findings)	Nursing Implications
Chen, Y-J., Cheng, S-F., Lee, P-C., Lai, C-H., Hou, I-C., Chen, C-W. (2019). Distraction using virtual reality for children during intravenous injections in an emergency department: A randomised trial. *Journal of Clinical Nursing, 29*(3-4), 503-510. doi: 10.1111/jocn.15088	136 patients and their primary caregivers. Randomized control trial. Quantitative.	Head mounted display, Xiaozhai V4, and an iPhone with four virtual environments consisting of roller coasters, space exploration, a wildlife park, and travel destinations. The VR usage began once the injection sites were chosen and then ended 3 minutes later.	A 0-10 Wong-Baker Faces Pain Rating Scale (WBFPS) and 0-4 Children's Fear Scale (CFS) was used to rate pain and fear. A p value of <0.05 was determined to be statistically significant.	Both pain and fear scores rated by the children, their primary care giver, and the nurse all scored lower in the VR intervention group when compared to the control group, all having a p value <.05, thus showing statistical significance.	Results from this study showed virtual reality effectively decreased the amount of pain and fear of school aged children when they have an intravenous injection in the emergency department.
Piskorz, J., Czub, M. (2017). Effectiveness of a virtual reality intervention to minimize pediatric stress and pain intensity during venipuncture. *Journal for Specialists in Pediatric Nursing, 23*(1), e1220. doi: 10.1111/jspn.12201	This study included 38 children and adolescents ages 7-17 Posttest only between group quasi-experimental study. Quantitative.	Head-mounted Oculus DK2 HMD with a hands-free Multiple Object Tracking (MOT) based game designed by the authors of the study. The game was designed for application to children of various ages and skill levels because its difficulty can be controlled by adjusting the number of objects needing to be tracked.	A 0 to 100 Visual Analogue Scale (VAS) was used by participants to rate their pain and stress intensity during the venipuncture.	Pain intensity in the VR group was 59% lower than the control group, ($p < 0.02$). This put the VR groups stress levels 73.4% lower than the control groups, ($p < 0.01$).	This study provides evidence that VR can effectively be used to decrease the levels of pain and stress a pediatric patient has when undergoing a blood draw procedure.

Walther-Larsen, S., Petersen, T., Friis, S. M., Aagaard, G., Drivenes, B., Opstrup, P. (2019). Immersive virtual reality for pediatric procedural pain: A randomized clinical trial. *Hospital Pediatrics, 9*(7), 501-507. doi: 10.1542/hpeds.2018-0249	Sixty-four children ages 7 to 16 years old scheduled to have a venous cannulation. Randomized and observer-blinded clinical trial. Quantitative.	Samsung Galaxy S6 mobile-based Gear VR goggles and remote controller were used to *Seagull Splash*.	Pain was measured using the Visual Analog Score (VAS) A *p* value less than or equal to 0.05 was considered statistically significant and a pain score on a 0 to 100 scale with a difference of 20 was considered clinically relevant.	No significant difference of pain between the intervention and control group. The VAS score of the VR group was 27 of 100 vs 15 of 100 in the control group ($p = 0.23$). However, 100% of children who used the VR intervention answered they would it again, versus only 84.9% in the control group.	While evidence from this study does not support the intervention of VR as a way to decrease procedural pain in the pediatric population, there was higher patient satisfaction when it was used as a multimodal approach for pain management during procedures in children.
Aydın, A. I., Ozyazıcıo, N. (2019). Using a virtual reality headset to decrease pain felt during a venipuncture procedure in children. *Journal of PeriAnesthesia Nursing, 34*(6), 1215-1221. doi: 10.1016/j.jopan.2019.05.134	120 children aged 9 to 12 years old who underwent venipuncture procedures. Randomized control trial. Quantitative.	A VR headset was used to play "Aquarium VR." The participants in the experimental group began watching the "Aquarium VR" a minute before their venipuncture procedure and it remained on until the end of the procedure.	Pain was measured using the Visual Analogue Scale (VAS) and the Wong-Baker Faces Pain Scale (WBFPS). A *p* value < 0.05 was accepted to be statistically significant	On both pain scales, pain levels were lower in the experimental group and the *p* values were <0.05, showing a statistical significance.	Results from this study support VR's ability to decrease pain felt during a procedure in the pediatric population when used as a distraction intervention.

Atzori, B., Hoffman, H. G., Vagnoli, L., Patterson, D. R., Alhalabi, W., Messeri, A., Grotto, R. L. (2018). Virtual reality analgesia during venipuncture in pediatric patients with onco-hematological diseases. *Frontiers in Psychology* *9*(2508). doi: 10.3389/fpsyg.2018.02508	This study recruited 15 children and adolescents with either oncological or hematological disease and who were required to have a venipuncture twice in a year. Within-subject design. Quantitative.	Used a VR helmet and the Personal 3D Viewer Sony: HMZ T-2, which was supported by a laptop. The software chosen was SnowWorld, which was designed specifically to provide distraction during a painful procedure. This VR scenario requires the patient to use a mouse (with the hand not having the venipuncture) to throw snowballs at characters such as penguins and snowmen.	Pain was evaluated with a visual analog scale (VAS) and also based on "time spent thinking about pain", "pain unpleasantness", and "worst pain." The study also measured fun and nausea experienced during the procedure. The quality of the VR was only explored in the "Yes VR" group. Results with a *p* value <0.05 were considered significant.	The mean pain scores for "time spent thinking about pain" was 3.23 ± 2.98 in the "No VR" condition and 1.33 ± 1.05 in the "Yes VR" condition, (p <0.05). The mean pain score for "pain unpleasantness" was 3.27 ± 3.43 in the "No VR" condition and 0.93 ± 1.16 in the "Yes VR" condition ($p < 0.01$). The mean pain score for "worst pain" was 3.60 ± 3.00 in the "No VR" condition and 2.00 ± 1.20 in the "Yes VR" condition, ($p <$ 0.05).	Results from this study supports that virtual reality used during venipunctures has the ability to decrease pain levels in children and adolescents.

Atzori, B., Grotto, R. L., Giugni, A., Calabrò, M., Alhalabi, W., Hoffman, H. G. (2018). Virtual reality analgesia for pediatric dental patients. *Frontiers in Psychology, 9*(2265). doi: 10.3389/fpsyg.2018.02265	This study consisted of five patients with ages ranging between 7 to 17 years old who needed dental fillings or tooth extractions from the dentist during two separate visits at least one week apart Pilot study with proof-of-concept study using a within subject design. Quantitative.	This study used Oculus Rift DK2 and CV1 virtual goggles and a wireless mouse which allowed the patient to interact with the virtual environment while still keeping their head still during their dental procedure. The software SnowWorld was chosen.	Pain was evaluated based on "time spent thinking about pain", "pain unpleasantness", and "worst pain" using a questionnaire. The study also measured fun and nausea experienced during the procedure. The quality of the VR was only explored in the "Yes VR" group. Results with p <0.05, was considered significant.	The mean pain score for "pain unpleasantness" was 2.40 ± 1.52 in the "No VR" condition and 0.60 ± 0.55 in the "Yes VR" condition, (p < 0.05). The mean pain score for "worst pain" was 3.80 ± 2.59 in the "No VR" condition and 2.20 ± 1.79 in the "Yes VR" condition, (p < 0.05). The mean pain scores for "time spent thinking about pain" was 2.60 ± 1.95 in the "No VR" condition and 1.00 ± 1.00 in the "Yes VR" condition, (p = 0.08)	Results of this study provide support for VR effectiveness at distracting pediatric patients during dental procedures, thus decrease their levels of pain and increasing the amount of fun experienced during the procedures.

Liu. K. Y., Ninan,S. J., Laitman, B. M., Goldrich, D. Y., Iloreta, A. M., Londino, A. V. (2020). Virtual reality as distraction analgesia and anxiolysis for pediatric otolaryngology procedures. *The Laryngoscope*. doi: 10.1002/lary.29148	53 children and adolescents ages 7 to 17 who were to undergo an in-office flexible or rigid nasal endoscopy were recruited for this study. Randomized control trial. Quantitative.	Using a handheld control and Oculus Go VR googles, participants in the experimental group were immersed in a virtual environment software called SpaceBurgers where they have to shoot asteroids, French fries, and hamburgers that are flying towards them. This game was specifically designed to not require head and body movements, so they remained still during their procedure.	A 0 to 10 rating Wong-Baker FACES pain score, and a 0 to 100 rating Subjective Units of Distress (SUDS) anxiety score. Their caregivers answered questions about their opinion on how well their child's pain was managed and filled out a SUDS score. Both the participant and their caregivers filled out a seven-point Likert scale to give a procedure satisfaction score. A Childhood Emotional Manifestation Scale (CEMS) was filled out by the physician who completed the nasal endoscopy. A $p < 0.05$ was determined to be statistically significant	Patient's self-report of the Wong-Baker FACES scale was 0.80 ± 1.06 in the experimental group vs. 2.26 ± 2.38 in the control group, (p = .018). Patients self-report of anxiety on the SUDS scale was 9.50 ± 12.48 in the experimental group vs 38.48 ±29.83 in the control group, (p = 0.0002). The participants procedural satisfaction was 6.40 ± 0.77 in the experimental group vs. 4.74 ± 1.74 in the control group, (p = .0002). The CEMS score for the experimental group was 5.15 ± 0.46 vs. 9.64 ± 5.66 in the control group, (p = .0001).	This study provides evidence supporting the hypothesis that VR can be used to decrease pain and anxiety in children and adolescents when they must undergo a nasal endoscopy procedure.

Caruso, T. J., George, A., Menendez, M., De Souza, E., Khoury, M., Kist, M. N., Rodriguez, S. T. (2019). Virtual reality during pediatric vascular access: A pragmatic, prospective randomized, controlled trial. *Pediatric Anesthesia 30*(2), 116-123. doi: 10.1111/pan.13778	259 children ages 7 to 18 undergoing vascular access were enrolled in this study. Prospective randomized controlled trial. Quantitative.	This study used a Samsung GearVR headset that used a Samsung S7 or S8 mobile device. Three different VR experiences were used including Ocean Rift, Pebbles the Penguin, or Space Pups. Participants in the VR group received a brief explanation of how the game works before their procedure.	Pain was measured using the Faces Pain Scale-Revised (FPS-R). Fear was measured using the Child Fear Scale (CFS). A p value <.05 was deemed statistically significant.	There was no statistical significance in the difference in changes in procedural pain scores (increased, unchanged, or decreased) between the VR group and control group (p = 0.62). When comparing postprocedural pain between the two group, there also was no statistically significant difference (p = 0.59). Changes in fear scores between the VR and control groups, (p = 0.015) showing a statistically significant difference between the groups.	Unlike other studies completed similar to this one, this study shows no evidence supporting VR as a distraction intervention that decrease procedural pain in children and adolescents. It does however support its ability to decrease fear before and after a procedure.

Kipping, B., Rodger, S., Miller, K., Kimble, R. M. (2011). Virtual reality for acute pain reduction in adolescents undergoing burn wound care: A prospective randomized controlled trial. *Burns 38*(5), 650-657. doi: 10.1016/j.burns.2011.11.010	41 adolescents aged 11-17 undergoing burn dressing changes. Prospective randomized control trial. Quantitative.	Patients in the experimental group used the eMagin Z800 3DVisor head mounted display and a joystick to play Chicken Little (for ages 11-13 years old) or Need for speed (ages 14-17 years old).	Pain was measured using the VAS scale for participants self-report and the caregiver observations and Faces, Legs, Activity, Cry, Consolability (FLACC) scale was used by the nurses. The patient's heart rate and oxygenation were physiological measurements used alongside the scales.	The results of this study showed no statistically significant difference between the VR group and the control group on the VAS, or heart rate and oxygen saturation levels. The FLACC rating by nurses in the procedure showed a statistically significant difference in the pain levels of participants during the removal of their dressings, with those in the VR group showing less pain. 3 of 20 patients in the VR group and 9 of 21 in the control group required rescue doses of Entonox. Enough difference to show statistical significance.	While results from this study did not show a consistent statistically significance in difference of results of the two groups, it does support VR having some effect on lessening the pain levels felt but better results may be obtained in future studies that utilize more immersive and customizable VR equipment.

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Caruso, T. J., George, A., Menendez, M., De Souza, E., Khoury, M., Kist, M. N., Rodriguez, S. T. (2019). Virtual reality during pediatric vascular access: A pragmatic, prospective randomized, controlled trial. *Pediatric Anesthesia 30*(2), 116-123. doi: 10.1111/pan.13778

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