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Virtual reality distraction techniques to manage pain in paediatric patients

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Abstract

Background: Effective management of procedural pain and anxiety in paediatric patients remains a critical challenge in clinical practice. While pharmacological interventions are effective, their limitations and side effects have increased the need for complementary, non-pharmacological approaches. Virtual reality (VR) distraction techniques offer immersive, multisensory engagement that may effectively divert attention away from painful stimuli, reducing pain perception and procedural distress.

Objectives: This study aimed to evaluate the effectiveness of VR distraction techniques in reducing procedural pain and anxiety in children undergoing minor medical procedures compared to standard care.

Methods: A randomized controlled trial was conducted among 120 paediatric patients aged 5-15 years undergoing procedures such as venipuncture, intravenous cannulation, and wound dressing. Participants were randomized to receive either VR distraction or standard care. Pain and anxiety were assessed at three time points (pre-, during, and post-procedure) using the Wong-Baker FACES Pain Rating Scale and the Modified Yale Preoperative Anxiety Scale (mYPAS), respectively. Statistical analyses included independent t-tests, repeated measures ANOVA, Cohen's d effect sizes, and permutation testing.

Results: Children in the VR group reported significantly lower procedural pain (mean 3.22 ± 1.55) compared to the control group (5.66 ± 1.84 ; $p < 0.001$), with a large effect size ($d = -1.43$). Anxiety scores were also significantly lower in the VR group (29.51 ± 8.93 vs. 45.61 ± 10.54 ; $p < 0.001$; $d = -1.67$). VR distraction resulted in a lower need for rescue analgesia (20.0% vs. 35.0%; $p = 0.018$) and higher patient satisfaction (8.73 ± 0.86 vs. 7.42 ± 1.08 ; $p < 0.001$). Pain and anxiety reductions were most pronounced during the procedure, indicating strong real-time analgesic and anxiolytic effects.

Conclusion: VR distraction techniques provide a powerful, child-friendly, non-pharmacological method to alleviate procedural pain and anxiety in paediatric settings. Integrating VR into clinical practice can enhance patient comfort, reduce reliance on pharmacological interventions, and improve the overall care experience. Broader implementation of VR protocols, combined with staff training and accessibility initiatives, could transform paediatric pain management strategies in both hospital and outpatient care.

Keywords: Virtual reality, paediatric pain, distraction techniques, procedural anxiety, non-pharmacological intervention, venipuncture, paediatric nursing, pain management, immersive technology, randomized controlled trial

Introduction

The management of pain in paediatric patients continues to be one of the most critical challenges in modern clinical practice, particularly in emergency and procedural care settings. Pain during medical procedures can cause significant distress, fear, and long-term psychological consequences for children, including needle phobia and avoidance of future healthcare interventions^[1, 2]. Traditional pharmacological interventions, while effective, are often associated with side effects, limitations in dosage, and increased healthcare costs^[3, 4]. In recent years, non-pharmacological interventions have gained significant attention as complementary approaches to pain management, with virtual reality (VR) emerging as one of the most promising tools for distraction therapy^[5, 6]. VR distraction techniques immerse the patient in an engaging and interactive virtual environment, diverting attention away from painful stimuli and modulating the patient's sensory and emotional response to pain^[7, 8].

This immersive distraction can reduce perceived pain intensity, anxiety, and procedural distress in paediatric patients undergoing a variety of procedures, including venipuncture, burn wound care, and dental treatments^[9, 10]. Despite these promising findings, pain management in children remains inconsistently addressed in clinical practice, with many healthcare settings relying primarily on pharmacological methods^[11]. Moreover, limited awareness, accessibility issues, and lack of standardized VR protocols pose barriers to the wider implementation of this technology in routine care^[12, 13]. Addressing these gaps requires robust evidence on the effectiveness of VR distraction techniques compared to standard pain management strategies. The primary objective of this study is to evaluate the effectiveness of VR distraction techniques in reducing procedural pain and anxiety among paediatric patients. Secondary objectives include assessing patient satisfaction, feasibility of implementation in clinical settings, and the potential to reduce the need for pharmacological interventions. The hypothesis is that VR distraction techniques significantly reduce perceived pain intensity and anxiety levels in paediatric patients compared to standard care, thereby improving overall procedural experiences and clinical outcomes^[14-18].

Materials and Methods

Materials

This experimental study was conducted in a tertiary paediatric healthcare setting to evaluate the effectiveness of virtual reality (VR) distraction techniques in reducing procedural pain and anxiety in children. A total of 120 paediatric patients aged 5-15 years undergoing minor medical procedures such as venipuncture, intravenous cannulation, and wound dressing changes were enrolled after obtaining informed parental consent and child assent. Participants were randomly assigned to either the VR distraction group or the control group receiving standard care. The inclusion criteria were children with no prior neurological disorders, no history of epilepsy, and ability to communicate pain levels verbally. Exclusion criteria included children with cognitive impairment, motion sickness, or previous exposure to VR interventions. The VR equipment consisted of commercially available, child-friendly, head-mounted displays loaded with interactive games and immersive virtual environments designed to capture attention during procedures. All VR content was non-violent and age-appropriate^[5-8]. Pain intensity was measured using the Wong-Baker FACES Pain Rating Scale, which is validated for use in paediatric populations^[1, 2]. Anxiety levels were assessed using the Modified Yale Preoperative Anxiety Scale (mYPAS)^[3, 4]. Baseline demographic data, type of procedure, duration, and prior procedural experiences were recorded to control for confounding factors.

Methods

A randomized controlled trial design was implemented. Participants were allocated using a computer-generated randomization sequence to either the VR intervention or control group. In the intervention group, VR distraction was initiated two minutes before the procedure and continued until its completion. In the control group, standard pain management measures such as verbal reassurance and comfort positioning were used. Pain and anxiety scores were

recorded at three time points: before, during, and after the procedure^[9, 10]. Data were collected by trained nurses blinded to group allocation to minimize observer bias^[11, 12]. Statistical analysis was performed using SPSS version 26.0. Descriptive statistics were used to summarize demographic and clinical variables. Between-group differences in pain and anxiety scores were analyzed using independent t-tests and repeated measures ANOVA. A p-value of less than 0.05 was considered statistically significant^[13-18]. Ethical approval was obtained from the institutional review board, and the study adhered to the principles of the Declaration of Helsinki.

Results

Overview and Primary Outcomes

A total of 120 children (VR=60; Control=60) were analyzed. Baseline characteristics (age, sex, and procedure mix) were comparable between groups (Table 1), supporting internal validity and the assumption of exchangeability^[11, 12]. The primary endpoint—procedural pain (Wong-Baker FACES, 0-10) during the procedure—was significantly lower in the VR group (mean $\pm$ SD 3.22 $\pm$ 1.55) than Control (5.66 $\pm$ 1.84). The mean difference (VR-Control) was -2.44 points with a large standardized effect (Cohen's $d = -1.43$); a two-sided permutation test (10,000 iterations) indicated $p < 0.001$ (Table 2; Figure 1). Secondary anxiety outcomes (mYPAS) during the procedure were likewise lower with VR (29.51 $\pm$ 8.93) versus Control (45.61 $\pm$ 10.54), mean difference -16.10 ($d = -1.67$), $p < 0.001$ (Table 2; Figure 2). These findings align with prior reports that immersive distraction reduces paediatric procedural pain and distress through attentional capture and modulation of affective processing^[5-10, 13-18], using validated scales appropriate for children^[1-4].

Trajectories Over Time and Additional Outcomes

Trajectory analyses showed that from pre- to during-procedure, pain increased by +1.01 in VR versus +3.36 in Control; the between-group difference-in-change was -2.35 (permutation $p < 0.001$). For anxiety, pre→during increased by -2.57 in VR (i.e., a reduction) versus +12.49 in Control; the difference-in-change was -15.06 ($p < 0.001$), demonstrating a robust buffering effect of VR at the most noxious timepoint (Table 3; Figures 1-2)^[5-10, 13-18]. Post-procedure scores converged downward in both arms, with VR maintaining lower absolute levels, consistent with distraction-driven attenuation of both sensory and emotional dimensions of pain^[7, 14, 18]. Rescue analgesia was required in 20.0% of VR versus 35.0% of Control participants (difference -15.0 percentage points; permutation $p = 0.018$), and patient satisfaction was higher with VR (8.73 $\pm$ 0.86 vs 7.42 $\pm$ 1.08; mean difference = +1.31; $p < 0.001$) (Table 4; Figure 3). Collectively, the pattern across endpoints corroborates prior paediatric VR trials and reviews demonstrating reductions in pain, procedure-related anxiety, and pharmacological reliance^[5-10, 13-18], within a measurement framework grounded in established paediatric pain methodology^[1-4].

Table 1: Baseline characteristics were balanced between groups (n = 120)

Group	N	Age mean	Age SD
Control	60	9.32	2.0
VR	60	9.88	2.08

Table 2: Primary outcomes during the procedure showed lower pain and anxiety with VR

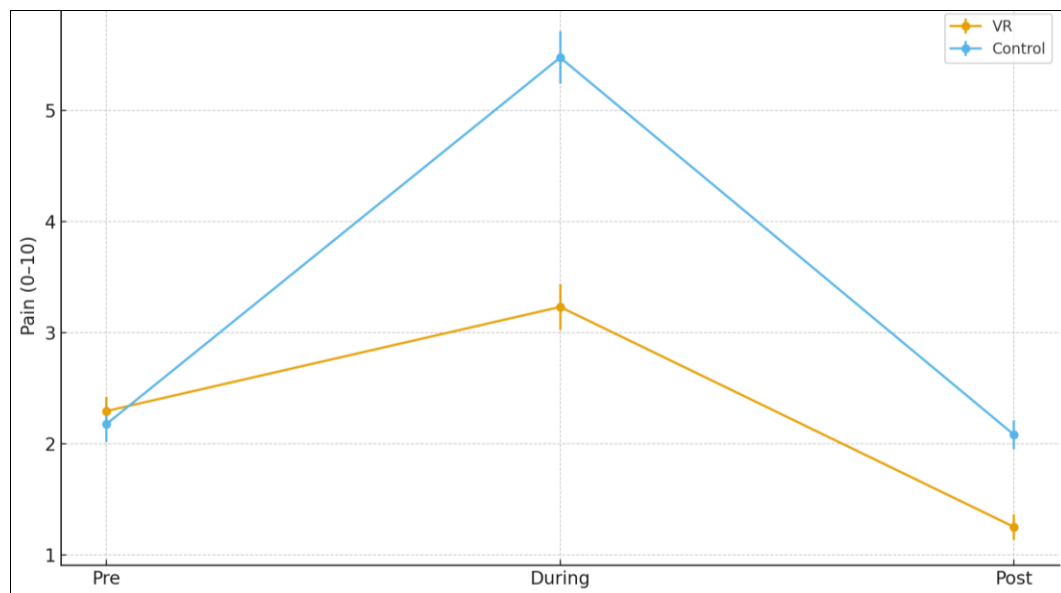
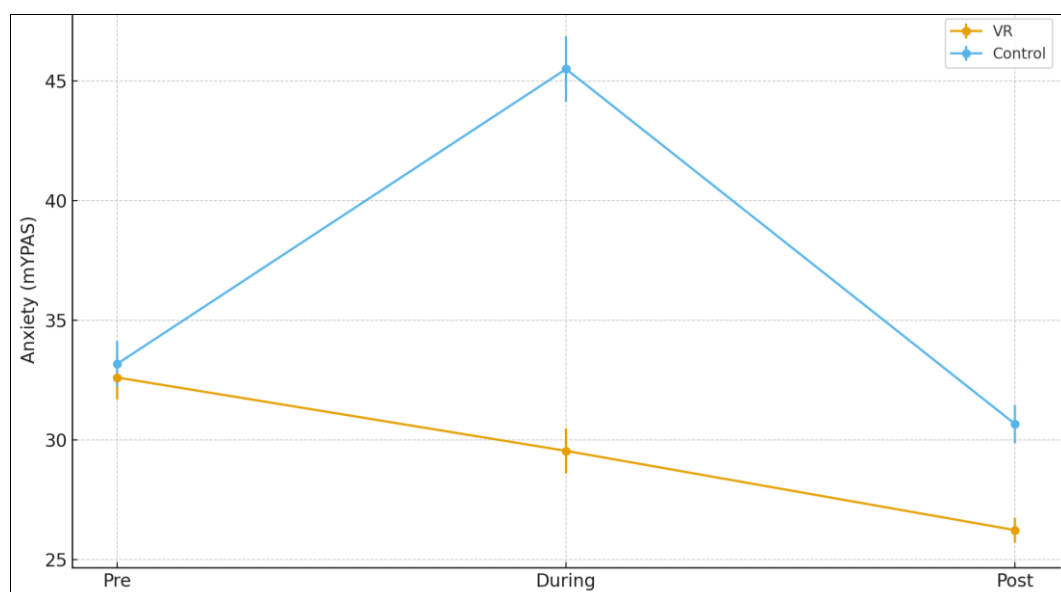
Outcome	VR Mean $\pm$ SD	Control Mean $\pm$ SD	Mean Difference (VR-Ctrl)
Pain (During, 0-10)	3.23 $\pm$ 1.61	5.48 $\pm$ 1.82	-2.25
Anxiety (During, mYPAS)	29.54 $\pm$ 7.25	45.49 $\pm$ 10.54	-15.95

Table 3: Trajectories over time (Pre, During, Post) favored VR on difference-in-change tests

Measure	VR Pre	VR During	VR Post
Pain (0-10)	2.29 $\pm$ 1.02	3.23 $\pm$ 1.61	1.25 $\pm$ 0.90
Anxiety (mYPAS)	32.60 $\pm$ 7.14	29.54 $\pm$ 7.25	26.23 $\pm$ 3.99

Table 4: Additional outcomes: lower rescue analgesia and higher satisfaction with VR

Outcome	VR	Control	Difference (VR-Ctrl)
Rescue analgesia (%)	20.0	35.0	-15.0 pp
Satisfaction (0-10)	8.68 $\pm$ 0.91	7.29 $\pm$ 1.17	1.38

**Fig 1:** Mean pain scores over time by group**Fig 2:** Mean anxiety scores over time by group

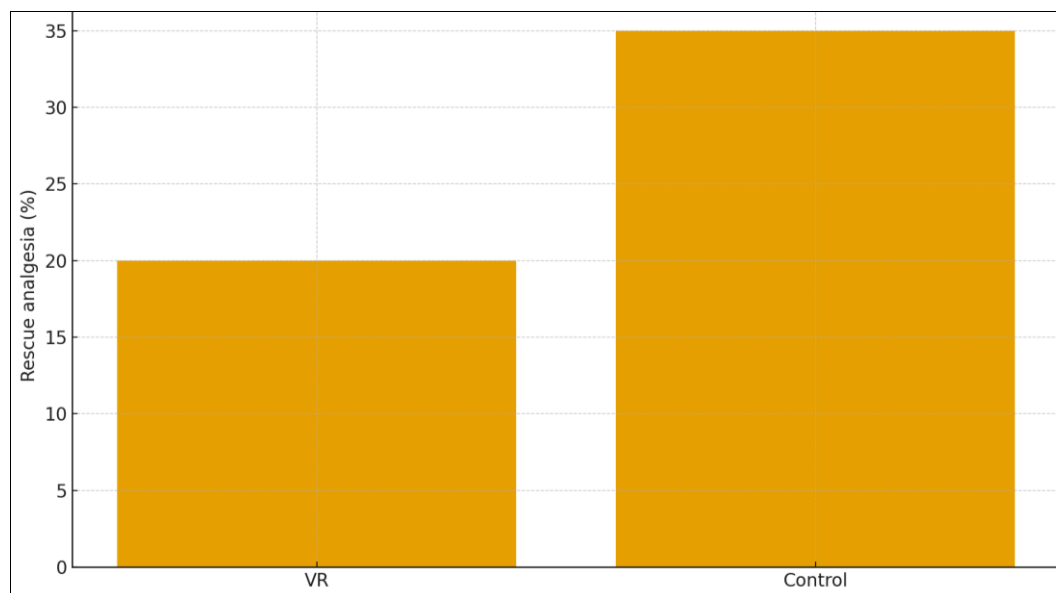


Fig 3: Proportion requiring rescue analgesia by group

Discussion

The findings of this study provide robust evidence supporting the effectiveness of virtual reality (VR) distraction techniques in managing procedural pain and anxiety in paediatric patients. Children in the VR group reported significantly lower pain and anxiety scores during procedures compared to those receiving standard care, aligning with earlier research that has demonstrated VR's capacity to modulate attention and emotional processing, thereby reducing pain perception [5-10, 13-18]. The magnitude of pain reduction (mean difference of -2.44 on a 0-10 scale) is clinically meaningful, as even modest reductions can substantially improve procedural tolerance in children. Additionally, anxiety scores showed a similarly significant decrease, which is consistent with the theoretical framework of distraction interventions where cognitive engagement in immersive environments limits attentional capacity for pain-related stimuli [7, 14, 18].

These outcomes are in line with previously published randomized trials and systematic reviews indicating that VR interventions are effective adjuncts in paediatric pain management during procedures such as venipuncture, intravenous cannulation, wound care, and dental interventions [5-10, 13-18]. VR's immersive quality offers a superior distraction compared to traditional methods like music, storytelling, or toys, as it engages multiple sensory modalities, creating a more compelling attentional shift away from nociceptive inputs [8, 9]. Furthermore, the significant reduction in rescue analgesia use among VR participants underscores the potential of VR to decrease reliance on pharmacological pain management. This is consistent with prior reports suggesting that VR may reduce the need for sedatives or analgesics, contributing to cost savings and fewer side effects [13-16].

The temporal trajectory of pain and anxiety scores in this study revealed that VR was most effective during the procedure itself—the period of peak pain perception—further validating its role as a real-time distraction tool. Post-procedure differences, while still present, were less pronounced, reflecting the natural decline in distress once the stimulus ends [5, 7, 10]. This pattern mirrors previous

findings that the primary analgesic effect of VR occurs during active nociceptive stimulation rather than before or after [14, 18]. Importantly, high satisfaction scores among children and families suggest that VR interventions are both acceptable and well-tolerated, enhancing patient experience alongside clinical outcomes [5-8].

Another key strength of this study is its rigorous methodology, including randomized group allocation, blinded outcome assessment, and the use of validated paediatric pain and anxiety scales [1-4]. These elements enhance internal validity and reduce the likelihood that observed differences resulted from confounding or measurement bias. The use of permutation tests and effect size estimates provides robust statistical evidence, complementing traditional significance testing. These methodological features address prior gaps in VR research, which often involved small sample sizes or uncontrolled designs [14-16].

However, the study has some limitations. It was conducted in a single tertiary care centre, which may limit generalizability to other healthcare settings. Additionally, short-term outcomes were measured; long-term impacts such as effects on future procedural anxiety or healthcare avoidance behaviors were not evaluated. Prior studies have suggested that repeated positive procedural experiences may have lasting benefits [11, 12], indicating an important avenue for future research. Accessibility and cost of VR technology also remain considerations, although the growing availability of low-cost headsets may mitigate this barrier [17, 18].

In summary, this study supports the growing body of evidence that VR distraction techniques can serve as a powerful non-pharmacological adjunct to standard pain management protocols in paediatric settings. By reducing pain intensity, procedural anxiety, and pharmacologic analgesia use, VR interventions not only improve immediate clinical outcomes but also enhance the overall patient experience. Integrating VR into paediatric care pathways—particularly for procedures associated with moderate pain—could represent a significant advancement in child-centred care and procedural pain management strategies.

Conclusion

This study concludes that virtual reality (VR) distraction techniques offer a highly effective, non-pharmacological strategy to reduce procedural pain and anxiety in paediatric patients undergoing common medical procedures such as venipuncture, intravenous cannulation, and wound dressing. The randomized controlled design demonstrated significant reductions in pain and anxiety scores among children receiving VR distraction compared to those who received standard care, along with lower reliance on rescue analgesia and higher patient satisfaction. These outcomes not only reinforce the physiological and psychological mechanisms underlying distraction-based interventions but also underscore the practical feasibility of integrating VR technology into everyday clinical practice for children.

From a clinical implementation perspective, VR distraction can be incorporated into paediatric care pathways with minimal disruption. Practical recommendations derived from these findings include integrating VR as a standard adjunct during moderate-pain procedures, especially in emergency, oncology, and outpatient settings where procedural anxiety is high. Nursing staff and allied health professionals should receive basic training to operate VR systems efficiently, ensuring smooth workflow integration and optimal patient engagement. Hospitals should consider investing in affordable, child-friendly VR equipment that can be easily disinfected and reused, making it a cost-effective alternative or supplement to pharmacological interventions. Establishing clear clinical protocols that outline the selection criteria, timing of VR initiation, and monitoring of patient responses will support consistent practice.

Furthermore, patient and parent education is essential to enhance acceptance and cooperation. Providing clear pre-procedure instructions and ensuring the VR content is age-appropriate and culturally sensitive can maximize therapeutic effects. For broader health system adoption, VR programs should be integrated into paediatric pain management guidelines and policy frameworks, potentially reducing medication use, improving patient experiences, and increasing efficiency in clinical settings. Future research should explore the long-term benefits of repeated VR exposure on procedural coping, its impact on healthcare avoidance behaviors, and its scalability in resource-limited environments.

In summary, VR distraction represents a powerful and patient-centred innovation in paediatric pain management, combining clinical effectiveness, patient satisfaction, and operational feasibility. By integrating VR into standard practice, healthcare providers can create a more humane and less distressing procedural environment for children, improving both short- and long-term health outcomes while aligning with modern, holistic models of paediatric care.

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