Special Interest Group on Pain in Childhood
INTERNATIONAL ASSOCIATION FOR THE STUDY OF PAIN

Pediatric Pain Letter
Commentaries on pain in infants, children, and adolescents

February 2026 **Vol. 28 No. 1** **https://pediatric-pain-letter.org/**

Editor: Abbie L. Jordan, PhD, a.l.jordan@bath.ac.uk

Commentary

Pathways to Immersive Healing: Exploring the Mechanisms of Virtual Reality for Pediatric Chronic Pain Management

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Emerging evidence supports virtual reality (VR) as a tool for management of acute and chronic pain (Ding et al., 2025), but limited literature exists specifically for VR applications for pediatric chronic pain (Hess et al., 2025). Children and adolescents have unique physical and cognitive developmental needs that must be addressed in addition to their pain experiences. Because youth with chronic pain face social, academic, medical, and even familial barriers that are distinct from those with acute pain conditions, proven VR techniques for acute pain may not be directly translatable. It is therefore important to elucidate VR mechanisms that target the unique needs of youth living with chronic pain and promote engagement in rehabilitation-focused pain interventions, such as physical therapy, occupational therapy, cognitive behavioral therapy, and mind-body techniques, among others.

Herein, we aim to describe the different potential mechanisms of action of VR for pediatric chronic pain and identify promising areas for further research. To inform this commentary, we reviewed literature published since 2017, emphasizing systematic reviews outlining VR applications for chronic pain management. Given the limited pediatric-specific literature on chronic pain, studies with pediatric or lifespan populations were included. We focused on evidence supporting various uses of VR in pediatric chronic pain rehabilitation and the efficacious promise of this technology. Through this review we classified five significant categories of VR applications for pediatric chronic pain management including: (1) movement promotion; (2) distraction to facilitate engaging in difficult treatments; (3) use of illusion/embodiment; (4) exposure to reduce fear of pain and behavioral avoidance; (5) relaxation skill coaching, without or without a biofeedback component.

Movement Promotion

Movement promotion is a central treatment goal in chronic pain rehabilitation, aiming to improve daily functional movement and reduce maladaptive activity/inactivity patterns. It typically involves graded reintroduction of activities that patients previously found most challenging or pain-provoking (O'Sullivan et al., 2015). Specifically, intensive interdisciplinary pain treatment (IIPT) programs for pediatric chronic pain populations offer patients targeted functional restoration-focused, graded activities with a team of physical, occupational, and recreational therapists, as well as psychologists, that help restore long-term physical functional and psychosocial goals (Harrison et al., 2019; Seth et al., 2025). Movement promotion in IIPT has been linked with psychosocial benefits such as improved self-efficacy, reduced fear of physical activity, and improved anxiety and depression (Giertych et al., 2025; Harrison et al., 2019; O'Sullivan et al., 2015).

The translation of movement promotion activities into VR experiences includes immersive games that target desired movements, including those developed specifically for pain patients

(Griffin et al., 2020) and commercial games used in physical therapy (see Table 1). In their pilot study of a clinical VR program ("Fruity Feet") designed specifically for pediatric patients with chronic extremity pain conditions, Griffin and colleagues (2020) found that after interacting with the VR tool, patients reported high levels of immersion and significantly decreased pain, avoidance, and functional limitations. Most interestingly, patients also reported increased distraction from their pain during VR. Other movement-based VR studies have demonstrated similar results (Chau et al., 2020; Meyns et al., 2017; Saby et al., 2024), illustrating the promise VR holds as a tool to facilitate functionally restorative movement for pediatric chronic pain patients.

Distraction

Distraction-based techniques have been used for both adult and pediatric pain treatment by stimulating cognitive activities like memory tasks, interactive play, music, and more. These tools are proven to reduce pain intensity and distress and promote improved physiologic arousal (Asefi Rad & Wippert, 2024; Bukola & Paula, 2017). Distraction in a VR setting involves allocating one's cognitive and attentional capacity to the VR stimuli, thereby reducing pain perception and sensitivity as the brain is competitively diverted from processing pain signals and toward the immersive and engaging tool (Trost et al., 2021). Notably, distraction is believed to drive the effectiveness of acute VR interventions, facilitating outcomes such as reduced procedural and burn-injury pain, decreased chemotherapy-related symptoms, and improved emotional well-being during painful procedures and hospitalizations (Indovina et al., 2018; Trost et al., 2021).

VR-based distraction techniques have also been used to facilitate engagement in difficult treatments for pediatric patients experiencing chronic pain. What makes distraction techniques especially interesting in chronic pain is that they are often embedded as a secondary effect into VR games with a different primary focus, such as movement promotion games (Griffin et al., 2020), and in exposure therapy (Huang et al., 2022). Therefore, distraction is a tool that allows patients to engage in activities that require focusing attention on something other than their pain, such as moving the affected body part or focusing on a relaxing guided virtual meditation while tolerating weight-bearing for lower extremity pain. Although not necessarily always the explicit focus, many commercially available VR games provide distraction that can be leveraged to facilitate patient engagement in painful and/or anxiety-provoking therapeutic tasks (see Table 1).

Virtual Embodiment

Embodiment can be defined as the combined sense of having a body and being a body, which is tied to self-identity (Lundh & Foster, 2024). The experience of embodiment includes senses of agency, body ownership, and self-location (Guy et al., 2023). Notably, embodiment has been previously targeted through graded motor imagery (GMI) technology and mirror therapy (MT), such as having a patient observe their unaffected limb moving in a mirror, thereby producing the perception of the unaffected limb replacing the injured one. Limited results indicate that this therapy may improve pain and function by reorganizing cortical networks. Specifically, the MT component is hypothesized to provide a visual illusion of pain-free movement in response to cortical activation via GMI technology (Méndez-Rebolledo et al., 2017).

A small literature also suggests that experiencing embodiment through VR may have long-term, site-specific analgesic effects when observing one's own body through a virtual avatar lens (Matamala-Gomez et al., 2019). Embodiment is a promising tool for adults experiencing chronic pain, as a recent pilot study found virtual embodiment may improve perceived disability and helplessness (Saby et al., 2024). While pediatric-specific embodiment studies are scant, many with insufficient sample sizes and unstandardized methods (Felnhofer & Weiss, 2023; Shahrbanian et al., 2009), research suggests children may be more susceptible to virtual environments than adults (Won et al., 2017). This is further supported by literature on neuroplasticity in youth where specific brain regions supporting executive, social, and emotional functions are highly responsive and malleable to external influences and shape later behavior (Kolb & Gibb, 2011). This heightened period of suggestibility may therefore

amplify the impact of embodied experiences and environmental exposures of pediatric populations as compared to other age groups. Therefore, the apparent success in adult patients suggests further research into pediatric patients is warranted.

Exposure to Reduce Fear of Pain

Exposure therapy is a widely established treatment for improving avoidance behaviors and functional limitations, including in the chronic pain context. One study found that graded in-vivo exposure treatment significantly improved pain-related fears, avoidance behaviors, and pain acceptance (Simons et al., 2019). Virtual reality exposure therapy (VRET) is also an effective treatment for phobias, including agoraphobia and arachnophobia, anxiety-related disorders, and even PTSD (Carl et al., 2019; Parsons & Rizzo, 2008). In adult chronic pain patients, Trost et al. (2014, 2015) first applied VRET to facilitate movement associated with increased pain and avoidance behaviors, demonstrating the powerful benefit of exposure therapy in chronic pain management.

In researching VRET for pediatric populations, our findings demonstrate limited and conflicting results. One systematic review and meta-analysis of thirty-one trials examining the effectiveness of VR for pain management in different age groups found that VRET was effective at alleviating acute pain, lowering anxiety levels, and decreasing pulse rate, compared to a standard-care control group. However, we found only one study of pediatric chronic pain comparing VRET to a control condition, and this study found no group difference in increased pain tolerance (Huang et al., 2022). Not only does the lack of chronic pain studies limit the generalizability of findings, but so does the small sample size and unclear risk of bias noted by the authors, specifically selection and detection bias. Given this study did find youth were more attracted to and interested in VR technology, there needs to be more clinical research conducted on the effectiveness of VRET for a wide range of pediatric chronic pain patients.

Relaxation Skill Coaching With and Without Biofeedback

Relaxation skills include meditation, progressive muscle relaxation, diaphragmatic breathing, and guided imagery, among others. Relaxation skill coaching is efficacious and commonly used in treatment for anxiety disorders (Manzoni et al., 2008) and has increasingly become a common intervention for pain management (Vambheim et al., 2021). Specifically, within chronic pain, relaxation skill coaching is thought to significantly reduce psychological and physical stress on the body and improve secondary outcomes, including anxiety and depression, well-being, and effective coping (Vambheim et al., 2021). The impact of relaxation skill coaching for chronic pain patients can also be measured and amplified through biofeedback. Incorporating feedback on the physiological changes they experienced during relaxation (e.g., heart rate, respiration, etc.) allows patients to self-regulate their physiological responses to pain and stress.

Relaxation skill coaching has also been effectively utilized as a VR mechanism for acute and chronic pain management, with and without biofeedback technology (Ahmadpour et al., 2019; Calderone et al., 2025; Eijlers et al., 2019). While a limited number of small clinical studies have examined its effect on pediatric chronic pain, emerging results are promising and demonstrate VR relaxation/biofeedback mechanisms are efficacious in reducing pain and stress in pediatric populations (Ahmadpour et al., 2019; Recker et al., 2025; Wong et al., 2022). There are a number of commercially available VR games for relaxation that provide immersive, calming environments (see Table 1). Given the encouraging early findings, researchers should focus on conducting larger, well-controlled trials of VR-based relaxation skill coaching. Further, comparative studies would be helpful for determining whether the addition of biofeedback enhances VR-based relaxation training outcomes.

Table 1. Examples of Commercially Available VR Games That Can Be Useful for Chronic Pain Treatment

Game Title	Platform	Mechanism of Effect	Applications
Fruit Ninja VR	Meta Quest	Movement	Arm swinging to slice fruit flying through the air
Beat Saber		Movement	Use lightsabers to hit blocks to the beat of music
Walkabout Mini Golf VR	Meta Quest	Movement	Gentle reaching and walking playing mini golf in a virtual world
Job Simulator	Meta Quest	Movement	Participants pretend to work in jobs that engage them in standing, reaching and grabbing
Open Brush	Meta Quest	Movement	Big arm movements with painting and drawing
Elixir	Meta Quest	Movement	Participants Mix magic potions with their arms
Dance Central VR	Meta Quest	Movement	Participant dance movements on the screen
Carnival Games VR: Alley Adventure	Carnival Gams VR	Movement	Light exercise that improves hand-eye coordination and upper-body movement
Angry Birds VR: Isle of Pigs	Angry Birds VR; Meta Quest	Movement	Builds arm strength and range of motion
Gorilla Tag	Meta Quest	Movement	Arm swinging and climbing while playing tag with others
VR Masterchef Junior	Walmart VR; Meta Quest	Movement	Arm movement and coordination through VR cooking
OhShape	Meta Quest; OhShape	Movement	Full body stretching and flexibility through body shape matching
PowerBeats VR	Steam PowerBeats VR	Movement	Aerobic movement following rhythm with music
Nature Treks VR	Meta Quest	Relaxation	Exploration of nature scenes like beaches and forests
Color Space	Meta Quest	Movement; Relaxation	Participants use their hands to paint through slow, relaxing movements
Wander	Meta Quest	Distraction	Travel around the world through VR using Google Street View
Google Earth VR	Google VR	Distraction	Travel around the world through VR using Google Earth
Minecraft	Vivecraft	Distraction	Engaging VR Game
Guided Mediation VR	Guided Meditation VR	Distraction; Relaxation	Calming meditation
The Lab	Steam	Movement; Distraction	Exploration game with different engaging activities
The Blu	Steam	Distraction	Cinematic exploration game

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Conclusion

VR is a promising alternative or adjunct to pharmacological therapies for pediatric chronic pain treatment, with multiple potential mechanisms of effect. When selecting the type of VR to use for pediatric chronic pain management, it is important to consider the clinical outcomes associated with each VR application. For example, movement promotion can improve physical functioning and work in tandem with distraction applications to redirect attention away from pain, aiding in decreased pain and improved emotional well-being. Similarly, embodiment-based interventions may be associated with pain reduction and improved perceived disability via reorganization of cortical networks. Lastly, while data is limited, VR exposure therapy can target pain-related fear and avoidance, while relaxation skill coaching may help with pain and stress reduction and enhance coping.

Although the current literature is promising, the research base is small, with variable results to date. As such, we lack strong, specific evidence for VR's effects in pediatric chronic pain management. Our exploration suggests the need for larger, well-controlled trials with standardized measures to thoroughly evaluate the effects of the multiple potential mechanisms of VR for pediatric chronic pain management. There is also a need for further investigation into the long-term outcomes of these VR mechanisms, especially those that improve functional limitations and reduce overall fear of pain, as seen most notably with movement and exposure-based VR mechanisms.

While there are many potential beneficial outcomes associated with VR-based therapies that warrant further investigation, researchers must also address potential risks or contraindications associated with VR use in pediatric populations. Literature examining the safety of virtual reality use in children suggests VR use may be associated with cybersickness symptoms, including dizziness and nausea, and increased anxiety and discomfort (Bexson et al., 2024); Caruso et al., 2020; Goldsworthy et al., 2023). However, overall, the symptoms appear to be rare and exposure dependent. Therefore, pre-existing conditions must be considered, with explicit exclusion criteria, and an emphasis on clinician or caregiver monitoring must be included in all clinical or commercial instruction.

Additionally, while VR interventions have become increasingly accessible clinically and commercially, there are still barriers to clinical uptake, that limit VR's accessibility and feasibility for pediatric chronic pain patients. Notably, a recent study found clinician-reported knowledge gaps of VR and inadequate training for clinical uptake of VR, technological malfunctions, and financial restrictions. These barriers were associated with clinicians' lack of motivation to adopt VR technology in clinical settings (Felnhofer et al., 2025). Therefore, in addition to the need for further research, further effort is needed to make utilization of this immersive technology more accessible to pediatric chronic pain treatment providers. Lastly, in addition to understanding clinician experiences, it is crucial to incorporate patient and parent perspectives to inform the feasible and effective use of VR tools for pediatric chronic pain management.

Acknowledgements: The authors acknowledge the assistance of Tina Afshari, B.A., who compiled the information included in Table 1.

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