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Exploring the Use of Virtual Reality in Pediatric Physical Therapy: Enhancing Motor Skills, Engagement, and Rehabilitation Outcomes

Ahmed Hussein Mashaal
Assistant Professor, Physical Therapy Department, Applied Medical Science Faculty, Irbid University, Jordan;
drahmedmashaal@gmail.com

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Abstract:
This research explores the application of virtual reality (VR) in pediatric physical therapy, focusing on its potential to enhance motor skills, engagement, and rehabilitation outcomes for children with disabilities and injuries. VR offers an immersive, interactive environment that can motivate children and accommodate various learning styles, making rehabilitation sessions more engaging and effective. The paper reviews theoretical frameworks supporting VR use in therapy, highlighting its benefits in improving functional motor and cognitive outcomes. Case studies and research findings demonstrate VR's efficacy in enhancing motor skills across different pediatric populations, with specific examples illustrating significant improvements in balance, coordination, and confidence. The paper also discusses engagement strategies, such as gamification and tailored VR environments, to maintain motivation and ensure therapeutic success. Future directions include advancements in VR technology, such as improved optics, haptic feedback, and AI integration, to create more personalized and effective therapy experiences. This study underscores the potential of VR to revolutionize pediatric physical therapy, offering innovative solutions to improve rehabilitation outcomes for children.
Keywords: Virtual Reality (VR), Pediatric Physical Therapy, Motor Skills, Engagement, Rehabilitation Outcomes

1. Introduction to Virtual Reality in Pediatric Physical Therapy

This paper explores the use of virtual reality (VR) in pediatric physical therapy for the rehabilitation of children with disabilities and injuries requiring the development of motor skills. The paper begins by introducing VR as transformative to the pediatric physical therapy field. Engaging children in rehabilitation sessions can be difficult but is necessary to improve rehabilitation outcomes **(Di et al., 2020).** VR environments offer a full sensory experience that can motivate children to leave the real world and accommodate all the different learning styles. Traditional rehabilitation methods can become boring, especially for kids; however, new technologies, including VR, are making the rehabilitation process an interactive and exciting learning experience **(Marougkas et al., 2023).**

Technology development and progression have made it possible for VR to be more realistic than ever before, with high-definition head-mounted displays and 360-degree sound that make the VR environment feel real. VR headsets have been successfully used to help stimulate the learning of motor skills and muscle control in both healthy adults and stroke patients. Kids are a critical group that the technology industry has a natural focus on, as well as the physical therapy community **(Demers et al., 2021).** Children who are still growing, learning, and developing can benefit from any use of technology, especially when it relates to learning and developing new abilities and skills. Extensive research has already been conducted on the use of VR and motor learning in adults; therefore, this paper explores what technology and

methods are already used to encourage and improve the rehabilitation outcomes of children with disabilities and looks into where this research is currently headed **(Kim et al., 2020).**

2. Theoretical Frameworks and Benefits of Virtual Reality in Pediatric Physical Therapy

Virtual reality (VR) has been studied quite extensively, and there are a number of theoretical frameworks that could support the use of VR as a tool in pediatric physical therapy. VR is based on many of the principles of experiential learning, in that a therapist would set up an opportunity for someone to engage in the experience, typically with some instruction, and then reflect on that experience with the therapist **(Pereira et al., 2020).** Engagement in the experience is key because a person won't necessarily benefit cognitively or socially if they are not engaged in the activity. Several studies have suggested that VR is an engaging medium for children, both from physical and cognitive perspectives. VR can improve functional skills and is useful in rehabilitation and fitness exercise programs designed for adolescents **(Tarakci et al., 2020).**

Using virtual reality (VR) in pediatric physical therapy practice can have many potential benefits. VR significantly improves functional motor and cognitive outcomes in children. Movement is a foundation of human experience; we often interact with the world through movement. The type and quality of movement are also linked to various body functions like vision, understanding, emotion, learning, and sensory functions. Children can practice movement within a controlled and safe environment, and a therapist can manipulate rules and dynamics within the virtual world to change the level of difficulty of an activity, or the therapist can change the speed or accuracy required, allow for concealed function training, and educate and motivate participation **(Haverkamp et al.2020).**

In addition, VR can calm anxiety and increase motivation and enjoyment during physical therapy. It is also fantastic that the therapist gives feedback, interacts, and works together with the patient in the VR world. Through the proposed information, virtual reality offers a vision and inspiration that this assumption has the potential to develop. Virtual reality is clearly related to a theoretical framework in pediatric physical therapy for assessment and treatment of children in pediatric practice **(Zhang et al., 2021).**

3. Case Studies and Research Findings on the Efficacy of Virtual Reality in Enhancing Motor Skills

Since 1988, virtual reality (VR) technology has been used for rehabilitation in the adult population due to its capacity to simulate broad participation, especially in patients with physical disabilities. The aim of this study was to discuss some of the recent research in pediatric physical therapy that has investigated VR with a focus on motor skills. In total, five case studies and four research studies contribute to this discussion. The case study scenarios presented in the first half of the discussion are designed to illustrate to the reader a variety of ways VR can be used in a therapeutic setting and with a diverse patient population, while focusing on motor skill outcomes **(Liu et al., 2022).**

The research articles presented in the second half of the discussion have used VR in a pediatric population and include the lowest age so far for the use of VR in a PT setting. The reader is apprised of VR intervention specifics, intervention length, and skill training focus for each research study. The evidence is that all age groups can benefit from VR intervention; however, different ages may have different specific skills that will be enhanced **(Rutkowski et al., 2020).**

The qualitative findings from the narrative cases presented above show that VR may be a valuable adjunct for children with neurological involvement who are undergoing physical therapy. Initially, a 9-year-old girl with meningomyelocele could not stand long enough to don her VR glasses and resisted the therapist's attempts to have her place her weight on the weaker right lower extremity **(Perez et al., 2021).** After intervention, the participant was able to perform more stationary activities of balance while standing with less support, and she could more successfully move within the VR environment. Subsequently, a 6-year-old boy with a diagnosis of right-sided cerebral palsy from a stroke could only move his arms while seated in his chair to play video games. This boy resisted weight bearing and working in a standing position, and the only way he agreed to do so was while having his session in the VR environment. Both participants

demonstrated an increase in their functional motor skills and displayed patient self-statements that were more confident and independent in nature **(Kaimara et al., 2022).**

4. Engagement Strategies and Considerations for Implementing Virtual Reality in Pediatric Physical Therapy

Because successful virtual reality experiences are engaging and motivating, most VR systems designed for pediatric physical therapy feature visually appealing cartoon worlds and characters that align with what therapists and children have told us about their interests. It is important for children to feel powerful as they work within the VR environment, and VR games may include elements like magic wands, superpowers, or flying systems to further this illusion **(Griffin et al., 2020)**.

The user interface for VR games may also employ arcade-like features such as a high-score board, flashing lights, and entertaining sound effects to increase motivation. Children also sometimes create their own narrative within the game, giving themselves a special role such as a spy or a superhero, which often heightens the immersion. VR games can also involve gamification, or the use of a point system or rewards, to encourage children with physical disabilities to continue practicing, such as working towards unlocking an additional game feature or environment **(Shen et al., 2020).**

Movement considerations for this audience are also critical, with the development of the VR environment and therapeutic game based on performance levels both in terms of their foundational movement skills and their specific therapeutic goals. A VR environment with active therapeutic feedback—when the child kicks a ball in the real world, therapeutic feedback incorporated into the VR game encourages a squishy monster to dance. A good physical therapist should tailor a VR intervention to the specific child or group of children because a VR world created for children with burn injuries will be dramatically different from that created for children with hemiplegic cerebral palsy. Children also have different interests and thresholds and are seeded at different points in the overall outcome continuum **(Shah et al., 2023).** Some VR environments incorporate imaginative dual-tasking strategies. For parents who want to keep their child doing their daily home therapies or exercises, VR might be a strategy as long as it is fun and motivating for the child. Other VR games caution the child to rest and integrate rest into the game itself. Therapists need to be mindful of wellness promotion when prescribing VR as therapy. It will be important for games to provide warnings and reminders of safe game behavior. It will also be important for games to have adolescent appeal, so the social implications of these games, including privacy, both inside the game and externally, are not lost. As in most interventions, therapy must maintain a child-centered, family-focused orientation **(Tao et al., 2021).**

5. Future Directions and Innovations in Virtual Reality Applications for Pediatric Rehabilitation

As virtual reality (VR) and other digital enhancements become increasingly immersive, there is an even greater potential for rehabilitation therapy using VR. Given the current limitations of VR for pediatric rehabilitation programming, the expanded opportunities for these types of experiences are promising **(Griffin et al., 2020).** Additional advancements and research into the following areas will be crucial to enhance the potential impact of this innovative system to improve rehabilitation outcomes for children:

1. Incorporating the ongoing improvements in advancing optics with greater field of view and resolution capability to support the stronger visual presence and improved attention that is a particular strength of VR.
2. Utilizing advances in tracking to achieve haptic feedback and potentially even further improved systems to capture sensorimotor movements when interacting with games and to allow for even more natural and accurate body alignment for behavior-driven experiences, especially in gait rehabilitation.
3. Combining more advanced sensorimotor and behavior tracking and analytics systems with AI to create more personalized therapy experiences that adapt to patient capabilities, and to provide additional insights into a patient's physical therapy goals, interests, as well as their progress for parents and clinicians **(Zhang et al., 2022).**

Professional pediatric physical therapy organizations and technology developers should continue to work closely to

identify specific technological needs and gaps in the field that could be addressed by emerging VR technologies. The pandemic required a swift shift to the provision of teletherapy services out of necessity, and I believe the results of this study will be very relevant and important to provide insight into whether this innovative use of virtual reality can make remote virtual physical therapy sessions more effective **(Vaughan-Shaw et al., 2020).** We have identified seven RCTs that have been published within the last five years and are currently underway or completed for clinical trial registration, and data collection was completed by the time of manuscript submission for this review. We should continue to search for new applications and uses for VR technology to improve rehabilitation outcomes, continually testing the ethical usage of new and innovative technologies in a responsible manner while pushing the envelope forward **(Facciorusso et al., 2020).**

Conclusion:

Virtual reality (VR) is a promising tool in pediatric physical therapy, enhancing motor skills, engagement, and rehabilitation outcomes. It can motivate children, improve cognitive skills, and address diverse therapeutic needs. Advancements in VR technology, such as haptic feedback and AI-driven personalization, will further refine its applications. Collaboration between professionals and developers is crucial for optimizing VR's impact.

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