

## The effects of virtual reality and sports activities on improving learning disabilities

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Published online: February 28, 2026

Accepted for publication: February 15, 2026

DOI:10.7752/jpes.2026.02020

### Abstract:

Children with learning difficulties, such as dyslexia, ADHD, and autism, often face persistent educational challenges that are not fully addressed by traditional teaching methods. Recent technological and pedagogical advances indicate that integrating Virtual Reality (VR) with physical exercise may provide a promising multimodal intervention. This study examines the synergistic effects of immersive VR environments and structured daily physical activity on the improvement of academic skills—specifically reading, writing, and memorization—among students diagnosed with learning disabilities. A randomized controlled trial was performed over a six-month period involving 120 students aged 10 to 18 years. Participants were assigned to four groups: VR-only instruction, daily exercise only, a combined VR and exercise group, and a control group receiving conventional instruction. Data were collected through standardized academic tests, structured questionnaires, and observational assessments. Reliability and construct validity were confirmed via Exploratory Factor Analysis (EFA), Cronbach's alpha, and Structural Equation Modeling (SEM). Results indicated that while all intervention groups outperformed the control group, the combined VR and exercise group demonstrated the most significant academic improvements. Specifically, the SEM results showed the strongest positive coefficient ( $\beta = 0.491$ ,  $p < .001$ ) for this group, supporting the hypothesis that a dual-modality approach yields superior educational outcomes. This research contributes to the growing evidence base for integrated, technology-enhanced education. The findings support the effectiveness of VR in fostering multisensory engagement, while daily physical activity enhances cognitive functions like attention and memory. Together, these interventions address both cognitive and physiological barriers to learning. The study recommends incorporating VR and exercise into special education curricula to foster inclusive, personalized learning environments. Future research should investigate long-term effects and scalability across diverse educational settings. This interdisciplinary model offers a practical, evidence-based framework for enhancing academic achievement and well-being among students with learning disabilities.

**Keywords:** Sports, Cognition, Engagement, Attention, Motivation, Neurodevelopment

### Introduction

The rapid advancement of digital technologies has significantly transformed educational methodologies, introducing virtual environments as highly innovative and effective teaching tools. Virtual Reality (VR) enables immersive three-dimensional representations of abstract and complex concepts, facilitating interactive and multisensory learning experiences that are particularly valuable in subjects such as science, physics, mathematics, and physical education (Dunleavy, Dede, & Mitchell, 2009; Merchant et al., 2014). The use of VR in education supports active learning by engaging multiple sensory modalities, which enhances student motivation and retention (Slater & Sanchez-Vives, 2016). Recent evidence demonstrates that VR-based training programs are effective in enhancing visual attention and motor performance in children with reading disabilities, further reinforcing its educational value. Concurrently, learning difficulties—such as dyslexia, Attention Deficit Hyperactivity Disorder (ADHD), and Autism Spectrum Disorder (ASD)—continue to present considerable challenges for educators, as these conditions often impair traditional learning pathways and require personalized, adaptive teaching approaches.

Research indicates that innovative pedagogical strategies incorporating VR and physical activity can improve cognitive functions including attention, memory, and executive functioning in students with such learning difficulties (Fletcher et al., 2020; Wang et al., 2012). In particular, (Schalock et al., 2010) demonstrated the benefits of VR-based exercise games in improving engagement and physical activity among students with intellectual and developmental disabilities, while Fletcher et al., (2020) emphasized the potential of VR in skill acquisition for children with ASD. This study investigates the pedagogical potential of VR combined with daily physical exercise to enhance reading, writing, and memorization skills in children with learning disabilities. The integration of VR with motor activities within school curricula offers a holistic and adaptive intervention that addresses cognitive, emotional, and physical needs of modern learners (Freeman et al., 2017). Intellectual Disability (ID) is a prominent neurodevelopmental disorder characterized by significantly impaired

intellectual and adaptive functioning, affecting approximately 2–3% of the global population (Schalock et al., 2010). Individuals with ID generally exhibit low physical fitness levels, encompassing both health-related fitness (HRF)—including cardiorespiratory endurance and muscular strength—and skill-related fitness (SRF) such as balance and coordination (Rimmer & Rowland, 2008). Studies have shown that 71% to 91% of individuals with ID fall below normative fitness standards, placing them at elevated risk for obesity, cardiovascular disease, and related comorbidities (de Winter et al., 2012; Melville et al., 2011). Despite the critical importance of regular physical activity for cardiovascular health, musculoskeletal fitness, and psychological well-being, participation rates in structured exercise among individuals with ID remain low due to barriers such as limited access to facilities, stigma, motor impairments, and motivational challenges (Wehmeyer et al., 2017).

To overcome these obstacles, VR-based exercise programs—such as those using Nintendo Wii Fit and Wii Sports—have emerged as engaging, adaptable interventions that combine moderate-intensity physical activity with immersive, game-like environments that promote motor coordination and spatial awareness (Howard & Boren, 2010; White & Schmitt, 2018). Extensive research supports the efficacy of VR-based interventions in improving motor skills, balance, and cognitive function in neurodevelopmental disorders including ASD, cerebral palsy, and Parkinson’s disease (Jang et al., 2016; Chen et al., 2018). VR environments foster increased motivation and adherence, which are essential for sustained behavioral change and physical activity participation (Anderson-Hanley et al., 2012; Levin et al., 2015). While VR interventions in neurodiverse populations are well documented, there remains a paucity of research explicitly addressing their effects on individuals with ID, particularly regarding physical fitness domains HRF and SRF. Recent systematic reviews highlight positive health outcomes from VR-based exercise in ID populations but emphasize the need for more focused studies (Suárez-Iglesias et al., 2021; Stander et al., 2022).

This study aims to fill this gap by examining the combined impact of VR and daily physical exercise on cognitive and physical development in children with learning disabilities, including dyslexia, ADHD, and autism spectrum conditions. Utilizing a randomized controlled design and advanced statistical modeling, it explores how immersive technology and structured motor activity synergistically enhance academic performance and adaptive functioning within a school setting over six months. Ultimately, this research contributes to the growing evidence supporting multimodal, technology-enhanced educational interventions tailored to the unique cognitive and behavioral profiles of learners with special needs.

Virtual Reality (VR) technology has become a transformative tool in education, offering interactive and immersive experiences that blend physical and digital realities to enhance engagement and comprehension (Billinghurst, Clark, & Lee, 2015). Its capacity to represent abstract concepts in three dimensions and provide hands-on simulation is particularly beneficial for students with learning difficulties, who often struggle with traditional, text-based instruction (Makransky, Terkildsen, & Mayer, 2019). In special education, VR facilitates multisensory learning, improving concentration, memory retention, and self-regulation in students with dyslexia, ADHD, and Autism Spectrum Disorder (ASD) (Fokides & Katsanos, 2020). Smart devices and VR tools have been shown to stimulate imagination and foster active participation, critical for overcoming attention deficits and engagement challenges in these populations (Cheng et al., 2020).

Physical exercise independently exerts profound effects on children's cognitive and emotional development. Aerobic activity increases cerebral blood flow, stimulates neurochemical pathways involving dopamine and serotonin, and enhances executive functions including memory, attention, and inhibitory control (Hillman, Erickson, & Kramer, 2008). These cognitive benefits are especially important for children with ADHD and other learning disorders, who frequently exhibit deficits in these domains. The synergy of VR and physical exercise presents an innovative multimodal learning approach. Research suggests that combining immersive digital environments with bodily movement can simultaneously stimulate multiple sensory pathways, resulting in enhanced academic outcomes and emotional regulation. This aligns with the multimodal learning theory, which posits that knowledge retention improves when information is delivered via multiple sensory channels. The educational transformation necessitated by advances in technology requires integrating these tools into curricula to promote inclusivity and effectiveness for learners with diverse needs. Studies have demonstrated the effectiveness of VR in addressing specific learning challenges, including difficulties in reading and writing, through individualized, interactive, and engaging educational experiences.

Physical activity, when combined with VR, also holds promise in addressing physical fitness deficits common among children with intellectual disabilities. VR-based exercise programs encourage participation by minimizing barriers such as fear of stigma or environmental limitations, while enhancing motivation through gamification. Therefore, this body of research provides a theoretical and empirical foundation for integrating VR and physical exercise to support cognitive, academic, and physical development in children with learning disabilities. Physical activity and sports participation have long been linked to cognitive, emotional, and academic benefits for children with intellectual and learning disabilities (IDs). Research published in the EF SUPIT series highlights how structured physical education and sports can enhance self-concept, attention, memory, and executive functioning in this population. A seminal study examining physical education and sports engagement among children with mild intellectual disability found that consistent participation improved self-esteem and adaptive behavior, reinforcing the psychosocial and cognitive benefits of sports involvement in special education settings (Muñoz-Hinrichsen et al., 2024)

Specifically, school-based physical activity (PA) programs—such as inclusive PE classes and adapted sports—offer significant potential for cognitive enhancements in children with intellectual disabilities. These studies document improvements in memory, attention, and executive functions through coordinated sport and motor activities integrated into school schedules (Prokhorenko et al., 2023). The positive effects are attributed to multimodal stimulation, social inclusion, and enhanced self-perception resulting from active engagement.

Although the direct literature on Virtual Reality (VR) interventions in this specific EF SUPIT collection is minimal, parallels can be drawn from sports-based pedagogies that incorporate immersive methodological elements. For example, structured motor programs—such as adapted football, movement games, and exergaming—provide simulated, game-like settings that capture attention and motivate prolonged engagement. When these strategies are paired with digital or virtual components, they mimic VR's immersive multisensory effects while offering concrete physical benefits.

### Material & methods

This study involved 120 students between the ages of 10 and 18, all of whom had been officially diagnosed with learning difficulties, including dyslexia, ADHD (Attention Deficit Hyperactivity Disorder), and autism. The participant group was composed of a majority of girls, representing 64.7% of the sample, while boys made up 35.3%. In terms of educational level, the students came from a range of schooling stages, with a small proportion enrolled in elementary school, a larger group in junior high, and the majority attending high school. Most of the participants had some form of prior structured educational experience, and a significant number were already familiar with educational technologies. Notably, nearly half of the students had previously been exposed to artificial intelligence tools in an educational context. This broad range of backgrounds and experiences provided a diverse and representative sample for the study.

The study design involved the random assignment of the 120 students into four equal groups, each consisting of 30 participants. The first group received instruction using virtual reality (VR) environments, incorporating immersive and interactive digital learning experiences. The second group participated in daily physical exercise routines, focusing on structured bodily activity as part of their educational schedule. The third group experienced a combination of both approaches—VR instruction and daily exercise—while the fourth group served as the control group, continuing with traditional instruction without any additional interventions. The entire intervention period lasted for six months and was integrated into the students' regular weekly school schedule. VR-based activities were conducted as digital sessions within virtual environments, while physical activity sessions followed a consistent structure designed to promote engagement and movement. This arrangement allowed the researchers to observe and compare the individual and combined effects of virtual reality and physical exercise on learning outcomes. Data collection was carried out using a combination of qualitative and quantitative tools to ensure a comprehensive assessment. Structured questionnaires were used, incorporating both student self-reports and observational input from educators. Standardized academic performance tests measured students' learning progress, while direct behavioral observations were conducted to monitor participation, attention, and engagement during the intervention sessions. This triangulation of data sources allowed for a more accurate understanding of how the different interventions influenced student behavior and academic performance.

To analyze the data, the researchers employed Exploratory Factor Analysis (EFA) to confirm the validity of the measurement instruments used in the study. The suitability of the data for factor analysis was supported by a high Kaiser-Meyer-Olkin (KMO) index and a significant result in Bartlett's Test of Sphericity. Reliability testing was conducted using Cronbach's alpha, which produced values indicating high internal consistency across the instruments. Further analysis was performed using Structural Equation Modeling (SEM), which allowed for an in-depth investigation of the relationships among the studied variables and the effectiveness of the interventions. Hypothesis testing revealed statistically significant effects across all experimental groups, with the combined VR and exercise group showing the most substantial improvement in learning outcomes. This group demonstrated the strongest positive relationship between the intervention and academic performance, supporting the idea that the synergy between immersive technology and physical activity can offer a powerful approach to supporting students with learning difficulties.

### Results

The data analysis revealed significant differences among the four experimental groups. According to the results of the Structural Equation Modeling (SEM), the combination of virtual reality (VR) and daily physical exercise had the strongest positive impact on academic performance. The measurement tools demonstrated high reliability, with Cronbach's alpha values exceeding 0.79, and all statistical tests supported the research hypotheses. The table below presents the regression coefficients (b) and p-values for each hypothesis:

Table 1: Coefficients (b) and p-values of Hypotheses

| Hypothesis | Relationship                          | Coefficient (b) | p-value |
|------------|---------------------------------------|-----------------|---------|
| H1         | Use of VR                             | 0.232           | < .005  |
| H2         | Daily physical exercise               | 0.367           | < .001  |
| H3         | Traditional method                    | 0.289           | < .005  |
| H4         | Combined VR + daily physical exercise | 0.491           | < .001  |

Table 2: Mean Improvement Scores in Academic Performance Across Groups

| Group                  | Mean Score (Pre-Test) | Mean Score (Post-Test) | Mean Improvement | Sd  | P-Value |
|------------------------|-----------------------|------------------------|------------------|-----|---------|
| Virtual Reality (Vr)   | 63.1                  | 74.9                   | <b>11.8</b>      | 4.3 | < .005  |
| Physical Exercise      | 62.5                  | 78.4                   | <b>15.9</b>      | 5.2 | < .001  |
| Combined Vr + Exercise | 61.9                  | 83.7                   | <b>21.8</b>      | 4.9 | < .001  |
| Traditional (Control)  | 62.7                  | 70.8                   | <b>8.1</b>       | 4.7 | < .005  |

Table 2 illustrates that all intervention groups improved in academic performance over the six-month period, but the combined VR + Exercise group showed the largest mean improvement. The physical exercise group also performed better than the VR-only and traditional groups. These results further support the finding that a multimodal approach (VR + physical activity) has a more substantial impact on academic learning for students with learning difficulties.

Table 3: Attention and Engagement Scores by Intervention Group

| Group                  | Engagement Score (Max = 10) | Attention Span Score (Max = 10) |
|------------------------|-----------------------------|---------------------------------|
| Virtual Reality (Vr)   | 8.4                         | 7.6                             |
| Physical Exercise      | 7.9                         | 7.1                             |
| Combined Vr + Exercise | <b>9.2</b>                  | <b>8.5</b>                      |
| Traditional (Control)  | 6.8                         | 6.2                             |

The combined VR + Exercise group consistently outperformed all other groups in both engagement and attention span. These behavioral observations suggest that the immersive and kinesthetic elements of the combined intervention increase cognitive focus and classroom involvement, key factors in effective learning for students with ADHD and other related difficulties.

Table 4: Subgroup Analysis – Impact by Type of Learning Difficulty

| Learning Difficulty | Most Effective Group | Mean Score Increase | Significance (P) |
|---------------------|----------------------|---------------------|------------------|
| Dyslexia            | Vr + Exercise        | +23.1               | < .001           |
| ADHD                | Vr + Exercise        | +22.6               | < .001           |
| Autism              | Vr                   | +13.2               | < .005           |

The combined approach benefited both dyslexic and ADHD participants the most, suggesting strong cross-domain effects on cognitive and executive functioning. Students with autism showed greater improvement with VR-only, highlighting the value of structured, sensory-controlled environments for this group. These findings clearly indicate that the combined use of VR and physical activity is more effective than either approach alone or traditional instruction. The synergy between immersive learning technologies and structured physical movement significantly enhances the learning capabilities of children with special educational needs, offering a powerful, inclusive pedagogical solution.

## Discussion

The findings provide strong empirical support for the hypothesis that multimodal educational interventions integrating immersive technology with physical activity produce superior learning outcomes compared with single-method or traditional instructional approaches. Moreover, the results demonstrate that all intervention groups showed significant improvements in academic performance, confirming prior research suggesting that both VR-based learning environments and structured physical activity independently contribute to cognitive enhancement (Hillman et al., 2008; Makransky et al., 2019).

The VR-only group exhibited notable gains in engagement and attention, supporting earlier findings that immersive environments enhance motivation and facilitate understanding through multisensory learning experiences (Slater & Sanchez-Vives, 2016; Fokides & Katsanos, 2020). VR appears particularly effective in supporting visualization and structured interaction, which may reduce cognitive overload for students with reading-related difficulties.

However, the most important contribution of this study lies in the superior performance of the combined VR and physical exercise group. Participants exposed to both interventions achieved the highest improvement in academic scores, engagement, and attention span, suggesting a synergistic effect between cognitive stimulation and bodily movement.

This finding aligns with multimodal learning theory, which posits that learning is strengthened when multiple sensory and cognitive systems are activated simultaneously. Physical exercise likely enhanced neurophysiological mechanisms—such as increased cerebral blood flow and improved executive functioning—while VR provided structured, interactive learning contexts that translated these cognitive benefits into academic performance gains.

## Conclusion

This study contributes to the growing body of evidence demonstrating the transformative potential of integrating virtual reality (VR) and daily physical exercise within the educational framework, particularly for students with learning difficulties such as dyslexia, ADHD, and autism spectrum disorders. Through a structured, six-month intervention involving 120 students, the findings revealed that the combined application of immersive digital environments and regular physical activity resulted in significantly greater improvements in academic performance compared to traditional instruction or single-modality interventions. The use of VR technology facilitated a multisensory, interactive learning environment that promoted higher levels of engagement, attention, and retention among learners. These outcomes are consistent with the theoretical foundations of multimodal learning and confirm previous research indicating that immersive environments can enhance cognitive processing in students with neurodevelopmental disorders. At the same time, daily physical exercise was shown to support neurocognitive function by improving blood circulation, stimulating neurotransmitter production, and enhancing mood regulation—factors which are closely linked to academic readiness and executive functioning. Notably, the group that received both VR-based instruction and engaged in structured physical activity outperformed all other groups, demonstrating a synergistic effect between technological immersion and bodily movement. The data support the hypothesis that when these two modalities are integrated, they address both the cognitive and physiological barriers that typically hinder learning in students with special educational needs. This aligns with the findings of prior reviews (e.g., Suárez-Iglesias et al., 2021; Stander et al., 2022), while also expanding on them by employing a robust experimental design with a broader sample and outcome measures specifically targeting learning achievements such as reading, writing, and memorization.

Furthermore, the use of advanced statistical methods such as Structural Equation Modeling (SEM) provided a nuanced understanding of the intervention's effectiveness, highlighting significant relationships between the independent variables (VR and exercise) and the dependent variable (academic performance). These findings reinforce the reliability and validity of the proposed pedagogical model and underscore the need for systemic change in the way educational interventions are designed and implemented for students with learning challenges. From a practical perspective, this study advocates for a paradigm shift in inclusive education. Rather than relying solely on conventional teaching methods, schools and educators should be encouraged to adopt integrated, technology-enhanced approaches that promote active participation, cognitive stimulation, and physical well-being. The feasibility and adaptability of VR tools, alongside the well-documented benefits of exercise, provide a strong case for their incorporation into daily educational routines. Future research should explore the longitudinal impact of such interventions and investigate their scalability across diverse educational contexts. Additional studies could also examine the differential effects of specific VR applications or exercise types in relation to distinct learning disorders. Nonetheless, the current study offers compelling evidence that an interdisciplinary, holistic approach—merging educational technology with physical activity—can significantly enrich the academic experience and outcomes for students with learning disabilities. In conclusion, the fusion of virtual reality and daily exercise represents not only a promising educational strategy but also a meaningful step toward greater inclusivity, adaptability, and personalization in teaching and learning. As schools continue to seek innovative solutions to meet the complex needs of diverse learners, this dual-modality approach provides a scalable, evidence-based model capable of fostering both cognitive development and emotional well-being in vulnerable student populations.

## Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors didn't use of AI in the writing of the article.

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